

9.4 – Chemical Monitoring and Management:

Δ. Construct word and balanced formulae equations of all chemical reactions as they are encountered in this module:

• **EQUATIONS:**

– **Different products under different conditions:**

▪ *Complete* combustion:

➤ propane + oxygen \longrightarrow carbon dioxide + water

➤ $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$

▪ *Incomplete* combustion:

➤ propane + oxygen \longrightarrow carbon + carbon monoxide + water

➤ $C_3H_8(g) + 3O_2(g) \longrightarrow C(s) + 2CO(g) + 4H_2O(g)$

– **Haber Process:**

▪ nitrogen + hydrogen \rightleftharpoons ammonia + heat

▪ $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ/mol}$

– **Sulfate Content in Fertilizer:**

▪ barium chloride + sulfate \rightleftharpoons barium sulfate + chloride

▪ $BaCl_2(aq) + SO_4^{2-}(aq) \rightleftharpoons BaSO_4(s) + 2Cl^-(aq)$

– **How Ozone Protects Us From UV Radiation:**

▪ Oxygen reacts with UV, forming 2 radicals:

➤ $O_2 + \text{UV radiation} \longrightarrow 2O\cdot$

▪ Radical reacts with oxygen, forming ozone:

➤ $O\cdot + O_2 \longrightarrow O_3$

▪ Ozone reacts with UV, forming oxygen and a radical:

➤ $O_3 + \text{UV radiation} \longrightarrow O\cdot + O_2$

▪ Radical reacts with ozone, creating oxygen:

➤ $O\cdot + O_3 \longrightarrow 2O_2$

– **All the CFC-Related Equations:**

▪ Formation of *chlorine radical*:

➤ $CCl_2F_2(g) + \text{UV radiation} \longrightarrow \cdot Cl(g) + \cdot CClF_2(g)$

▪ Reaction of *ozone*:

- $\cdot\text{Cl}_{(g)} + \text{O}_3_{(g)} \longrightarrow \cdot\text{ClO}_{(g)} + \text{O}_2_{(g)}$
- Regeneration of *chlorine*:
 - $\cdot\text{ClO}_{(g)} + \text{O}_{(g)} \longrightarrow \cdot\text{Cl}_{(g)} + \text{O}_2_{(g)}$
- Removal of *chlorine radical*:
 - $\cdot\text{Cl}_{(g)} + \text{CH}_4_{(g)} \longrightarrow \text{HCl}_{(g)} + \cdot\text{CH}_3_{(g)}$
- Removal of *chlorine monoxide radical*:
 - $\cdot\text{ClO}_{(g)} + \text{NO}_2_{(g)} \longrightarrow \text{ClONO}_2_{(g)}$
- Formation of *molecular chlorine*:
 - $\text{HCl}_{(g)} + \text{ClONO}_2_{(g)} \longrightarrow \text{Cl}_2_{(g)} + \text{HNO}_3_{(g)}$
- Decomposition of *molecular chlorine*:
 - $\text{Cl}_2_{(g)} + \text{UV radiation} \longrightarrow 2\cdot\text{Cl}_{(g)}$
- **The Heavy-Metal Sulfide Test:**
 - The sulfide-test is based on the following equilibrium:
 - $\text{S}^{2-}_{(aq)} + 2\text{H}_3\text{O}^+_{(aq)} \rightleftharpoons \text{H}_2\text{S}_{(aq)} + 2\text{H}_2\text{O}_{(l)}$

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

- *Outline the role of a chemist employed in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining the chemical principle that the chemist uses:*
 - SITE: <<http://www.chem.unsw.edu.au/RACI/profiles.html>>
 - **Robert Evans:**
 - Robert Evans is an environmental chemist.
 - He is employed by Orica Ltd, and works at Botany Industrial Park, Sydney.
 - **Role:**
 - As an environmental chemist at an industrial location, his main role ensuring the site's adherence to EPA (environment protection authority) regulations.
 - This job includes:
 - The management of disposal of contaminated wastes (such as neutralising strongly acidic or basic wastes, or incinerating toxic wastes).
 - Ensuring noise levels comply with EPA standards for industry.
 - Investigating reports of contamination in soil or groundwater, determining the source of contamination, and then correcting the damage.
 - Preparing periodic reports and presentations.
 - **Chemistry:**
 - Chemical principles needed for this role include:
 - Understanding acid/base reactions (neutralising wastes).
 - Knowing valid chemical sampling techniques.
 - Various techniques of chemical analysis of samples, including gravimetric and volumetric analysis, as well as AAS.
 - Understanding site geology and groundwater flow patterns.
- *Identify the need for collaboration between chemists as they collect and analyse data:*
 - As **chemistry** is such a broad field of knowledge, people tend to specialise within a particular branch, such as *polymer* chemistry or *analytical* chemistry.

- However, in real-life situations, many chemical problems require expertise and in depth knowledge from a wide range of chemical branches.
- Hence, collaboration between chemists is essential for solving chemical issues, or when dealing with large amounts of data being collected, as the chemists provide input and expertise from their own particular field, for a common goal.
- As chemists often work in teams, collaboration and communication is required to collectively benefit the team, as they collect and analyse information.
 - **EG:** An industrial process would require collaboration between physical chemists (for equilibrium considerations), organic chemists (for how the reaction occurs) and analytical chemists (for monitoring products).
- *Describe an example of a chemical reaction such as combustion, where reactants form different products under different conditions and thus would need monitoring:*
 - **Combustion:**
 - Chemical reactions can form different products under different *conditions*.
 - Take, for example, the *combustion* of a simple hydrocarbon, propane.
 - In an environment with adequate amounts of oxygen, propane combusts completely, forming only carbon dioxide and water:
 - propane + oxygen \longrightarrow carbon dioxide + water
 - $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \longrightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
 - In an environment with insufficient oxygen, propane combusts incompletely, and can form a range of different products, such as carbon (soot), carbon monoxide, carbon dioxide and water.
 - propane + oxygen \longrightarrow carbon + carbon monoxide + water
 - $\text{C}_3\text{H}_8(\text{g}) + 3\text{O}_2(\text{g}) \longrightarrow \text{C}(\text{s}) + 2\text{CO}(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
 - **Monitoring:**
 - Hence, under different conditions, chemical reactions can proceed in different ways, as seen by the combustion reaction above.
 - However, in certain situations (such as in car engines), only one reaction is desired. Thus, the reaction conditions must be monitored to ensure that only (or mostly) the wanted reaction occurs.

- *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 a more detailed study:*
- THE VARIETY OF CHEMICAL OCCUPATIONS:
 - The large *range* of jobs available in the **chemical** industry includes:
 - Analytical chemistry.
 - Bio-molecular chemistry.
 - Colloid and surface science chemistry.
 - Environmental chemistry.
 - Industrial chemistry.
 - Inorganic chemistry.
 - Electrochemistry.
 - Organic chemistry.
 - Physical chemistry.
 - Polymer chemistry .
- A SPECIFIC CHEMICAL OCCUPATION:
 - A summary of the job of an **environmental** chemist:
 - *Job includes reviewing operation of effluent water treatment systems and ensuring compliance with government environmental regulations. Reviewing industry's compliance with government environmental noise standards. Assessing levels of potential contamination in wastes (e.g. soil) intended for landfill disposal and classifying them in accordance with government guidelines. Managing disposal of contaminated wastes. Investigating reports of contamination in soil or groundwater to determine source and then arranging to correct it. Determining whether gas stack emissions contain unacceptable levels of regulated materials. Advising engineers/managers of corrective actions needed if any of the above parameters show faults in systems. Answering public or professional enquiries or complaints regarding environmental performance.*

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

- *Identify and describe the industrial uses of ammonia:*
 - **Ammonia** (NH₃) is a gas with a strong odour; it has many industrial uses.
 - It is used to make:
 - Solid and liquid fertilisers (through a reaction with sulfuric acid or nitric acid to form ammonium sulfate fertiliser and ammonium nitrate fertiliser).
 - Nitric acid (through the *Ostwald Process*).
 - Explosives, sodium carbonate, pharmaceuticals, household cleaners, fibres and plastics, as well as refrigerants.
- *Identify that ammonia can be synthesized from its component gases, nitrogen and hydrogen:*
 - From its molecular formula (NH₃) we can see that *ammonia* is composed of **nitrogen** and **hydrogen** atoms.
 - Hence, theoretically, ammonia should be able to be *synthesised* from these gases.
- *Describe that synthesis of ammonia occurs as a reversible reaction that will reach equilibrium:*
 - The industrial production of *ammonia* is called the HABER PROCESS.
 - The basic chemical reaction of this process is the reaction of gaseous hydrogen and nitrogen to form ammonia:
 - nitrogen + hydrogen \rightleftharpoons ammonia
 - $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
 - From the chemical reaction, we can see that it is clearly a reversible reaction, and hence it does NOT go to completion, but reaches a point of **equilibrium**.
- *Identify the reaction of hydrogen with nitrogen as exothermic:*
 - The reaction of hydrogen with nitrogen (*Haber Process*) can be represented as:
 - $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H = -92 \text{ kJ/mol}$
 - From the chemical equation, we can see that ΔH is less than zero, and hence the reaction is an *exothermic* reaction.
- *Explain why the rate of reaction is increased by higher temperatures:*

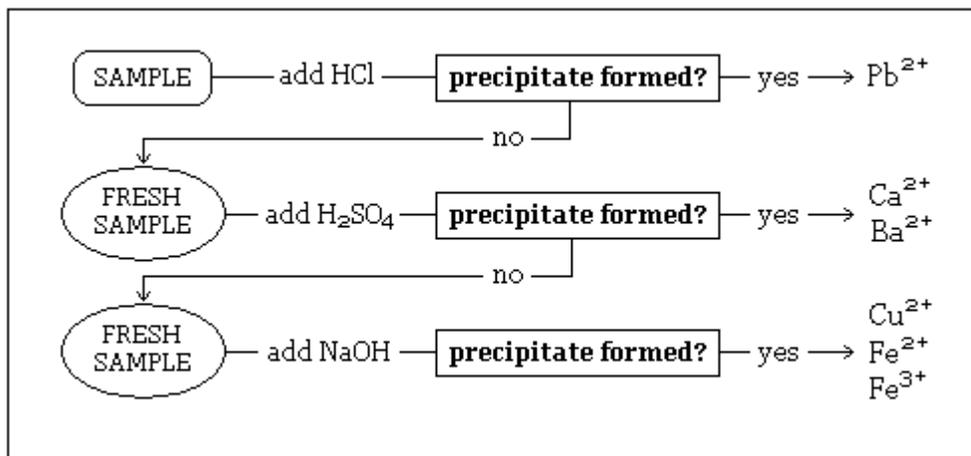
- **RECALL:**
 - Before any chemical reactions can occur, there must be an energy input.
 - The *activation energy* of a reaction describes the minimum amount of energy input necessary for that reaction to occur.
- The *rate of reaction* is a term used to describe how FAST a reaction occurs.
- There are 2 reasons why higher temperatures result in a higher rate of reaction:
 - As temperature is increased, **energy** is delivered into the reaction as *thermal energy*. This thermal energy is converted into *kinetic energy*, and particles begin to move faster. This causes more collisions between particles, and hence more reactions occur.
 - Also, if the temperature is higher, there is more chance that colliding particles will have the necessary *activation energy* for the reaction to take place.
- For the Haber Process (and all reversible reactions in general), at higher temperatures, the rate of reaction of both the *forward* and *reverse* reactions are increased, and hence equilibrium is reached faster.
- *Explain that the use of a catalyst will lower the reaction temperature required and identify the catalyst(s) used in the Haber process:*
 - A **catalyst** is a substance that increases the rate of reaction of a chemical reaction, but does not itself take part in the reaction.
 - Catalysts work by reducing the activation energy of reactions.
 - For the Haber Process, the catalyst used is iron oxide (*magnetite*; Fe₃O₄).
 - The catalyst is finely ground, to produce a large surface area, and has its surface partly reduced to elemental iron.
- *Explain why the yield of product in the Haber process is reduced at higher temperatures using Le Chatelier's principle:*
 - In terms of industrial reversible reactions, the term '**yield** of product' describes how much product is formed at the point of *equilibrium*:
 - It has nothing to do with RATE of reaction.
 - Since we know the Haber Process is an exothermic reaction, we can predict the effects of higher temperatures using Le Chatelier's principle:

- If an increase in temperature is imposed onto the 'system' (the reaction) then the 'system' will shift itself to counteract this imposed change.
 - Since the 'system' will want to *cool* itself, to oppose the heating, the reaction that is *endothermic* will be encouraged.
 - The forward reaction is exothermic, hence the reverse reaction is endothermic.
 - Thus, at higher temperatures, the reverse reaction occurs more
 - But this produces reactants, not products; thus the yield of products reduces.
- *Analyse the impact of increased pressure on the system involved in the Haber process:*
 - According to Le Chatelier's principle, increasing the pressure will favour the side that will *reduce* the pressure (i.e. has LESS moles of gas).
 - In this reaction, there are less moles of gas on the product side (*gas ratio* is 4:2) and hence increasing the pressure will encourage the forward reaction.
 - In addition, higher pressures also increase the reaction rate because the gas molecules are closer and at higher concentrations.
 - *Explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate and equilibrium:*
 - In order for the Haber Process to be economically viable, we need to consider yield of products, rate of reaction, as well as costs.
 - Hence, a compromise ('*balancing act*') of all the above must be made:
 - **Temperature:** Higher temperatures will produce ammonia *faster*, but lower temperatures will produce *more* ammonia. Hence a moderate temperature of about 500°C is used, together with the iron/iron-oxide catalyst.
 - **Pressure:** Increased pressure will produce *more* ammonia, also *faster*, but it will be expensive to build and maintain high-pressure equipment. The benefits of high pressure outweigh the costs, and so a pressure of 35 MPa is used.
 - EXTRA: Another step taken to encourage the economic formation of products is the continuous liquefaction and removal of ammonia as it is produced. This reduces the concentration of ammonia, and hence encourages the forward reaction, according to Le Chatelier's principle.

- *Explain why monitoring of the reaction vessel used in the Haber process is crucial and discuss the monitoring required:*
 - **Monitoring of Reaction Conditions:**
 - TEMPERATURE; the temperature of the vessel must be monitored so that it is kept within an acceptable range ($\approx 500^{\circ}\text{C}$). This is due to the yield and rate considerations, as above. Also, at excessively high temperatures, the iron catalyst will melt, and will be destroyed.
 - PRESSURE; the pressure of the vessel must be monitored for yield and rate considerations, as stated above. Also, if pressures read excessively high levels, it will become extremely dangerous, and an explosion may occur.
 - **Monitoring of Reactants:**
 - RATIO of REACTANTS; the ratio of the incoming gases has to be monitored so that it is maintained at a constant 1:3 (N_2 to H_2). This is because a build-up of any gas must be avoided, as this may dangerously increase the pressure.
 - CONTAMINANTS; the concentration of contaminants must be monitored for various reasons. O_2 must be completely removed, as it introduces the risk of an explosive reaction with H_2 . CO , CO_2 and sulfur compounds must be at very low levels, as they all poison the catalyst. Levels of argon and methane must also be kept at low concentrations as they lower the efficiency of the reaction.
- *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:*
 - Before the invention of the industrial Haber Process in 1914, the global source of nitrates (for fertilisers and explosives) came from *saltpetre* from South America.
 - During WWI, Germany's supplies of nitrogen compounds was cut off; this threatened to cause widespread starvation, as well as cause Germany to rapidly lose the war (they relied on saltpetre to make explosives).
 - However, with the invention of the Haber Process, Germany (and later the rest of the world) had a cheap source of nitrates from elemental nitrogen and hydrogen.
 - Thus, the significance of this was that it greatly lengthened the War.

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

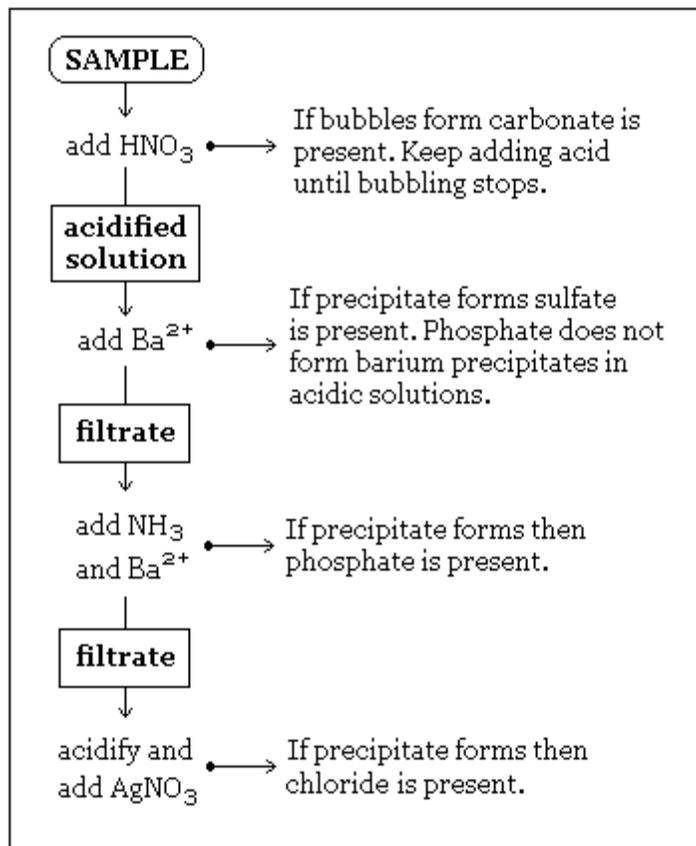
- *Deduce the ions present in a sample from the results of tests:*
 - Ions that are being tested:
 - **Cations:** Ba^{2+} , Ca^{2+} , Pb^{2+} , Cu^{2+} , Fe^{2+} and Fe^{3+}
 - **Anions:** PO_4^{3-} , SO_4^{2-} , CO_3^{2-} and Cl^-
 - When *given* a flowchart, it is very easy to deduce the ion(s) present.
 - However, you need to memorise the tests for the above ions.
 - We use *precipitation* reactions to identify ions in solution.
 - There are 2 situations possible: when there is only one ion present in a sample, or when there is a mixture of ions in a sample.
 - CATIONS (when only **one** ion is present):
 - To determine the ion present, HCl, H_2SO_4 and NaOH is added in that order, and the formation of a precipitate would indicate which ion it is:



- Firstly, **HCl** (Cl^- ions) is added to the sample. If a white precipitate forms, then the unknown ion is LEAD (Pb^{2+}); the precipitate is lead chloride (PbCl_2).
 - To *verify*, add a few drops of potassium iodide (KI) to a fresh sample. Pb^{2+} ions form a vibrant yellow precipitate with iodide (I^-) ions.
- Next, **H_2SO_4** (SO_4^{2-} ions) is added to a FRESH SAMPLE. If a precipitate forms, the unknown ion is *either* calcium (Ca^{2+}) or barium (Ba^{2+}):
 - To distinguish the two ions, add a few drops of sodium fluoride (NaF) to a new sample. Ca^{2+} forms a precipitate with fluoride (F^-), but Ba^{2+} does not.

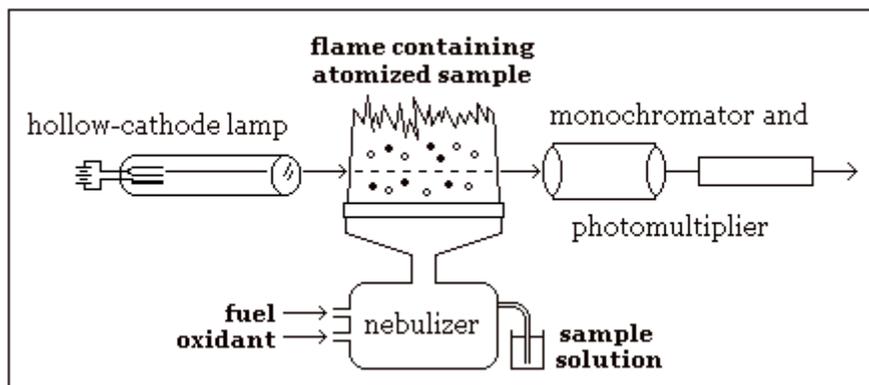
- Lastly, **NaOH** (for OH^- ions) is added to a fresh sample. If a precipitate forms, the ion is either copper (Cu^{2+}), iron(II) (Fe^{2+}) or iron(III) (Fe^{3+}):
 - If the precipitate is blue then the ion is Cu^{2+} . To further verify that it is copper, dissolve the precipitate in ammonia (NH_3), and if it is $\text{Cu}(\text{OH})_2$ it will form a deep-blue solution.
 - If the precipitate is NOT blue, then the ion is either Fe^{2+} or Fe^{3+} . Using a fresh sample, add:
 - ◆ A few drops of potassium thiocyanate (KSCN) solution. Fe^{3+} reacts with thiocyanate ions (SCN^-) to form a *blood red* precipitate.
 - ◆ A few drops of PURPLE potassium permanganate (KMnO_4) solution. Fe^{2+} decolourises the permanganate ion (MnO_4^-), changing the solution from purple to colourless.
- CATIONS (when there is a **mixture** of ions):
 - When there is a mixture of ions, there is the risk that the test for one ion will interfere with the test for another ion.
 - Once a precipitate is formed, the reagent is added until no more precipitate will form (this is to remove all traces of a specific cation).
 - The mixture is then filtered or centrifuged to remove the precipitate, and then further tests are performed on the remaining solution.
 - The *procedure* for identifying ions in a mixture:
 1. Add **HCl** solution; if a precipitate forms, Pb^{2+} is present in the mixture. Keep adding HCl until no more precipitate forms, then filter.
 2. Divide the filtrate into 2 portions:
 - ◆ Add **NaF** to one portion; precipitate indicates the presence of Ca^{2+} .
 - ◆ Add **H_2SO_4** to the other portion; if a precipitate forms, Ba^{2+} or Ca^{2+} ions are present in the mixture. Completely precipitate out all the barium and calcium ions, then filter.
 3. Add **NaOH** solution; if there is a precipitate, mix NH_3 into the solution and filter. A presence of any blue precipitate indicates Cu^{2+} , while any green or brown precipitate indicates iron ions (to distinguish iron(II) and iron (III), use thiocyanate and permanganate tests on new samples).

- ANIONS (when only **one** ion is present):
 - **Carbonate** (CO_3^{2-}):
 - Add dilute nitric acid (HNO_3); if bubbles of a colourless gas form (that when passed through limewater turns it cloudy) carbonate is present.
 - If the solution has a pH of 8-11 then carbonate is likely present.
 - **Sulfate** (SO_4^{2-}):
 - If the addition of $\text{Ba}(\text{NO}_3)_2$ (barium nitrate) in to an acidified sample produces a thick white precipitate, then sulfate is present:
 - ◆ Acidify solutions using dilute nitric acid (does not form precipitates).
 - If acidification and addition of $\text{Pb}(\text{NO}_3)_2$ (lead nitrate) produces a white precipitate, then sulfate is present.
 - **Phosphate** (PO_4^{3-}):
 - If the addition of $\text{Ba}(\text{NO}_3)_2$ (barium nitrate) to an ALKALINE sample produces a white precipitate, phosphate is present.
 - ◆ Use ammonia (NH_3) to make solutions basic.
 - If acidification followed by the addition of $(\text{NH}_4)\text{MoO}_4$ (ammonium molybdate) solution produces a yellow precipitate, phosphate is present.
 - **Chloride** (Cl^-):
 - If the addition of AgNO_3 (silver nitrate) to an acidified sample produces a white precipitate that dissolves in ammonia solution and darkens in sunlight, then chloride is present.
- ANIONS (when there is a **mixture** of ions present):
 - Again, care must be taken not to cause interference between tests:
 - The procedure:
 1. Add nitric acid; any bubbling indicates the presence of carbonate. Keep adding acid until all bubbling stops.
 2. Acidify solution with more nitric acid. Add Ba^{2+} (through barium nitrate). If a precipitate forms, sulfate is present. Filter solution.
 3. Make the filtrate alkaline by adding ammonia. Add more Ba^{2+} ions. If a precipitate forms, phosphate is present. Filter solution.
 4. Acidify solution again and add Ag^+ ions; precipitate indicates Cl^- ions.



- Describe the use of atomic absorption spectroscopy (AAS) in detecting concentrations of metal ions in solutions and assess its impact on scientific understanding of trace elements:
 - **AAS** (Atomic Absorption Spectroscopy):
 - AAS is a method of quantitatively determining the concentrations of metal ions in solutions; it is extremely sensitive and measures to parts-per-million.
 - It was developed by an Australian scientist, Alan Walsh, and his CSIRO team in the early 1950s.
 - **How AAS Works:**
 - Firstly, a solution of a test sample being analysed is fed into a nebulizer (also called an *atomiser*) where the liquid solution is made into a spray or *mist*.
 - The mist is then mixed with a fuel and its oxidant (usually a mixture of oxygen and acetylene).
 - The mixture is combusted into a flame; this flame gives compounds, molecules and ions the energy to become ATOMS.

- Then, depending on the element being tested for, a specific hollow-cathode lamp is used (for example, if cobalt is being tested for, a cobalt lamp is used, where the cathode in the lamp is cobalt metal).
- When current is passed into the lamp, it produces light in a spectrum specific to the element (i.e. the element's *emission spectrum*).
- When this light is passed through the flame, the atoms absorb this emission spectrum, as they are the same element as the cathode in the lamp (there is an exact match of emission and absorbance wavelengths).
- The atoms in the flame absorb the light in specific wavelengths, and then this 'changed' light is passed into the monochromator. This device then selects that specific wavelength(s) which are absorbed, and compares it to a reading without the flame/atoms, and determines a reading called **absorbance**.
- Absorbance is proportional to concentration, and hence the unknown concentration of the element can be determined:
- 'Absorbance' is an arbitrary unit, so the AAS device must be calibrated using *standard solutions* (solutions of an element of known concentration).



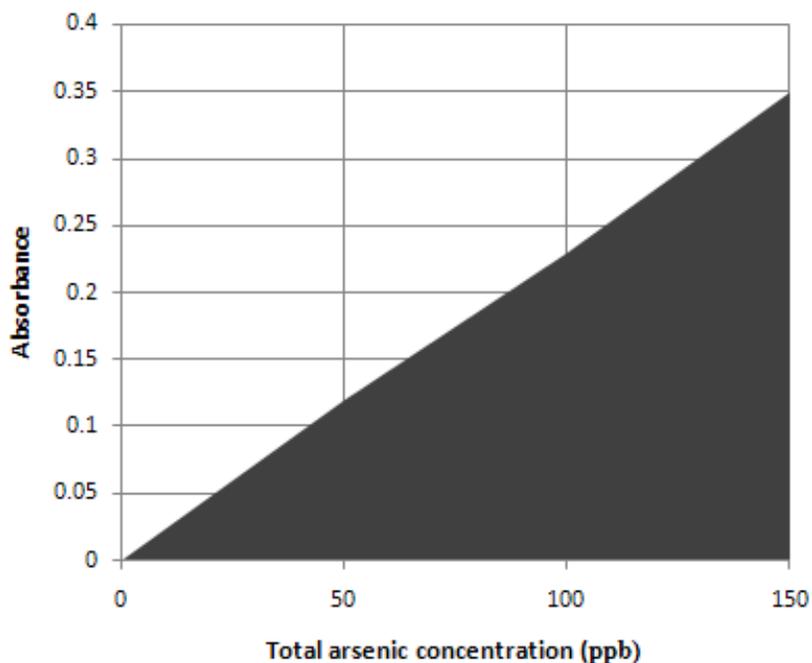
– **Uses of AAS:**

- It is used to monitor concentrations of heavy-metals in the environment as well as in food, for health and safety reasons. AAS is used even at low concentrations, these metals are very dangerous.
- It is used to measure concentrations of micronutrients in soils.
- Used to measure levels of pollutants in water, soil and air.
- It can determine the concentration of *trace elements* in living things and hence determine the cause of deficiency-related diseases.

- **The Impact of AAS On Understanding of Trace Elements:**
 - *Trace elements* are elements that are required in living things in very small amounts (in the range of 1-100 ppm).
 - Trace elements are needed in minute quantities for the proper growth, development, and physiology of organisms.
 - For example, common trace elements in humans are zinc, cobalt, copper, nickel, molybdenum, iodine and selenium.
 - Before the invention of AAS, analytical methods were not sensitive enough to measure the concentration of trace elements in organic samples.
 - The presence of these elements were often unnoticed, and the causes of diseases relating to trace-element deficiency (such as goitre; iodine deficiency) were unknown.
 - AAS showed that not only that there were trace amounts of elements in all organisms, but that these were also essential for their well-being.
 - Hence, AAS had a great impact on the understanding of trace elements:
 - Examples of AAS use related to trace elements:
 - In coastal SW Australia, animal health was very poor even though they were grazed on seemingly good pasture. AAS showed that there were cobalt deficiencies in the soil and the pasture, and this was corrected.
 - Arid areas of Victoria could not support legume crops until molybdenum deficiencies were detected and rectified.
- *Gather, process and present information to interpret secondary data from AAS measurements and evaluate the effectiveness of this in pollution control:*
 - AAS is an extremely effective tool in pollution monitoring and management.
 - It can be used to measure levels of pollutants in the soils, food, water and has many other applications in relation to pollution control.
 - **EG:**
 - AAS was used in Bangladesh to monitor levels of arsenic in drinking water.
 - Arsenic is a serious pollutant as it is extremely toxic.
 - The following AAS absorbance data was obtained by using standard solutions of arsenic of known concentration:

Total Arsenic Concentration	Absorbance
50 $\mu\text{g/L}$	0.12
100 $\mu\text{g/L}$	0.23
150 $\mu\text{g/L}$	0.35

- This data was then graphed on a *calibration curve*:



- Samples of drinking water were taken their absorbances were measured:

Sample	Absorbance
1	0.28
2	0.13
3	0.31

- These absorbances were then plotted on the graph, and from there the arsenic concentrations were estimated:
 - Sample 1 (124 ppb)
 - Sample 2 (61 ppb)
 - Sample 3 (163 ppb)
- Arsenic levels higher than 100 ppb were considered polluted.
- Hence, AAS is a very effective tool in pollution monitoring and control.

- *Gather, process and present information to describe and explain evidence for the need to monitor levels of specific ions in substances used in society:*
 - **Lead:**
 - Lead needs to be monitored because it is a severe neurotoxin.
 - It retards intellectual development in young children, causes brain damage and can lead to neurological disorders.
 - Until recently, lead was widely used as an additive in petrol; it was released in great quantities to the atmosphere in vehicle exhausts and deposited in the environment near highways.
 - Lead also used to be found in many paints, as these were often lead-based pigments; this lead was released into waterways, the soil and air when old houses were demolished.
 - Monitoring of lead concentrations of soil near highways, in water and in the atmosphere is essential to ensure that people are not exposed to harmful levels of toxic lead ions.
 - **Phosphate:**
 - Phosphate occurs in natural waterways at low concentrations and is essential for normal aquatic plant growth.
 - However, if phosphate levels become too high, it could set off an algal bloom; this will ‘choke’ the entire waterway, as the waterway will be completely surrounded by algae and drained of oxygen.
 - This has many detrimental effects on the ecosystem living in the water.
 - Hence, by monitoring the levels of phosphates in waterways and in consumer goods that reach waterways (e.g. detergents), scientists can guard against the development of algal blooms.
- **PRACTICAL** – *Perform first-hand investigations to carry out a range of tests, including flame tests, to identify the following ions:-*
 - **Cations:** *Barium, calcium, lead, copper and iron:*
 - **Anions:** *Phosphate, sulfate, carbonate and chloride:*

- In this practical, students were given vials of unknown solutions; vials were labelled as ‘mixtures of ions’ or ‘only one ion’.
- Using both precipitation and flame tests, the contents of the vials were determined.
- **Precipitation Tests:**
 - Please see ABOVE for a very in-depth coverage of precipitation tests used to determine anions and cations present in a sample.
- **Flame Tests:**
 - Flame tests were only used to identify cations.
 - Anions cannot be identified by flame tests.
 - Out of the given list of cations, only *barium*, *calcium*, and *copper* produce a distinctive flame colour when sprayed into a flame:
 - Ba^{2+} gives a *pale-green* flame.
 - Ca^{2+} gives a *brick-red* flame.
 - Cu^{2+} gives a *blue-green* flame.
- **PRACTICAL** – *Identify data, plan and select equipment and perform first-hand investigations to measure the sulfate content of lawn fertiliser and explain the chemistry involved:*
 - In this practical, the sulfate content of a lawn fertiliser was calculated.
 - This is an example of **gravimetric analysis**; it is a quantitative analysis.
 - **METHOD:**
 - In a dry beaker, 5 grams ($\pm 0.01\%$) of fertilizer was electronically weighed.
 - All the fertilizer was carefully transferred to a mortar and pestle, where it was ground into a fine powder.
 - The powder was transferred into a beaker; using a wash bottle with distilled water, all the residue was washed into the beaker up to the 200 mL mark.
 - 50 mL of 0.1 M hydrochloric acid was added, and the mixture stirred until all of the fertilizer dissolved.
 - The mixture was then heated to its boiling point; the flame was turned off, and barium chloride was added in drops, which formed a precipitate:
 - $\text{BaCl}_{2(\text{aq})} + \text{SO}_{4}^{2-}(\text{aq}) \rightleftharpoons \text{BaSO}_{4(\text{s})} + 2\text{Cl}^{-}(\text{aq})$
 - Barium chloride was added until no more precipitate formed.

- The mixture was *digested* (heated just below boiling point) for 30 minutes, stirring every now and then, and then the precipitate was allowed to settle.
- The beaker and its contents was then cooled in an ice-bath.
- Using a sintered-glass crucible (which had its mass recorded), connected to a vacuum pump, the mixture was filtered.
- The crucible was washed with water, and then ethanol, and then dried in an oven to a constant mass.
- The difference between the crucible's original weight and weight after drying (which was the mass of BaSO₄) was found to be 5.92 g.

– CALCULATING SULFATE CONTENT:

$$\text{mass of BaSO}_4 \text{ formed} = 5.92 \text{ g}$$

$$\begin{aligned} \text{percentage of sulfate in BaSO}_4 &= \text{molar mass sulfate} / \text{molar mass BaSO}_4 \\ &= (32.1 + 4 \times 16.0) / (137.3 + 32.1 + 4 \times 16.0) \\ &= 41.2 \% \end{aligned}$$

$$\begin{aligned} \text{mass of sulfate in BaSO}_4 &= 5.92 \times 41.2 \% \\ &= 2.44 \text{ g} \end{aligned}$$

$$\begin{aligned} \text{percentage of sulfate in fertilizer} &= \text{mass of SO}_4 / \text{mass of fertilizer} \times 100 \\ &= 2.44 / 5.0 \times 100 \\ &= 48.9 \% \end{aligned}$$

- *Analyse information to evaluate the reliability of the results of the above investigation and to propose solutions to problems encountered in the procedure:*

– RELIABILITY:

- The use of a very precise electronic scale ensured accurate measurement.
- The fertilizer was ground into a powder to ensure that all of it dissolved; if some sulfate stayed in solid form, the measurements would be inaccurate.
- The washing of the mortar and pestle into the beaker was to ensure all of the fertiliser was transferred into the beaker.
- Hydrochloric acid was added to aid in the dissolving of the fertiliser.
- *Slowly* forming precipitates (using a dropper) at a *high* temperature ensures the formation of large particles.

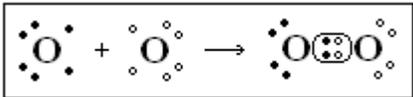
- Also, the mixture was digested for half an hour to allow the particles to grow.
 - Large particle size meant fewer losses of BaSO_4 through the filter.
 - The mixture was cooled in ice-water to greatly reduce the solubility of BaSO_4 to ensure that virtually all of the sulfate precipitated out.
 - A sintered-glass crucible was used instead a filter-paper as filter paper pores are too large; they allow an unacceptable level of BaSO_4 through.
 - The washing with water and ethanol removed any traces of contaminants.
- SOLUTIONS to **Problems Encountered:**
- Human errors in measurement were the main source of inaccuracies; more careful measurement of fertilizer mass, would ensure better results.
 - There were small losses of barium sulfate due to its very small solubility. This was why the beaker was cooled in ice-water before filtering (solubility decreases at low temperatures). However, due to time constraints, cooling did not occur to a great extent.
 - Longer digestion times would allow larger particles to form, and less loss of barium sulfate through the filter would occur.
 - There was possibly some barium sulfate left on the beaker walls before filtering; this would be solved by washing out the beaker with distilled water.
 - An incomplete drying of the sintered glass crucible (due to moist environment, as well as time constraints) would be solved by a longer period of heating, as well as by using a dessicator.

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

- *Describe the composition and layered structure of the atmosphere:*
 - The **atmosphere** is a layer of gas, 200-300 km thick, that surrounds the Earth.
 - COMPOSITION:
 - The atmosphere's main composition of gases is:
 - 78% *nitrogen*.
 - 21% *oxygen*.
 - 0.9% *argon*.
 - Other gases that make up an extremely small percentage of the atmosphere are *carbon dioxide*, oxides of *nitrogen* (NO_x), *sulfur* compounds (SO_2 and H_2S), *carbon monoxide*, *neon*, *helium*, *hydrogen*, *ammonia*, *ozone* (O_3) and volatile organic compounds, such as *methane*.
 - The atmospheric levels of these less abundant gases is measured in the unit called '**ppm**' (parts per million).
 - The levels of *water vapour* in the atmosphere varies greatly according to weather, location, and other factors, and hence is often disregarded.
 - STRUCTURE:
 - The atmosphere is divided into layers, each with its own characteristics.
 - The first layer is the *troposphere*, followed by the *stratosphere*, then the *mesosphere*, *thermosphere*, *ionosphere* and then finally the *exosphere*.
 - For this course, we will focus our atmospheric study on the troposphere (called the 'lower atmosphere') and the stratosphere.
 - **Troposphere:**
 - Extends up from the surface of the Earth, to 15 km high.
 - At about 15 km high is the *tropopause*; it marks the end of the troposphere, and is the beginning of the stratosphere.
 - The troposphere is the region where 'weather' is experienced.
 - *Temperature Profile:*
 - ◆ Temperature decreases as altitude increases (as you go up).

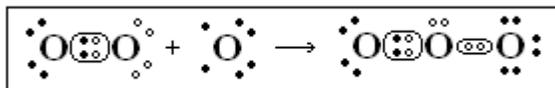
- **Stratosphere:**
 - Extends from 15 km (the *tropopause*) to 50 km.
 - At about 50 km high is the *stratopause*, where the mesosphere begins.
 - The stratosphere has no ‘weather’.
 - The *ozone layer* is in the stratosphere.
 - *Temperature Profile:*
 - ◆ Temperature increase as altitude increases.
- *Identify the main pollutants found in the lower atmosphere and their sources:*
 - POLLUTANTS:
 - **Carbon monoxide:** From motor cars, bush fires, cigarettes, gas stove-tops.
 - **Oxides of nitrogen** (NO + NO₂): From vehicles and power stations.
 - **Sulfur dioxide:** combustion and metal extraction (from sulfide ores).
 - **Hydrocarbons:** From vehicles and industrial solvents.
 - **VOCs** (*volatile organic compounds*): industrial plants, domestic solvents.
 - **Particulates** (*soot, asbestos, etc.*): combustion, mining, bushfires.
 - **Airborne lead:** lead smelters and lead-based paint from old houses.
 - GAS MIXING:
 - Hot air rises and cold air falls.
 - For the *troposphere*, its bottom is warmer than its top (because temperature decreases as altitude increases); hence, the air from the bottom is always rising to the top. That is, there is constant mixing of gases (*convection*).
 - This means that pollutants released at the Earth’s surface by human activity are rapidly dispersed throughout the troposphere.
 - This is what causes the lower atmosphere to be so rapidly polluted.
 - For the *stratosphere*, its bottom is colder than its top (because temperature increases as altitude increases); hence, there is little movement of gases. The cold air at the bottom and hot air at the top simply stays there.
 - This ‘protects’ the stratosphere from pollutants released at the surface, as gas mixing stops at the tropopause. The only way pollutants enter the stratosphere is by slow *diffusion* of gases.

- *Describe the formation of a coordinate covalent bond:*
 - **RECALL:**
 - The *valence shell* is the outermost electron shell of an atom.
 - Chemical reactions occur because of the activity of valence electrons; for example, if valence electrons are transferred from one atom to another, this is a chemical reaction resulting in the formation of an *ionic bond*.
 - To achieve *chemical stability*, all atoms seek to have an **octet** (8) of electrons in their valence (outermost) shells.
 - In a normal covalent bond, two atoms **SHARE** electrons in order for both to have a complete shell of eight electrons:
 - **EG:** 2 oxygen atoms can share electrons to form a covalent bond and make an oxygen molecule (O₂). Notice that each oxygen contributes 2 electrons to the covalent bond (the ‘bubble’):


 - **TIP** - To count the electrons that belong to an atom, count **BOTH** electrons in bonds (all of them), as well as the electrons not in bonds.
 - For example, the left oxygen atom in the O₂ molecule has 4 electrons not in a bond, as well as 4 electrons in a bond. Hence it has a total of 8 electrons, which makes it a stable atom.
 - However, in a coordinate covalent bond between two atoms, one atom will *donate* a pair of electrons to the other to form a bond, so both can have an octet:
 - Further explained in the next dot-point.
- *Demonstrate the formation of coordinate covalent bonds using Lewis electron-dot structures:*
 - **RECALL:**
 - In LEWIS electron-dot structures, atoms are represented by their chemical symbol, surrounded by only valence electrons; e.g. oxygen will be represented as an ‘O’ surrounded by 6 electrons (see ABOVE).
 - Use different symbols for the electrons of different atoms (e.g. crosses/dots).

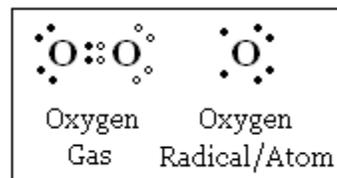
- A *coordinate-covalent* bond involves one atom donating a pair of electrons to the other to form a bond, so both can have an octet; all the electrons in the bond come from one atom:

- **EG:** In the OZONE (O_3) molecule, one of the oxygen atoms forms a coordinate covalent bond with an oxygen atom:



- **TIP** – When asked to draw a Lewis diagram of ozone, check that all oxygen atoms have only 6 electrons of their own, but 8 electrons bonded altogether:
 - Left: 4 unbonded electrons + 4 electrons in covalent bond = 8
 - Middle: 2 unbonded + 4 in covalent bond + 2 in coordinate covalent = 8
 - Right: 6 unbonded + 2 in coordinate covalent = 8
- *Compare the properties of the oxygen allotropes O_2 and O_3 and accounts for them on the basis of molecular structure and bonding:*
 - **RECALL:**
 - Allotropes are different structural forms of the same element.
 - For example, allotropes of carbon are graphite and diamond.
 - Allotropes can exhibit very different physical AND chemical properties.
 - Oxygen has 2 stable allotropes; oxygen gas (O_2) and ozone gas (O_3).
 - These two allotropes exhibit different many different properties, and these can be explained in terms of molecular structure and bonding:
 - **Colour:** O_2 is colourless, while O_3 is a pale blue gas:
 - No explanation available.
 - **Boiling Point:** The boiling point of O_2 is -183°C , while O_3 has one of -111°C :
 - The boiling point of O_2 is lower than that of ozone as O_2 has a lower molecular mass, hence requiring less energy in the boiling process.
 - **Solubility in Water:** O_2 has very low solubility in water compared to O_3 :
 - Non-polar O_2 does not form strong intermolecular forces in the polar water. Ozone has a bent structure, which creates a slight polarity in the molecule, allowing it to have intermolecular interactions with water.
 - **Chemical Stability:** Ozone is much less stable than O_2 :

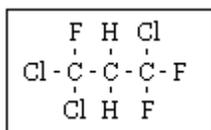
- To decompose oxygen, its double bond has to be broken; this requires considerable amounts of energy. However, the single bond (coordinate covalent bond) in ozone requires much less energy to be broken, and hence ozone is much less stable (readily decomposes to O₂).
- **Oxidising Strength:** O₂ is a moderately strong oxidising agent, while O₃ is an extremely strong oxidising agent:
 - The oxidising strength of ozone comes from the weakness of the single bond; it easily releases an oxygen which can then oxidise a compound.
- *Compare the properties of the gaseous forms of oxygen and the oxygen free radical:*
 - Free radicals are atomic or molecular species with unpaired electrons.
 - They are NOT ions.
 - **EG:** The *oxygen* free radical:
 - The oxygen free radical has two pairs of electrons, as well as two **unpaired** electrons (see diagrams); these unpaired electrons are highly reactive.
 - It is basically an oxygen atom; they have the same electron configuration.
 - The oxygen free radical can be made either by passing electrical current through oxygen gas to decompose it, or by exposure to U.V. radiation:
 - $O_2 \longrightarrow 2O\cdot$
 - The oxygen radical is very short-lived, and will instantly react with other radicals, and so it cannot be compared to oxygen gas in terms of physical properties such as boiling point or colour.
 - However, a comparison can be made in terms of reactivity:
 - The oxygen free radical is much more reactive than oxygen gas.
- *Describe ozone as a molecule able to act both as an upper atmosphere UV radiation shield and a lower atmosphere pollutant:*
 - The action of ozone (as well as its value) depends greatly on where it is located.
 - In the upper atmosphere (*stratosphere*) ozone is found as the ‘ozone layer’. It is extremely crucial part to life on Earth.
 - However, in the lower atmosphere (*troposphere*), ozone is a serious air pollutant.



- **Ozone in the Upper Atmosphere:**
 - Ozone in the stratosphere, in the form of an *ozone layer*, protects us from harmful ultraviolet radiation (UV light):
 - There are 3 forms of UV light; UV-A, UV-B and UV-C.
 - The ozone-layer blocks the harmful UV-B and UV-C rays from passing through the atmosphere; these can cause many cancers and severe sunburn.
 - The useful UV-A (needed for photosynthesis) can still pass through.
 - The following equations show how ozone is formed and destroyed as well as how it protects us from harmful UV radiation:
 - $\text{O}_2 + \text{UV radiation} \longrightarrow 2\text{O}\cdot$
 - $\text{O}\cdot + \text{O}_2 \longrightarrow \text{O}_3$
 - $\text{O}_3 + \text{UV radiation} \longrightarrow \text{O}\cdot + \text{O}_2$
 - $\text{O}\cdot + \text{O}_3 \longrightarrow 2\text{O}_2$
 - Every time an oxygen/ozone reacts with UV light, it absorbs it.
 - Hence ozone can be said to be an upper atmosphere UV radiation shield.
- **Ozone in the Lower Atmosphere:**
 - However, when ozone is found in the lower atmosphere (*troposphere*), it is considered a serious air pollutant.
 - This is because ozone can cause serious health and environmental problems.
 - HEALTH ISSUES:
 - Ozone is poisonous to humans; as a strong oxidant, it can react with body tissue, especially with sensitive mucous membranes when breathed in.
 - Ozone causes breathing difficulties, aggravates respiratory problems and produces headaches and premature fatigue.
 - PHOTOCHEMICAL SMOG:
 - When ozone is found as a component of *smog* it is a serious pollutant, and can be very hazardous for health.
 - Sunlight splits nitrogen dioxide and the free radical produced joins with oxygen to form ozone: $\text{NO}_2 \longrightarrow \text{NO} + \text{O}\cdot$. Also, hydrocarbons and PAN (*peroxyacyl nitrates*) can be present in the smog.
- Thus ozone is both as a major pollutant, and a UV radiation shield.

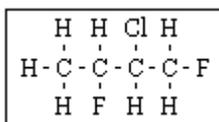
- Identify and name examples of isomers (excluding geometrical and optical) of haloalkanes up to eight carbon atoms:

- **Haloalkanes** are compounds formed when one of the hydrogens of an alkane is replaced by a *halogen* atom (F, Cl, Br or I).
- *Naming Haloalkanes*:
 - There is a systematic IUPAC method of naming haloalkanes.
 - **EG**: Name this haloalkane:

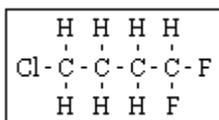


1. Firstly, count the number carbons in the longest carbon chain; in this case, there are 3, so the parent alkane is PROPANE.
 2. Next identify, name and number the halogens, using ‘*fluoro-*’, ‘*chloro-*’, ‘*bromo-*’ and ‘*iodo-*’ as prefixes instead of chemical names. Say we take the left-most carbon as carbon-1 (C₁); then, there are 3 chlorines (2 on C₁ and 1 on C₃), and there are 3 fluorines (1 on C₁ and 2 on C₃). For multiple halogens, use the prefixes *di-*, *tri-*, and *tetra-*. Hence, so far we have propane, 1,1,3-trichloro- and 1,3,3-trifluoro.
 3. To make the full name, place the parent alkane at the end, and place the halogens in *alphabetical* order: 1,1,3-trichloro-1,3,3-trifluoropropane.
 4. Now CHECK; say instead we took the right-most carbon as C₁. In that case, the name would be 1,3,3-trichloro-1,1,3-trifluoropropane. You MUST take the name with the *lower sum* of numbers.
 5. In this case, both names have an equal sum. If this occurs, you give the lower numbers to the more electronegative halogen (F > Cl > Br > I). Hence, the **correct** name is *1,3,3-trichloro-1,1,3-trifluoropropane*.
- Isomers:
 - **Isomers** are compounds that have the same *chemical* formula, but different *structural* formula.
 - Carbon compounds, such as *haloalkanes* are able to form many different isomers; the longer the chain, the more isomers are possible.

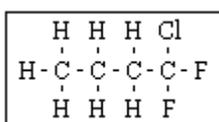
- **EG:** Draw 4 isomers of $C_4H_7ClF_2$ and name them using IUPAC nomenclature:



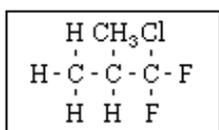
- 2-chloro-1,3-difluorobutane.



- 4-chloro-1,1-difluorobutane.



- 1-chloro-1,1-difluorobutane.



- 1-chloro-1,1-difluoro-2-methylpropane.

- *Identify the origins of chlorofluorocarbons (CFCs) and halons in the atmosphere:*

– **CFCs:**

- *Chlorofluorocarbons* are compounds that contain ONLY carbon, fluorine and chlorine; NO hydrogen atoms (e.g. CFC-12 is CCl_2F_2).
- CFCs were introduced in the 1930's (known as *freons*) as replacements for *ammonia* in refrigeration:
 - This was because had the required pressure-dependent properties that refrigerants needed, as well as that they were odourless, non-flammable, non-toxic and inert, much unlike the toxic, foul-smelling ammonia.
- CFCs were very widely used as:
 - Refrigerants in fridges and air-conditioners.
 - Propellants in aerosol spray cans.
 - Foaming agents in the manufacture of foam plastics like polystyrene.
 - Cleaning agents in electronic circuitry.

- These many uses released CFCs directly into the lower atmosphere.
 - As they were very inert and insoluble in water (rain), they remained in the troposphere, where air convection spread them throughout the atmosphere.
 - Very slowly, the CFC's began to diffuse through the tropopause and into the stratosphere, where problems began to occur.
- **Halons:**
- *Halons* are compounds that contain carbon and bromine, as well as other halogens; they are basically CFC's that also contain bromine (no hydrogen).
 - They are dense, non-flammable liquids that were widely used as effective fire-extinguishers (called BCF fire-extinguishers).
 - As they were used onto fires, the halons were released directly into the atmosphere, where they too slowly diffused into the stratosphere.
- *Discuss the problems associated with the use of CFCs and assess the effectiveness of steps taken to alleviate these problems:*
 - The biggest problem associated with the use of CFCs is the destruction of stratospheric ozone (i.e. *depletion of the ozone layer*):
 - As stated above, CFCs are very inert, and are not washed out by rain.
 - As a result, CFCs remain in the troposphere for many years, and eventually diffuse into the stratosphere, where they deplete the ozone layer.
 - This leads to more UV radiation reaching Earth, which greatly increases the chances of mutations and damage (especially cancer) in living things.
 - **How CFCs Destroy The Ozone Layer:**
 - Firstly, short wavelength UV radiation (that has not been removed by the ozone layer) attacks the CFC molecule and breaks off a chlorine atom:
 - $\text{CCl}_2\text{F}_2(\text{g}) + \text{UV radiation} \longrightarrow \cdot\text{Cl}(\text{g}) + \cdot\text{CClF}_2(\text{g})$
 - This chlorine atom (*radical*) then reacts with ozone, forming oxygen gas, and a chlorine monoxide radical (ClO):
 - $\cdot\text{Cl}(\text{g}) + \text{O}_3(\text{g}) \longrightarrow \cdot\text{ClO}(\text{g}) + \text{O}_2(\text{g})$
 - The chlorine monoxide radical then reacts with an oxygen radical, and the chlorine radical is *regenerated*:
 - $\cdot\text{ClO}(\text{g}) + \cdot\text{O}(\text{g}) \longrightarrow \cdot\text{Cl}(\text{g}) + \text{O}_2(\text{g})$

- The net result is that an ozone molecule and an oxygen radical have been converted into 2 oxygen molecules AND the chlorine has not been used up.
- The chlorine radical can then attack another ozone molecule and repeat the whole process thousands of times; this is a *chain reaction*.
- A very small amount of CFC in the stratosphere can do significant damage.
- **How Chlorine Radicals Are Removed:**
 - According to the above, theoretically, a single chlorine atom could destroy the entire ozone-layer; however certain natural reactions remove this radical.
 - The chlorine atom reacts with stratospheric *methane*, ending the chain reaction:
 - $\cdot\text{Cl}_{(g)} + \text{CH}_4_{(g)} \longrightarrow \text{HCl}_{(g)} + \cdot\text{CH}_3_{(g)}$
 - Neither HCl nor the methyl-radical has any effect on ozone.
 - Another important reaction for stopping ozone depletion involves the $\cdot\text{ClO}$ species reacting with nitrogen dioxide, forming *chlorine nitrate*:
 - $\cdot\text{ClO}_{(g)} + \text{NO}_2_{(g)} \longrightarrow \text{ClONO}_2_{(g)}$
- **The Antarctic Spring Ozone Hole:**
 - There is a serious periodic depletion of the ozone-layer that occurs every spring over Antarctica; it is called the ‘Ozone Hole’.
 - This is due to the conditions of Antarctica in winter, as well as spring.
 - Antarctic *winters* are perpetually dark; the cold conditions, as well as solid particulate catalysts in the air, encourage the following reaction to occur:
 - $\text{HCl}_{(g)} + \text{ClONO}_2_{(g)} \longrightarrow \text{Cl}_2_{(g)} + \text{HNO}_3_{(g)}$
 - This has zero effect on ozone levels during the winter.
 - However during early spring, the Sun begins to rise, and the situation changes dramatically; sunlight is able to split chlorine molecules:
 - $\text{Cl}_2_{(g)} + \text{UV radiation} \longrightarrow 2\cdot\text{Cl}_{(g)}$
 - Hence in spring there is another source of chlorine radicals to destroy more ozone; the concentration of ozone is reduced dramatically, causing a hole.
 - Eventually, the fixed amount of Cl_2 created over the winter is blown away by Antarctic winds and the ozone layer slowly regenerates.
- **Dealing With The CFC Problem:**
 - The only way to stop ozone depletion is to STOP releasing CFCs of any form.

- **INTERNATIONAL AGREEMENTS:**
 - The main way the CFC problem is being dealt with is by international agreements based on the common goal of phasing out CFCs.
 - The Montreal Protocol on Substances That Deplete the Ozone Layer (1987) is an international treaty designed to protect the ozone layer by phasing out the production of a number of substances believed to be responsible for ozone depletion.
 - Its goals include ceasing the manufacturing and banning the use of CFCs and certain haloalkanes by 1996, the end of halon use by 1994, the phasing out of HCFCs, as well as the provision of financial assistance to developing nations in order to help them reach the goals of Montreal.
- **CFC REPLACEMENTS:**
 - Finding alternative compounds to fulfil the roles of CFCs is a major step forward in preventing ozone depletion.
 - This is examined in greater detail below.
- *Dealing With Increased UV Radiation:*
 - Increasing UV levels have meant that more UV inhibitors need to be included in polymers (such as PVC) and Cancer Councils have advised the use of only sunscreens with a rating of SPF 30+ or greater.
- **Effectiveness of These Solutions:**
 - The Montreal Protocol is only effective if member nations ratify the protocol and adhere to its regulations; so far, the Montreal Protocol has been a huge success in international agreement and environmental health.
 - Certain CFC replacements are not as effective as the CFCs themselves; future technological advancement hopes to find better replacements.
 - There are still, however, significant levels of CFCs in the atmosphere, and current technology has no way of removing them.
- **The Greenhouse Problem:**
 - A less talked about issue of CFCs and HCFCs is that they contribute greatly to the increased *greenhouse effect* (thousands of times more than CO₂).
 - This may lead to climate change, and is the focus of the Kyoto Protocol.

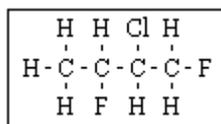
- *Present information from secondary sources to write the equations to show reactions involving CFCs and ozone to demonstrate the removal of ozone from the atmosphere:*
 - All the **CFC**-related equations from *above*:
 - Formation of *chlorine radical*:
 - $\text{CCl}_2\text{F}_2(\text{g}) + \text{UV radiation} \longrightarrow \cdot\text{Cl}(\text{g}) + \cdot\text{CClF}_2(\text{g})$
 - Reaction of *ozone*:
 - $\cdot\text{Cl}(\text{g}) + \text{O}_3(\text{g}) \longrightarrow \cdot\text{ClO}(\text{g}) + \text{O}_2(\text{g})$
 - Regeneration of *chlorine*:
 - $\cdot\text{ClO}(\text{g}) + \text{O}(\text{g}) \longrightarrow \cdot\text{Cl}(\text{g}) + \text{O}_2(\text{g})$
 - Removal of *chlorine radical*:
 - $\cdot\text{Cl}(\text{g}) + \text{CH}_4(\text{g}) \longrightarrow \text{HCl}(\text{g}) + \cdot\text{CH}_3(\text{g})$
 - Removal of *chlorine monoxide radical*:
 - $\cdot\text{ClO}(\text{g}) + \text{NO}_2(\text{g}) \longrightarrow \text{ClONO}_2(\text{g})$
 - Formation of *molecular chlorine*:
 - $\text{HCl}(\text{g}) + \text{ClONO}_2(\text{g}) \longrightarrow \text{Cl}_2(\text{g}) + \text{HNO}_3(\text{g})$
 - Decomposition of *molecular chlorine*:
 - $\text{Cl}_2(\text{g}) + \text{UV radiation} \longrightarrow 2\cdot\text{Cl}(\text{g})$
- *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:*
 - **Ammonia**:
 - Large scale (industrial) refrigeration has reverted back to using *ammonia* as a refrigerant, as was done prior to the discovery of CFCs.
 - However, great care is exercised, as ammonia is dangerous and toxic.
 - **HCFCs**:
 - *Hydrochlorofluorocarbons* are CFCs that contain hydrogen.
 - These were the first replacements for CFCs.
 - HCFCs contain C–H bonds that are susceptible to attack by reactive radicals in the troposphere and so are decomposed rapidly to a significant extent.

- This means that only a very small proportion ever reaches the stratosphere.
- HCFCs replaced CFCs in domestic refrigeration, as propellants in spray cans, as an industrial solvent and as a foaming agent.
- Effectiveness:
 - Small amounts of HCFCs do reach the stratosphere, and hence they are also ozone-depleting (10% the ozone-depleting potential of CFCs).
 - They are seen as only a temporary solution.
 - HCFCs also contribute massively to the greenhouse effect, and so their use is being phased out (complete ban by 2030).
- **HFCs:**
 - *Hydrofluorocarbons* are compounds that contain only carbon, hydrogen and fluorine (NO chlorine or bromine).
 - They are widely seen as a viable CFC and HCFC alternative, as they contain reactive C–H bonds (so they degrade in troposphere) as well as the fact that they do not contain any chlorine (and hence cannot form $\cdot\text{Cl}$ radicals).
 - Their ozone depleting potential is zero.
 - HFCs are very widely used in refrigeration and air-conditioning applications.
 - Effectiveness:
 - As they have zero ozone-depleting potential, HFCs are a good alternative to using CFCs in terms of atmospheric health.
 - However, they are not as effective refrigerants as CFCs, and are slightly more expensive.
 - They are also strong greenhouse gases, and so further research is required.
- *Analyse the information available that indicates changes in atmospheric ozone concentrations, describe the changes observed and explain how this information was obtained:*
 - **How Are Ozone Levels Measured?**
 - Stratospheric ozone levels are measured from ground-based instruments, from instruments in satellites and from instruments in weather-balloons.
 - Ozone levels are measured in Dobson Units (DU).
 - The measurements made indicate that changes in ozone levels have occurred.

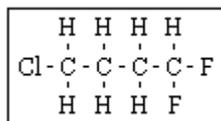
- **GROUND-BASED:**
 - The *ground-based instruments* used are UV spectrophotometers that are able to measure the intensity of light at specific wavelengths.
 - These instruments are pointed directly upwards towards the sky and are set to measure light intensity at the wavelengths of light at which ozone absorbs (such as UV-B and UV-C) and at wavelengths on either side (for light which ozone does not absorb).
 - A comparison of these 2 measurements gives a measure of the total ozone in the atmosphere per unit of area of Earth surface at that location.
- **BALLOON-BASED:**
 - These spectrophotometers can also be placed in high-altitude weather balloons that can rise above the stratosphere.
 - The instruments are pointed downwards, and measure ozone from above.
- **SATELLITE-BASED:**
 - An instrument called the TOMS (*total ozone mapping spectrophotometers*) have been placed on several US satellites.
 - They work similarly to the UV spectrophotometers as above, but as the satellites orbit the Earth, the TOMS is able to scan the entire globe and measure ozone concentrations as a function of altitude and geographical location.
- **The Changes Observed:**
 - Measurements of the total amount of ozone in a column of atmosphere have been recorded since 1957.
 - The main depletion of ozone has occurred over the Antarctic.
 - Scientists identified that a dramatic decline in springtime ozone occurred from the late 1970s over the entire Antarctic. The decline reached approximately 30% by 1985. In some places, the ozone layer had been completely destroyed.
 - The ozone decline over Antarctica during springtime is now not so dramatic, but often exceeds 50%.

- **PRACTICAL** – Gather, process and present information from secondary sources including simulations, molecular modelling kits or pictorial representations to model isomers of haloalkanes:

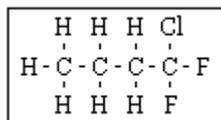
- In this experiment, **molecular modelling kits** were used to show different isomers of a haloalkane.
- The class was divided into groups, and each group was provided with a kit.
- Each group was provided with a haloalkane, which they were required to draw structural formula for, and then using the kit, 3 different isomers were formed.
- **JUSTIFY** the method:
 - The models created a good visual 3D representation of a chemical property; that is, isomerism.
- **RESULTS:**
 - Four isomers of $C_4H_7ClF_2$ with their IUPAC names:



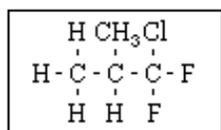
- 2-chloro-1,3-difluorobutane.



- 4-chloro-1,1-difluorobutane.



- 1-chloro-1,1-difluorobutane.



- 1-chloro-1,1-difluoro-2-methylpropane.

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:

- *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:*
- **Concentration of Common Ions:**
 - Usually, the concentration of all the ions in a solution is considered as a whole; this is called the *total dissolved solids*.
 - However, certain common ions have their concentrations individually measured; the results of these tests indicate different aspects of water quality.
 - Important ions whose concentrations are individually measured include metal cations such as *sodium* (Na^+), *magnesium* (Mg^{2+}), *calcium* (Ca^{2+}) and anions such as *chloride* (Cl^-) and the polyatomic *phosphate* (PO_4^{3-}) and *nitrate* (NO_3^-).
 - The concentrations of sodium and chloride are important indicators of the *salinity* of water system; any significant change in salinity (whether increase or decrease) can greatly affect any aquatic life.
 - *Magnesium* and *calcium* ions are measured to indicate water hardness, which is covered in more detail *below*.
 - Phosphate and nitrate ions are essential to aquatic life; however, excess levels of these ions leads to eutrophication and algal blooms, destroying waterways.
 - **MEASURING IONS:**
 - The concentration of the *metal cations* in samples is very quickly and easily measured using spectroscopic methods such as AAS.
 - Chloride levels can be measured by titrating the sample against silver nitrate, with potassium chromate as the indicator.

- The methods used to determine *phosphate* and *nitrate* levels in water samples are covered *below* (see ‘Monitoring Eutrophication’).
- **Total Dissolved Solids:**
- TDS (total dissolved solids) is the total mass of all solids dissolved in a given volume of water. It is given as either mg/L or ppm (both mean the same thing).
 - The dissolved solids are mainly composed of salts (ionic compounds).
 - TDS is related to the quality of water because clean water is relatively free of contaminants; a large amount of dissolved solids indicates unclean water.
 - **MEASURING TDS:**
 - A gravimetric method for determining TDS is by first filtering the water sample to obtain a clear solution, then *evaporating* the sample *dryness*, and weighing the solids. This method is very laborious and prone to inaccuracies, and hence electrochemical methods are preferred.
 - Because most of the dissolved solids are ions, the *electrical conductivity* of the water sample can be used to measure TDS. Although conductivity tests give a measure of total dissolved salts, this is quite an accurate approximation for TDS.
- **Hardness:**
- Hard-water is water with high levels of *calcium* and *magnesium* ions.
 - Hardness is an issue for water quality because hard-water creates ‘scale’ deposits of CaCO_3 and MgCO_3 on sinks and bathtubs. Also soap does not work in hard water, and forms scum-precipitates which can stain fabrics.
 - **MEASURING HARDNESS:**
 - The levels of these ions can be measured by titration against a compound known as EDTA (ethylene-diamine-tetra-acetic-acid).
 - Hardness is then expressed as mg/L of CaCO_3 .
 - Alternatively, the levels of Mg^{2+} and Ca^{2+} can be measured using AAS.
- **Turbidity:**
- Water *turbidity* means a ‘cloudiness’ of the water.
 - Turbidity is caused by the presence of suspended solids that are sufficiently small so that they do not settle upon standing and remain suspended.

- Turbidity gives water an undesirable appearance as well as a unpleasant taste.
- High levels of turbidity can affect the penetration of light through the water, which then reduces the rate of photosynthesis, reducing dissolved oxygen.
- **MEASURING TURBIDITY:**
 - Turbidity is measured using a turbidity tube.
 - A *turbidity tube* is a long hollow plastic cylinder that has a mark (usually a black cross) inscribed onto its flat bottom. Water is poured into the tube until the mark is no longer visible. The height of water at which this occurs is the turbidity measurement of the water.
 - Turbidity is measured in NTU (nephelometric turbidity units).
- **Acidity:**
 - The pH of a water system is a good indicator of its health.
 - Anything outside the normal range of 6.5-8.5 indicates a polluted system, caused by the discharge of some chemical into the water.
 - Great changes in acidity/alkalinity greatly affect the usability of water.
 - **MEASURING pH:**
 - The pH of water is measured using indicators, pH strips or a pH meter.
- **Dissolved Oxygen:**
 - DO (dissolved oxygen) refers to the levels of *molecular* oxygen (O_2) that are dissolved in a water sample.
 - Even though O_2 has very low solubility in water, this small amount is crucial to aquatic life; this oxygen is extracted and used for respiration.
 - Low oxygen levels (lower than 5 ppm) will cause many aquatic species to die. The water body will decay and develop undesirable characteristics.
 - **MEASURING DO:**
 - Dissolved oxygen can be measured using a chemical titration known as the *Winkler Method*. In this method, the dissolved oxygen oxidises manganese from Mn^{2+} to $Mn(IV)$ in alkaline solution. $Mn(IV)$ then oxidises iodide (I^-) ions to iodine (I_2) in acidic conditions. Iodine is then titrated against sodium thiosulfate ($Na_2S_2O_3$) using starch as in indicator.
 - Alternatively, an electronic oxygen sensor can be used.

- **Biological Oxygen Demand:**
 - The BOD (biological oxygen demand) of a water body is a measure of the concentration of dissolved oxygen that is needed for the complete breakdown of the organic matter in the water by anaerobic bacteria.
 - That is, it measures how fast bacteria (or other organisms) use up oxygen.
 - High BOD levels indicate large amounts of organic matter in the water, which will drain the water of oxygen; sewage has very high levels of BOD.
 - **MEASURING BOD:**
 - Two samples of water must be taken; the dissolved oxygen is measured in one of the samples immediately, while the other sample is placed in a sealed air-free container and incubated at 20°C for five days.
 - After 5-day incubation, the second sample's oxygen levels are measured and the difference in dissolved oxygen levels is the BOD.
- *Identify factors that affect the concentrations of a range of ions in solution in natural bodies of water such as rivers and oceans:*
 - The concentrations of a range of ions in bodies of water (such as rivers and oceans) is affected by a number of factors, both *natural* and *unnatural*:
 - It can be said that the source of water for all water-bodies is rain.
 - Rain contains very few ions (only very little Na⁺ and Cl⁻ from sea-spray) and so any increased levels of ions in water bodies is a result of what occurs in between rainfall and when the water flows into the water-body.
 - NOTE that the ion levels in rivers and lakes are much susceptible to change compared to oceans, which have much greater volumes of water.
 - **Natural Sources of Ions:**
 - If rain falls on bushland, and then runs-off into streams and rivers, it will only pick up small amounts of nitrates and phosphates from surface nutrients, as well as some Mg²⁺ and Ca²⁺ from minerals; TDS will be low (≤50).
 - If rain soaks into the ground and flows into *aquifers* (layers of permeable rock) and then into rivers, the water will have increased levels of Ca²⁺, Mg²⁺, Cl⁻, SO₄²⁻ and CO₃²⁻ which are dissolved from the soils and rocks the water flows through. TDS will be moderate (≈200).

- If water seeps down into rocks (*percolates*) in deep underground basins (*artesian basins*) and only reaches the surface centuries later, then the levels of the above ions will increase massively, as may contain other ions (such as Fe^{3+} , Mn^{2+} , Cu^{2+} and Zn^{2+} . TDS values are very high (>1000).
- **Land Clearing:**
 - When land is cleared of vegetation, the soil loses the stabilising effects of plant *roots* and so soil is easily moved and displaced.
 - If rain flows over cleared land, it will disturb dirt and sediment and carry it into the water body it flows into (this will greatly increase TURBIDITY).
 - The level of dissolved solids and ions (TDS) will increase, due to high levels of mineral ions in the soils (such as Na^+ , K^+ etc.)
- **Agriculture:**
 - When rain flows over land used for the growing of crops and pasture-land it leads to increased levels of *phosphates* and *nitrates* due to fertilizer run-off.
 - The turbidity will also increase, as well as the BOD, as organic matter (such as animal faeces) enters the water-ways.
- **Raw Sewage and Other Effluents:**
 - *Raw sewage*, if discharged directly into the water, will greatly increase the levels of many ions (especially nutrient ions such as nitrates and phosphates).
 - Sewage can increase a water-way's TDS by 200 or more; it also greatly increases turbidity, BOD and pathogen levels.
 - *Stormwater* run-off in urban areas can also carry high levels of ions.
 - *Industrial effluent* as well as *leaching* from rubbish dumps can increase the levels of dangerous HEAVY-METAL ions in water (such as Hg^{2+} and Cd^{2+}).
- *Describe the design and composition of microscopic membrane filters and explain how they purify contaminated water:*
 - A membrane filter is basically a thin film of *synthetic polymer* throughout which there are small pores of uniform size.
 - Common polymers used are *polypropylene* and *polytetrafluoroethylene* (PTFE).
 - Filters are classified according to the size of their pores, as this determines what type of particles can pass through.

- FILTER DESIGN:
 - There are many designs in which the filter can be formed; this depends on the purpose for which the filter was made.
 - One simple design involves a thin sheet of filter-membrane that is folded around a hollow core (such as a thin tube) and surrounded by a casing.
 - When water is passed over the membrane, clean water passes through and exits via the hollow core.
 - Another design involves forming the membranes into capillaries (tiny tubes) with a diameter of about 500 μm ; these are called *hollow fibre* filters.
 - Large numbers of these capillaries are bounded together to form a filtering unit that has a very large surface area.
 - Water is passed over the surface of the capillary and clean water passes through to the middle of the capillary and flows out.
- *Describe and assess the effectiveness of methods used to purify and sanitise mass water supplies:*
 - **Monitoring Catchment:**
 - The first step to ensure water used for human use is clean is to ensure that the area the water *flows* over (the CATCHMENT area) is kept clean.
 - This involves banning any land-clearing, industry or agriculture in the entire catchment area, to prevent sediment, animal waste or bacteria to build up in water supplies.
 - EFFECTIVENESS:
 - This is a very cheap and effective way of ensuring the purity of water for human use; by removing the sources of contamination, purity is ensured.
 - **Screening:**
 - Before the water from catchment areas is allowed to enter treatment plants or storage dams, it is passed through metal screens that remove large debris such as sticks, leaves, trash and other large particles which may interfere with subsequent purification steps
 - EFFECTIVENESS:
 - This step is effective for its purpose, but more treatment is needed.

- **Clarification and Flocculation:**
 - Certain suspended particles (called *colloidal particles*) cause water to become turbid, but are too small to be removed by conventional filtration.
 - In this step, these particles are coagulated together to form large particles, which can then be removed; this is called ‘flocculation’.
 - Firstly, the pH of the water is increased, as this encourages the formation of precipitates; this is achieved by adding lime.
 - Next, an electrolyte is added to force the particles to precipitate; iron(III) hydroxide or aluminium chloride is used (although Al^{3+} ions are preferred as they leave no metallic aftertaste in the water, as Fe^{3+} does).
 - The precipitate is first formed as very tiny particles, but as the water is gently agitated or stirred, the particles flocculate into larger particles.
 - **EFFECTIVENESS:**
 - Flocculation removes most of the suspended particles, as well as bacteria, which are caught up in the particle aggregates. It is very cost-effective, and relatively fast.
- **Sedimentation:**
 - Water that has been flocculated is then allowed to *settle* in large tanks; this causes the dirt and other particles to fall to the bottom of the tank as a sludge, where it is removed.
 - The clear water is then pumped to the filtration systems.
 - **EFFECTIVENESS:**
 - Sedimentation employs a natural force (i.e. gravity) to separate the sludge from clean water, and so reduces plant running costs.
 - The slow speed of sedimentation may affect its effectiveness.
- **Filtration:**
 - Water from the settling tank is then passed through a filter bed of fine sand and gravel; this removes the rest of the particulate matter, as well as the material that did not settle to the bottom of the tank.
 - Sometimes *anthracite* (metamorphic coal) is added to the filter beds, as it adsorbs organic matter and removes odours.

- **EFFECTIVENESS:**
 - Sand filtration removes a high proportion of the particulate matter that aggregated during flocculation, however extremely small particles are not removed (such as some bacteria and viruses).
 - It is suitable for providing water to urbanised areas.
- **Chlorination:**
 - Lastly, before water is pumped to homes, chlorine gas is bubbled through the water; this forms the hypochlorite ion (OCl^-) which can kill disease causing agents, such as bacteria and *some* viruses.
 - **EFFECTIVENESS:**
 - Chlorination is an effective way of removing most pathogenic organisms, but, it is not so effective at killing viruses
 - Also, chlorine may impart an unpleasant odour on the water.
- Alternative - **Membrane Filters:**
 - All the above are the steps taken to sanitize water in most Australian plants.
 - Alternatively, membrane filters can be used, which would replace many of the steps used above.
 - Membrane filters would remove the need for flocculation, sedimentation, sand filtration and also chlorination, because:
 - Their pore size is sufficiently small to remove suspended particles.
 - Membranes are very thin and allow the use of pressurization; this greatly speeds up the process, and hence removes the need for sedimentation.
 - Sand filtration is a slow process that membrane filtration supersedes.
 - Membrane filters can remove all bacteria AND viruses, as these organisms are much too large to fit through the pores of a membrane filter.
- However, membrane filters are considerably more *expensive* than current methods used, and so their use is limited by costs.
- *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*

– **Heavy Metals:**

- *Heavy metals* are the transition metals in addition to lead and arsenic.
- The heavy metals that are of the most concern due to their extremely detrimental effects on health (and hence should be monitored for the most) are *mercury, lead, cadmium, chromium* and *arsenic*.
 - The levels of these heavy metals is most easily quantitatively measured by using AAS, as their levels are usually very low.
- One of the most common quantitative tests for the presence of heavy metals is the *sulfide-test*:
 - A water sample is acidified, and then a few drops of sodium sulfide (Na_2S) is added. If a precipitate forms, then one of the following ions is present:
 - ◆ *Lead, silver, mercury, copper, cadmium* or *arsenic*.
 - If no precipitate forms in acidified conditions, then the sample is made alkaline. If this produces a precipitate, then one of the following is present:
 - ◆ *Chromium, zinc, iron, nickel, cobalt, manganese* or *aluminium*.
- **CHEMISTRY:**
 - The sulfide-test is based on the following equilibrium:
 - ◆ $\text{S}^{2-}(\text{aq}) + 2\text{H}_3\text{O}^+(\text{aq}) \rightleftharpoons \text{H}_2\text{S}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
 - When in acidic solution, equilibrium lies greatly to the right, and there is only a small amount of sulfide; this small amount is enough to precipitate the first group of heavy metals, but not the second.
 - In alkaline solution, the equilibrium lies to the left; there are large amounts of sulfide, and hence the 2nd group of heavy metals precipitates (as well as the 1st group; this is why the acidic test is done first).
- Other simple quantitative techniques to identify the presence of *heavy metals* includes other precipitation tests, flame tests (e.g. for copper).
- Other qualitative tests (besides AAS) includes volumetric and gravimetric analyses, colorimetry (using colorimeter devices) and chromatography.

– **Eutrophication:**

- *Eutrophication* is the process by which a water body becomes enriched with nutrients (SO_4^{2-} & NO_3^{2-}) to such an extent that an *algal bloom* is very likely.

- Eutrophication is not the same as algal blooms, but LEADS to algal blooms.
- Waterways need to be monitored for possible eutrophication in order to stop algal blooms from occurring.
- Algal blooms need to be prevented because:
 - Blue-green algae (*cyanobacteria*) in algal blooms produce poisons that can kill humans as well as livestock.
 - Water becomes unsuitable for normal recreational uses as it is clogged up with algae, which can cover rivers for kilometres
 - Algae can starve rivers of oxygen, killing all the aquatic life.
- To monitor waterways for eutrophication, the levels of nitrates and phosphates needs to be measured (*quantitative* testing only).
- NITRATES:
 - Methods to measure the nitrate levels in water usually involve measuring the *total nitrogen* levels in the sample.
 - Two methods are used: *Kjeldahl digestion*, and colorimetric methods.
 - The chemistry of Kjeldahl digestion:
 - ◆ The sample is heated with concentrated sulfuric acid to ‘digest’ any organic nitrogen compounds into ammonium sulfate.
 - ◆ This is then reacted with sodium hydroxide to form ammonia.
 - ◆ The levels of ammonia are then measured by back titration against a standardised solution of hydrochloric acid.
 - The chemistry of the colorimetric method:
 - ◆ In this method, the sample is completely digested, as above, except the sample is then treated with Nessler’s reagent, a chemical that reacts with nitrogenous compounds to form a yellow compound.
 - ◆ The colorimeter then measures the intensity of the yellow colour to calculate the concentration of nitrates.
 - If the levels of nitrate reaches too high, the water is called *eutrophic*.
- PHOSPHATES:
 - As above, techniques to measure phosphates actually measure the levels of *total phosphorus* present in the water sample.

- The main technique used is a colorimetric method.
- The chemistry of the colorimetric method:
 - ◆ In this method, a measured quantity of *ammonium molybdate* is added to the sample and completely dissolved.
 - ◆ A measured quantity of solid (powdered) *ascorbic acid* is then added, and this forms an intensely blue complex of a compound known as 'molybdenum blue'.
 - ◆ The intensity of the blueness is measured by a colorimeter and this places a value on the concentration of phosphate.
- If phosphate levels reach greater than 0.05 ppm (or mg/L), then the water is eutrophic and an algal bloom is extremely likely.
- *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:*
- For the local *Sydney* area, the water is supplied by **Warragamba Dam**.
- CATCHMENT AREA:
 - Warragamba Dam is Sydney's main water storage dam, and one of the largest domestic water supply dams in the world.
 - The dam lies on the Warragamba River, for which it is named.
 - Catchment areas are areas of land from which rain water drains toward a common water-body.
 - The Warragamba catchment has an area of about 9000 km² and extends from south of Goulburn, north to Lithgow, east to Werombi and Mittagong, and west to part of the Crookwell local government area.

- SOURCES OF CONTAMINATION:
 - Land Clearing:
 - Within the catchment area, there are various logging and land-clearing activities occurring to make way for more agricultural land.
 - This has led to increased turbidity in the water flowing into the dam (especially during heavy-flow periods).
 - Higher levels of dissolved solids in the water also occurs.
 - Agriculture:
 - There are various patches of land within the catchment area that are used for agricultural purposes such as growing crops or raising cattle.
 - Run-off from agricultural land contains high levels of phosphates and nitrates as a result of leeching fertilizers from the soil and crops.
 - Low-levels of pesticides (such as organochlorins and organophosphates) have been detected in the run-off from agriculture.
 - Water that runs over land used for cattle-grazing (pasture-land) can carry with it animal faeces (detected by high faecal coliform levels); this contamination leads to the growth of bacteria, as well as a high BOD.
 - Mining:
 - Within the catchment area are abandoned mines which water can flow into.
 - When water leaks into metal mines and flows out, it leaches out with it certain ions such as Zn^{2+} and Cu^{2+} which are heavy metal pollutants, as well as sulfides from the metal ores, which make the water acidic.
 - Coal mining occurs in the outer catchment area; possible contamination of the water involves disposal of mining wastes directly into water-ways.
 - Natural Soil:
 - The natural soil and rock strata around the catchment area have high levels of iron and manganese in them.
 - Rain water can leach out these minerals, in the form of Fe^{3+} and Mn^{2+} ions.
 - This leads to water with a coloured tinge and a metallic taste.
 - Sewage:
 - At certain places along the sewage line are places called '*overflow points*'.

- During times of heavy flooding the sewage treatment plants cannot handle the heavy input of stormwater flows, and so RAW untreated sewage is allowed to flow out of these overflow points.
- This leads to contamination of the water with bacteria and excess ions.
- Animals:
 - Certain feral and native animals may contaminate the water with their faeces directly, or by dying and decaying within the water.
 - This can lead to serious contamination of the water with pathogens.
 - This was the cause of the *Giardiasis* and *Cryptosporidium* scare of 1998.
- TESTING FOR CONTAMINANTS:
 - The testing for contaminants for Warragamba Dam occurs in a variety of locations; using multiple testing sites ensures that a wide range of information.
 - Most chemical tests are used to detect the levels common ions, and ensure that they remain below safe thresholds; this is especially true for nutrient ions.
 - The chemical tests available to determine levels and types of contaminants have already been described in greater detail (see *above*).
 - In summary:
 - The test for common ions uses electrical conductivity; the test for heavy metal ions is the sulfide-test, but AAS is used to determine quantities; the test for nitrates is Kjeldahl digestion; phosphates detection involves molybdenum colorimetry and BOD is measured using the Winkler method.
- WATER PURIFICATION:
 - The purification of water that is caught in the Warragamba catchment area is purified using the method described *above*.
 - It is a cost-effective method for sanitizing water to an acceptable degree.
 - In summary:
 - Water is first screened to remove large debris; flocculation then occurs using Fe^{3+} or Al^{3+} electrolytes, followed by shaking to encourage precipitate formation; this is then left in a sedimentation tank to settle; sludge is scooped out and the clean water is led onto a sand-bed filter; this filter consists of layers of sand and gravel and the water comes out clean.

- CHEMICAL ADDITIVES:
 - The 2 main chemical additives in Sydney water are *chlorine* and *fluoride*.
 - *Chlorine* (Cl_2) is added to the water supply as a disinfecting agent; chlorine gas is bubbled through the water just before it exits the plant. Hypochlorite ions are formed, and these kill bacteria and some viruses, sanitizing the water.
 - *Fluoride* (F^-) is added to the water because it is believed to strengthen tooth enamel in growing children. Fluoride ions are added in the form of sodium fluoride at a controlled concentration of 1 ppm.
- **PRACTICAL** – *Perform first-hand investigations to use qualitative and quantitative tests to analyse and compare the quality of water samples:*
 - In this practical, water samples were taken from the local Cook’s River and using a ‘StreamWatch’ kit the water quality tests were performed on-site.
 - Water samples were taken from various parts of the river, and the results were compared to the same tests performed on distilled water.
 - **Pollutants:**
 - This was a qualitative test performed on the water samples to detect pollution.
 - Any sort of colouration of the water (any deviation from ‘clear’) indicated the presence of a form of pollution; any ‘rainbow streaks’ meant hydrocarbons.
 - The water was smelt to detect any odours (another sign of pollution).
 - A sample bottle was filled half-way with sample water, and another bottle was filled with distilled water; both were shaken at the same time for equal periods of time. If the bubbles remained longer on the sample, this indicated the presence of detergents.
 - The presence of heavy metal pollution was performed in the laboratory; 1 mL of sodium sulfide was placed in 5 mL of sample water. Any precipitate indicated the presence of a heavy metal.
 - **Turbidity:**
 - This test was a relatively quantitative test, with turbidity measured in NTU.
 - Firstly, distilled water was poured into the turbidity tube, and it was clear all the way to the top of the tube. It was given a turbidity of <10 NTU.

- The sample water was collected in a bottle using a telescoping handle, and this water was poured into the tube; it had a much higher turbidity, and clouded the view of the cross on the bottom of the tube.
- **Temperature:**
 - A thermometer (with a rubber handle) was placed directly into the water way to accurately measure the temperature of the water; it was found to be within acceptable ranges.
- **pH:**
 - pH of water samples was done using strips of pH paper.
 - Firstly, the pH of distilled water was measured and found to be 7.
 - The pH of the water sample was then measured and found to be 7.5.
- **TDS:**
 - The total dissolved solids was measured using an electrical conductivity meter that measured in $\mu\text{S}/\text{cm}$ (microsieverts per centimetre).
 - The sample water had only slightly more ions than distilled water.
- **DO/BOD:**
 - The levels of dissolved oxygen was easily measured using an oxygen sensing metre found in the StreamWatch kit.
 - Two sample bottles were filled; one was capped air-free and sealed tightly, and the DO level in the other was measured immediately.
 - The other sample had the levels of DO measured 5 days later, and the difference was the BOD.
- **Hardness:**
 - For hardness, a titration method was used.
 - To a 100 mL sample, 1 mL of buffer solution (pH 10) was added, and 2-3 drops of Eriochrome Black T indicator was added.
 - This red-violet solution was titrated against a solution of EDTA until a permanent blue colour occurred.
 - A lack of definite change in colour meant there were no magnesium ions.