

9.4 Chemical monitoring and management: 1. Monitoring and managing reaction conditions

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[Edit: 18 Jun 10]

Prior learning: Preliminary modules **8.2** (8.2.1, 8.2.2) **8.3** (8.3.3, 8.3.5), **8.4** (8.4.1, 8.4.3, 8.4.4), **8.5** (8.5.1, 8.5.3, 8.5.4, 8.5.5); HSC modules **9.2** (9.2.2, 9.2.3), **9.3** (9.3.4, 9.3.5).

Background: In this module you may encounter new technical language that is necessary in chemistry.

Therefore it is a useful learning technique to build a personal glossary of the terminology encountered.

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

- the variety of chemical occupations
- a specific chemical occupation for more detailed study
- This syllabus point provides an opportunity to identify and **gather** information about practising male and female Australian scientists currently working as chemists. The Internet provides easy access to information on the work of individuals and teams of chemists. Gather information about the variety of chemical occupations and then, more specifically, the role of a chemist employed in a named industry or enterprise and the branch of chemistry undertaken by the chemist.

These scientists are from NSW and have been identified as "Tall Poppies" [*Rediscovering Science with NSW scientists*](#) ▶ NSW Department of Education and Training. Click on Tall Poppies and then scroll down to Dr Peter Rutledge from University of Sydney and Dr Pall Thordarson from the University of NSW.

Most universities provide information about the research activities of their academic staff. A suggested starting point for identifying some current research scientists all over Australia is [Chemistry at Australian Universities](#) ▶ Uniserve

Another source of information is to identify award winners. For example Royal Australian Chemical Institute (RACI) has [National Awards](#) ▶ . You may be able to then use an Internet search engine to find more information about an individual. One example would be Professor Mark von Itzstein, who designed and developed the anti influenza virus drug, Relenza. Professor von Itzstein won the Adrien Albert Award in 2005.

Range of occupations in chemistry

The Royal Australian Chemical Institute (RACI) has thirteen national divisions for membership:

- Analytical
 - Biomolecular
 - Cereal
 - Chemical education
 - Colloid and surface science
 - Environment
 - Industrial
 - Inorganic
 - Electrochemistry
 - Organic
 - Physical
 - Polymer
 - Solid state
- **Process** information that you gather to identify a variety of chemical occupations. You can assess the reliability of the information by considering information from various sources.

NewScientistJobs.com ► is a web site that you can use to identify the skills that are commonly required in a variety of advertisements; review the *Chemistry* section.

- **Present** your findings as a short summary. In presenting your findings, ensure that you select and use an appropriate method to acknowledge sources of information. For web site accessed, it is appropriate to provide acknowledgement in the following form:

Web reference(s):

*Author (if relevant), Title of item, web site owner, online (date last modified)
Available at (provide URL)*

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

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

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

[As you investigate the work of a special chemical occupation make note of how that occupation depends on and effects others.]

outline the role of a chemist employed in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses

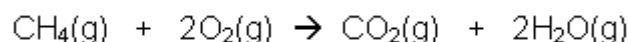
- A chemist working in the plastics industry may spend time as laboratory manager in a plastics factory, such as one that produces polyethylene. A chemist working in a plant that produces low density polyethylene (LDPE) needs to:
 - use computers to predict properties of the polymers based on different co-polymers, temperatures and catalysts.
 - constantly monitor the equipment to ensure that the required conditions and purity of reactants are maintained. An impurity can poison the catalyst, slowing a reactor, or stopping the reaction. A change in conditions can also seriously affect the properties of the product.
 - carry out quality control at the end of the product line to ensure that the product meets customer requirements. A quick test of viscosity would indicate if the polyethylene is suitable to blow into a thin-layer film. A quick test of density could indicate the amount of branching in the polyethylene molecules.
 - evaluate processes proposed by the product development section of the company including problems of contamination, bagging the product, the flow rate through the extruder, slippage and economy of production. This requires coordination with chemical engineers and technicians.
- The chemist undertaking the role described above could have studied a university course in applied chemistry or engineering or a TAFE chemical technician course.

Two scientists working in industry are Dr Alison Edwards at ANSTO, who specialises in Neutron Scattering and Dr Geraldine Jacobsen at ANSTO who works with Carbon Dating. Find out more about them. [*Rediscovering Science with NSW scientists*](#) ► NSW Department of Education and Training. Scroll down to their names and click on the presentation and/or any of the support resources.

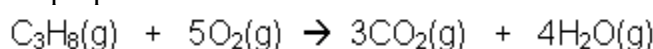
describe an example of a chemical reaction such as combustion, where reactants form different products under different conditions and thus would need monitoring

- Combustion of a gas, such as methane (CH₄), from natural gas, or propane, from liquefied petroleum gas (LPG), in a Bunsen burner needs monitoring.
 - If you need a high temperature flame, the air hole is fully open so that sufficient oxygen reaches the gas for complete combustion.

For methane:

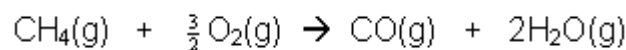


For propane:

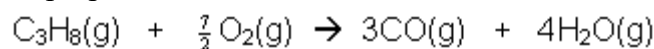


- If the air hole is partly open, incomplete combustion occurs, producing some carbon monoxide.

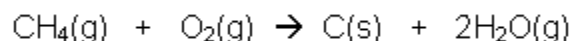
For methane:



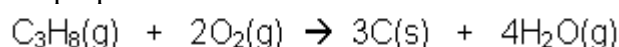
For propane:



- If the air hole is not open at all, carbon is produced. The heated carbon partly produced gives the low temperature flame its yellow colour.
- For methane:



For propane:



-
- Adjusting the fuel-to-air ratio is important in internal combustion engines and in industrial combustion of fuels. The more complete the combustion, the greater the amount of energy released. Incomplete combustion produces poisonous carbon monoxide.

9.4 Chemical monitoring and management: 2. maximise production

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[Edit: 24Jun08]

Prior learning: Preliminary modules **8.2** (8.2.2) **8.3** (8.3.2, 8.3.5), **8.5** (8.5.5) and HSC modules **9.2** (9.2.1), **9.3** (9.3.2, 9.3.4).

Background: There are some chemical reactions that have played a very important part in world history and human activity, allowing the development of industries and societies. The production of ammonia is one such example.

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

- **Gather** information about Fritz Haber from a range of resources including school textbooks, CD-ROMs such as *Encarta* or *Encyclopedia Britannica*, and the Internet. You should be able to gather information like that provided below.

[Fritz Haber](#) ► Nobel e-Museum

- To **process** the resources you find, assess their reliability by comparing the information provided. Look for consistency of information. Check for consistency with the information provided below.

The significance of Fritz Haber's work

World context: Nitrogen compounds were essential for the production of fertilisers and explosives. Much of the fertiliser originated in Chile, a long way from the industrial centres of Europe. It was known that the atmosphere contains large quantities of diatomic nitrogen. It would be advantageous to convert this readily available gas to usable compounds for agriculture and industry, cheaply and on a large scale.

Haber's contribution: Fritz Haber had studied under Robert Bunsen, in Germany, and was interested in the effect of heat on the chemistry of gases. In the early 1900s, Haber reacted nitrogen with hydrogen, using an iron catalyst, to form ammonia. Ammonia can be readily converted to a range of valuable products. In 1908 he had improved the reaction and in 1911 he was rewarded with a directorship at a German institute. Carl Bosch developed the chemical engineering necessary for the large-scale production of ammonia by the Haber-Bosch process.

Significance: Germany used the process to make explosives in World War I after the British cut off supplies of nitrate from Chile. This lengthened the war.

identify and describe the industrial uses of ammonia

- Ammonia is used to make solid and liquid fertilisers, explosives, nitric acid, sodium carbonate, some pharmaceuticals and household cleaners. It is also used as a refrigerant.
- To make solid fertilizer industrially, ammonia, which is a weak base, is reacted with sulfuric acid to form ammonium sulfate fertiliser and with nitric acid to form ammonium nitrate fertiliser.

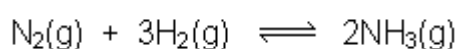
identify that ammonia can be synthesised from its component gases, nitrogen and hydrogen.

- Under pressure and heat, nitrogen and hydrogen react in the ratio of 1 volume of nitrogen to 3 volumes of hydrogen to produce 2 volumes of ammonia.



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

- The synthesis of ammonia occurs as a reversible reaction. This means that ammonia is formed from nitrogen and hydrogen (the forward reaction) and once some ammonia is produced, some nitrogen and hydrogen are formed from the ammonia (the reverse reaction). When nitrogen and hydrogen are initially added to a reaction vessel, the reaction is slow. Equilibrium is reached when the rate of the forward reaction is the same as the rate of the reverse reaction.
- To ensure that sufficient ammonia is produced, conditions need to be established that shift the equilibrium position to the right.

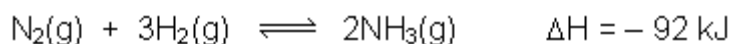


explain that the use of a catalyst will lower the reaction temperature required and identify the catalyst(s) used in the Haber process

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

identify the reaction of hydrogen with nitrogen as exothermic

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



explain why the rate of reaction is increased by higher temperatures

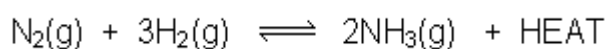
- As the temperature rises, the particles move more quickly and have higher kinetic energy. This increases the frequency of collisions between particles that can react and also increases the amount of energy available for the reaction. Most of the increased rate of reaction comes from more of the colliding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

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

- The forward reaction in which ammonia is formed is exothermic. Le Chatelier's principle states that if a system in equilibrium is disturbed, the system will adjust itself to minimise the disturbance. In this case, Le Chatelier's principle indicates that with high temperature providing more heat, the reverse reaction is favoured and the decomposition of ammonia occurs.

Another way to view it

If the reaction is written like that following, *heat* is like a product.



As temperature, and therefore the heat available increases, the equilibrium position shifts to the left and the yield of ammonia is reduced.

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

- In accordance with Le Chatelier's principle, increasing the pressure favours the production of ammonia because two molecules of gaseous ammonia occupy a smaller volume than the four molecules of gaseous reactants.
- High pressure also increases the reaction rate because the gas molecules are closer and at higher concentrations. However, high-pressure equipment is expensive and requires considerable energy to operate.
- To achieve an economic yield of about 30%, a pressure of 35 000 kPa (35 MPa or 345 atm) is used.

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

- As the temperature is increased more energy is available to exceed the reaction activation energy and thus the reaction rate between nitrogen and hydrogen to form ammonia increases. However increasing temperature favours decomposition of the ammonia product. A compromise temperature providing a satisfactory reaction rate and satisfactory yield of ammonia is selected.

- To achieve an economic yield of about 30%, the temperature is raised to 525°C and pressure of 35 000 kPa (35 MPa or 345 atm) is used.

Increasing yield

Liquefying and removing the ammonia as it is produced also increase the yield of ammonia.

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

- The raw materials must be monitored to ensure they are clean. Any carbon dioxide detected must be removed. It is often separated and diverted to use for the production of urea at a nearby fertiliser manufacturing plant. Any oxygen present could cause an explosion with the hydrogen.
- A chemical engineer or technician monitoring the reaction vessel needs to ensure that the appropriate temperature and pressure conditions are maintained, within an acceptable range, so that about 30% yield is achieved.
- The quality of the catalyst surface needs to be monitored to ensure good adsorption of the nitrogen and hydrogen gases. The system must be kept free of contaminants to ensure maximum surface of the catalyst is available for adsorption of nitrogen and hydrogen.
- Temperature needs to be monitored, as too high a temperature can permanently damage the catalyst.

[Haber process for ammonia synthesis](#) ► by Jayant M Modak, Department of Chemical Engineering
Indian Institute of Science, Bangalore 560012, India, printed in Resonance, 2002

9.4 Chemical monitoring and management: 3. Manufactured products are analysed

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Prior learning: Preliminary modules **8.2** (8.2.1, 8.2.3, 8.2.4, 8.2.5) **8.3** (8.3.1, 8.3.2, 8.3.3, 8.3.5), **8.4** (8.4.3, 8.4.4)

HSC modules **9.2** (9.2.3), **9.3** (9.3.1, 9.3.3).

Background: All legally manufactured products under current health and consumer regulations are analysed to ensure quality requirements and health and safety guidelines are adhered to, so as to protect the consumer. In order to comply with this aspect of society, companies conduct a series of accepted tests and report the information accordingly. Analytical chemists conduct the tests, usually following a flow chart concept.

The information below about tests is very closely allied to the information you will need to have worked on in your first-hand investigations in this section of the syllabus.

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

phosphate

sulfate

carbonate

chloride

barium

calcium

lead

copper

iron

Background

The tests used to separate ions from a mixture make use of the insolubility of certain cation-anion combinations. These insoluble ion combinations are called *precipitates*. If the crystals of insoluble salt are colourless, the insoluble salt precipitate appears white due to reflection of white light by the crystal surfaces.

- ***Perform*** a first-hand investigation using the procedure provided below. The results can then be used to identify tests for the cations and anions. You may need to modify the procedure depending on the availability of the chemicals or equipment.

Procedure:

1. Prepare or select solutions that contain the following cations: barium, calcium, lead, copper, iron(II), iron(III) and silver.
2. Prepare or select solutions that contain the following anions: phosphate, sulfate, carbonate, chloride, hydroxide and nitrate.
3. Determine the cation-anion combinations that form a precipitate by testing a small quantity of an appropriate cation solution with the same quantity of an appropriate anion solution, as indicated in the table

below. (A sample set of results appears in the notes for the next syllabus point.)

4.

Cations	Anions					
	<i>phosphate</i>	<i>sulfate</i>	<i>carbonate</i>	<i>chloride</i>	<i>hydroxide</i>	<i>nitrate</i>
<i>barium</i>	?	?	?	?	?	?
<i>calcium</i>	?	?	?	?	?	?
<i>lead</i>	?	?	?	?	?	?
<i>copper</i>	?	?	?	?	?	?
<i>iron(II)</i>	?	?	?	?	?	?
<i>iron(III)</i>	?	?	?	?	?	?
<i>silver</i>	?	?	?	?	?	?

5. NOTE: Copper, lead and silver compounds should not be disposed of into sink-waste systems. Collect for waste treatment and subsequent recycling or disposal.
6. Some cations may form similar colour precipitates with the same anion. Distinguish between these with a flame test by placing a small sample of the precipitates in a colourless Bunsen burner flame (with the air hole open).
7. From your table of results, identify tests that can be used to indicate the presence of a particular ion.
 - You can confirm your results or identify data that cannot be determined from the first-hand investigation by extracting information from solubility tables in **secondary sources**, such as a chemistry data book or chemistry textbooks.

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

The following outlines an appropriate process to study lead ions.

Background

Some foodstuffs are monitored for the presence of particular metals, e.g. lead, to ensure that we are not consuming poisons that can accumulate in our bodies.

The concentration of lead in our blood increases when we inhale air from busy roads. The concentration of lead in blood needs to be monitored, especially for populations

of children living near busy roads and workers in lead smelters. Action can then be taken or evidence used to make changes, such as in the use of petrol additives or location of worksites or in work practices.

- **Gather information** by looking in encyclopaedia, as well as searching the Internet using key words, such as *monitoring*, *lead* and *levels*. If you have access to CD-ROMs, such as *Encarta* or *Encyclopaedia Britannica*, search in them under *lead*.
- **Process** your information, making sure you assess its reliability by comparing information from various sources.
- **Present** information in the form of an *explanation*, describing and explaining evidence for the need to monitor levels of lead in substances used in society, such as food and fuel.
- An explanation has the following structure:

<i>Section and features</i>	<i>An explanation</i>
<i>A title or heading</i>	Example: <i>Why lead should be monitored in our environment</i>
<i>A phenomenon identification:</i> a general statement informing the reader what is being explained.	
<p><i>An explanation sequence:</i> a number of paragraphs in logical sequence. It is often useful to begin by describing the phenomenon or issues related to the explanation.</p> <p>The text should be characterised by the use of:</p> <ul style="list-style-type: none"> • appropriate technical terms • cause and effect connectives • time connectives 	

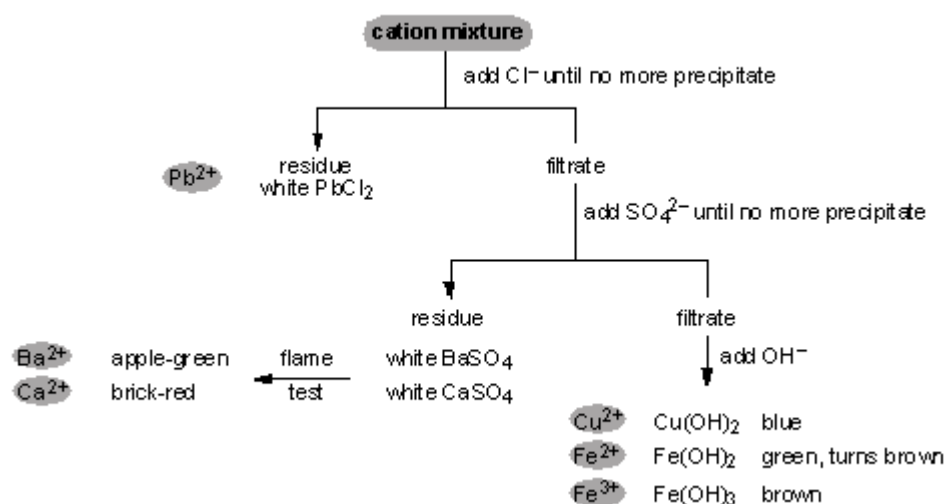
One place to start could be:

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

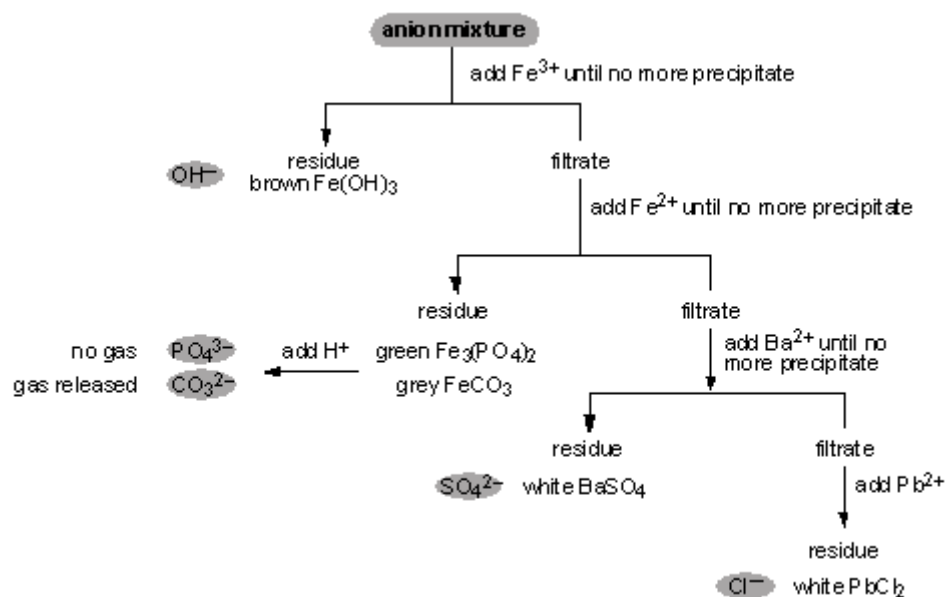
Ion identification flow charts

- There are several flow charts that can be used to assist in the identification of ions present in an aqueous sample. Two such flow charts follow. Assume that only one cation and one anion will be in your sample. Once those ions are identified there is no need to continue. In real-life water testing situations, this assumption cannot be made.

Cation identification



Anion identification



- You can use your own first-hand data to draw up your own flow charts to show how to identify, in a suitable sequence, the anions: phosphate, sulfate, carbonate and chloride, and the cations: barium, calcium, lead, copper, iron(II) and iron(III).

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

- For each of the procedures described below:
 - Determine the **type of data** that needs to be collected and explain the quantitative analysis that will be required for this data to be useful.
- Plan** your investigation by predicting possible issues that may arise during the investigation and identify strategies to address these issues if necessary. The preparation of flow charts for the procedures for each of the investigations would help here. There are several flow charts possible for some of these analyses.
- Perform** the investigation to analyse the concentration of the substance required. Modify the procedure to suit your equipment and materials and analyse the effect of any adjustment made. Check the label of the product to compare your analysis results with that stated for the product. More than likely, your values will be slightly different.

Some chemical analysis techniques

Sulfate content of lawn fertiliser

- Sulfate in ammonium sulfate fertiliser can be determined by precipitation as barium sulfate.



An excess of soluble barium salt, such as barium nitrate, is added to a solution containing a known weight of ammonium sulfate.

The particles of barium sulfate are too small to be trapped by ordinary filter paper. A sintered glass filter is needed to trap the BaSO_4 . The white residue of BaSO_4 is washed to remove other salt ions, the sintered glass filter dried until a constant weight. Knowing the original weight of the filter, the mass of BaSO_4 can be calculated.

Sulfate content is

$$\frac{(32 + 4 \times 16)}{(137.3 + 32 + 4 \times 16)} = \frac{96}{234.3} = 42.7\% \text{ of } \text{BaSO}_4$$

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

- A significant problem in separating solid barium sulfate from solution is the very small size of the crystals.

Search out information on ways of increasing crystal size and ways of effectively separating the solid barium sulfate from the solution.

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

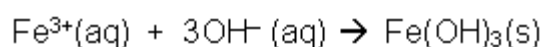
- AAS allows the detection of very small concentrations from samples of air, water or food. This activity depends on your ability to manipulate data and dilution factors. The absorbance values obtained using solutions of known concentration enable you to draw a *calibration graph*. Use the specific absorbance data provided to read off the corresponding concentration for the sample. The following information relates to the monitoring of arsenic and its analysis will allow you to evaluate the use of AAS.

A case study in the monitoring of arsenic

Arsenic-rich ground water is a serious threat to 20 million people in Bangladesh. *Solar oxidation and removal of arsenic* (SORAS) is a simple method that uses irradiation of water with sunlight in PET plastic, or other UV transparent bottles, to reduce arsenic levels in drinking water.

Groundwater in Bangladesh contains Fe^{2+} ions and Fe^{3+} ions. Fe^{3+} forms an insoluble hydroxide precipitate. Arsenic with an oxidation state of three, As(III), is only weakly adsorbed but arsenic with an oxidation state of five, As(V), is strongly adsorbed to the surface of iron(III) hydroxide particles as they precipitate out of solution.

The SORAS method involves adding about 6 drops of lemon juice to a litre of water in a 1.5 L PET bottle. The bottle is shaken vigorously for 30 seconds, then placed horizontally in sunlight for 4 to 5 hours. The UV energy, oxygen and water in the bottle produce oxidising conditions:



At the end of the day, the bottle is stood vertically. The As^{5+} is adsorbed onto the surface of the brown $\text{Fe}(\text{OH})_3$ as it precipitates overnight. The next morning, the liquid is decanted off or filtered through fine cloth leaving the last 100 mL, containing iron(III) hydroxide and arsenic(V), to be discarded. The citric acid from the lemon juice enhances the photochemical oxidation of the arsenic(III) and leads to much faster formation and settling out of precipitate.

Here are data that can be used to produce an AAS calibration graph for the arsenic levels in this study.

Total arsenic concentration	Absorbance
50 $\mu\text{g L}^{-1}$	0.12
100 $\mu\text{g L}^{-1}$	0.23
150 $\mu\text{g L}^{-1}$	0.35

Here are some AAS arsenic absorbance measurements for an investigation into the SORAS method:

Sample	Absorbance
ground water, before SORAS treatment	0.28
ground water, after SORAS treatment	0.13

- Draw a calibration curve of *absorbance* vs *total arsenic concentration*. Use the curve to ***gather*** data to determine the arsenic concentration before and after SORAS treatment.

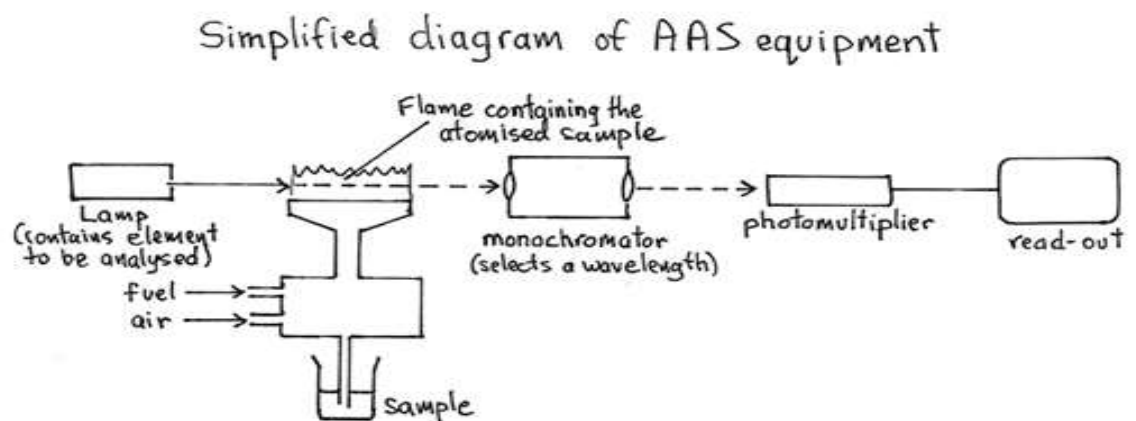
- People generally require about two litres of water a day and the recommended daily intake of arsenic by an adult is set at 150 micrograms (150 µg). **Process** the information extracted from the data by assessing the importance of the data and information gathered in relation to the acceptable levels of arsenic.
- **Present** your findings. By referring to the precision of AAS and to the quantities of arsenic in drinking water before and after treatment, evaluate the effectiveness of:
 - the SORAS method in reducing arsenic levels in drinking water to acceptable levels
 - the use of AAS in monitoring and controlling pollution in this situation.

[Atomic-absorption spectroscopy](#) ▶ Virginia Tech Chemistry Department, USA

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

- Each element has its own characteristic absorption spectrum that is related to its electron energy levels.

Atomic absorption spectroscopy (AAS) detects minute concentrations of an element in a sample of solution.



The flame containing the vapourised sample absorbs light at the particular wavelengths characteristic of the element in the flame and re-emits it in all directions. A detector records the intensity of light emerging from the flame. The intensity of light detected drops sharply at the wavelengths of light absorbed by the elements in the flame, thus producing an absorption spectrum. The relative intensity and pattern of changes of intensity within each of the bands in the absorption spectrum indicate the concentration of the element in the test sample.

- The study of the concentration of pollutants in our environment has been greatly enhanced and is more accurate and reliable since the development of AAS by the CSIRO scientist, Alan Walsh, in the 1950s. As Alan Walsh stated "the AAS method is a quick, easy, accurate and highly sensitive means of determining the concentrations of over 65 elements". It is used in a range of areas, such as medicine, agriculture, mineral exploration, metallurgy, food analysis, biochemistry and environmental monitoring. It has been described as the most significant advance in chemical analysis of the 20th Century.
- Trace elements are elements needed in very small amounts by living things. AAS enabled the measurement of the concentrations of many metals in the bodies of plants and animals and in their surrounding environments. This has proved to be enlightening in many practical situations. Two such situations include the following:
 - In coastal south-western Australia, animal health could not be maintained on seemingly good pastureland. AAS showed cobalt deficiencies in the soil and the pasture.
 - Arid parts of Victoria could not support legume crops until molybdenum deficiencies were detected by AAS and rectified.

[Alan Walsh and AAS](#) ► Australian Academy of Science.

9.4 Chemical monitoring and management: 4. Human activity and the atmosphere

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[Edit: 7 Jul 09]

Prior learning: Preliminary modules **8.2** (8.2.1, 8.2.2, 8.2.3, 8.2.5), **8.4** (8.4.2, 8.4.4), **8.5** (8.5.2, 8.5.3, 8.5.4, 8.5.5);

HSC modules **9.2** (9.2.2), **9.3** (9.3.2, 9.3.3).

You should be able to:

- manipulate data to change the units expressed into other units
- use the mole concept and associated calculations
- recall the prefixes for the first eight alkanes
- identify and apply cause and effect relationships.

Background: The chemical composition of the atmosphere depends on the gases released and absorbed at the surface of the Earth and the rates at which chemical reactions take place.

The many uses of chlorofluorocarbons (CFCs), initially thought to be a harmless group of substances, have been found to cause long-term problems for our atmosphere, humans and all ecosystems.

The discovery of the *ozone hole* has triggered more research, monitoring and problem solving amongst atmospheric scientists and mathematical modellers. International

agreements, such as the *Montreal protocol on substances that deplete the ozone layer* (1987), helped to manage the situation by reducing the production and use of CFCs. Alternative chemicals have been used in our homes and industry, in order to maintain the quality of life enjoyed by many people.

describe the composition and layered structure of the atmosphere.

- The atmosphere is made up of two main layers: the *troposphere* and the *stratosphere*. It is within these layers that ozone exists. The troposphere extends from the Earth's surface to 15 kilometres above sea level. Over 90% of Earth's gases are in the troposphere. Temperatures drop with altitude in the troposphere. At the top there is a region where the temperature remains reasonably stable. This is called the *tropopause* and it reduces the mixing of gases. The stratosphere (upper atmosphere) is above the tropopause. In the stratosphere temperatures rise with increasing altitude.
- The atmosphere is predominantly composed of nitrogen (78% by volume), oxygen (21%), and argon (0.93%), with the other gases in very small concentrations. Despite these small concentrations, many of the other gases (e.g. ozone) cause concern because of the reactions they can undergo.

[Composition of the atmosphere](#) ▶ CFC StarTec LLC, USA.

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

- Main pollutants and sources are listed in the following table.

Main pollutants	Main sources
carbon monoxide	incomplete combustion in stoves, cars, fires and cigarettes
nitrogen oxides	combustion at high temperatures in vehicles and power stations
volatile organic compounds, such as hydrocarbons	solvents and unburnt fuels
sulfur dioxide	some metal extraction processes and the burning of fossil fuels
lead	leaded fuels, metal extraction, renovating old houses containing leaded paints and electrical wire coverings
particulates	incomplete combustion, earthmoving dust storms and some agricultural and industrial practices

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

- The ozone molecules in the stratosphere form a very thin layer that protects us from harmful UV radiation.
- In contrast, the ozone in the troposphere is a pollutant, even at the very low concentrations compared with the other gases. Ozone is a very reactive molecule capable of oxidising many substances.
Fortunately most of the ozone occurs in the stratosphere.

describe the formation of a coordinate covalent bond.

Revision: covalent bond

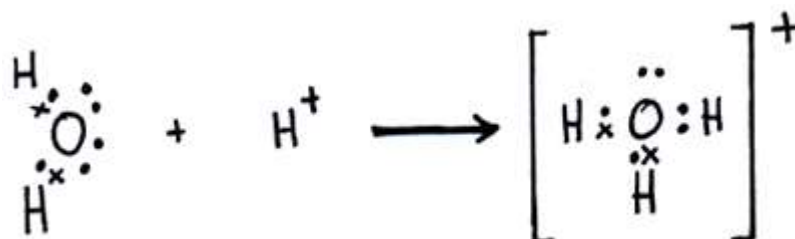
Non-metallic compounds contain covalent bonds. A covalent bond is a shared pair of electrons that keeps two atoms together. Normally one atom contributes one electron and the other joined atom contributes the other shared electron.

- A coordinate covalent bond forms when one atom in a species (a molecule or ion containing non-metallic atoms) provides both electrons in the covalent bond.
- Once formed this coordinate bond is indistinguishable from other covalent bonds.

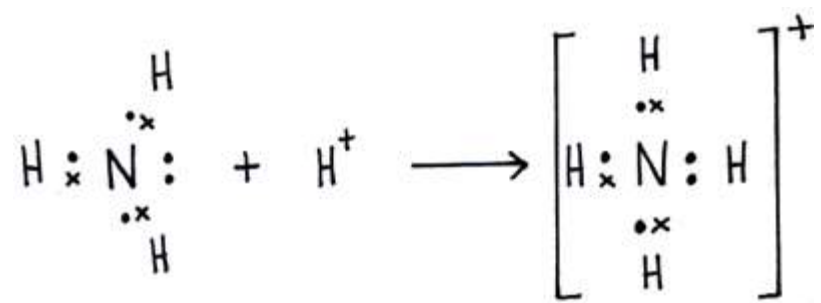
demonstrate the formation of coordinate covalent bonds using Lewis electron dot structures.

- Ions, such as the hydronium H_3O^+ and the ammonium NH_4^+ , contain a coordinate covalent bond. In the formation of the hydronium ion, one of the non-bonding electron pairs on the oxygen atom is used to form a covalent bond between the hydrogen ion H^+ (which has no electrons) and the oxygen atom.

Formation of a coordinate covalent bond in the hydronium ion



Formation of a coordinate covalent bond in the ammonium ion



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

Background

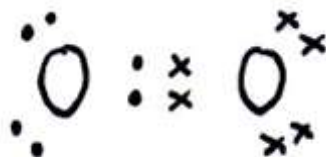
An allotrope is a different physical form of the same element, e.g. O₂ and O₃ are allotropes of oxygen.

- The chemical and physical properties differ, namely:

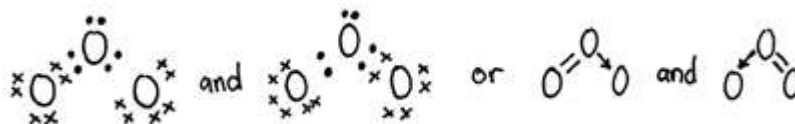
Properties	gaseous oxygen	gaseous ozone	Explanation
colour	colourless	blue	-
boiling point	-183°C	-111°C	The boiling point of diatomic oxygen is lower than that of the ozone as diatomic oxygen has a lower molecular mass requiring less energy in the boiling process.
solubility in water	sparingly soluble	more soluble than oxygen	Non-polar O ₂ does not form strong intermolecular forces in the polar water. Ozone has a bent structure, which provides for some polarity of the molecule in its interaction with water.
chemical stability	far more stable than the ozone molecule	far less stable than the oxygen molecule	Ozone is easily decomposed into oxygen molecules: $2\text{O}_3(\text{g}) \rightarrow 3\text{O}_2(\text{g})$ #More detailed information below.
oxidation ability	less powerful	more powerful	e.g. reaction with metals: oxygen forms the oxide as the only product whereas

	oxidant	oxidant	ozone reacts more readily producing the metallic oxide and an oxygen molecule.
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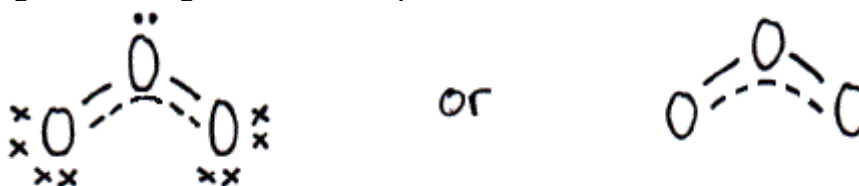
- #More detailed information regarding chemical stability:
- The oxygen molecule contains one double covalent bond $O=O$.
- Lewis electron dot structure for oxygen



- The ozone molecule can be represented as containing a covalent double bond and a coordinate covalent single bond. The coordinate covalent bond can be represented by an arrow.
- Lewis electron dot structure for ozone



- Measurements show that the bonds between the oxygen atoms in ozone are of equal length and strength and can be represented so:

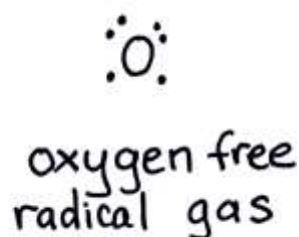
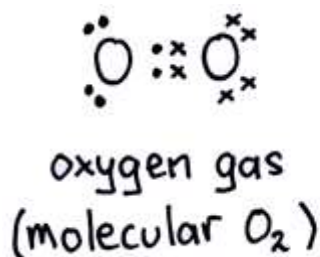


- The two identical oxygen to oxygen bonds in ozone consist of a single bond and a partial bond. This results in lower stability of the ozone molecule, compared with the diatomic oxygen molecule.

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

- The oxygen atom in its ground state (electrons in the lowest possible energy levels) has 3 pairs of electrons in its valence shell.
- When UV energy splits an oxygen molecule, two oxygen atom radicals are formed, i.e. they each have two electron pairs and two unpaired electrons. The energy absorbed in the splitting and the unpaired electrons make the free radical very reactive.

Lewis electron dot structure of gaseous forms of oxygen



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

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

- CFCs were developed to replace ammonia as a refrigerant in the 1930s. At the time, their properties were found to be 'safer' than the ammonia.
- Their properties, such as inertness and low boiling point (near room temperature), also led them to be used more widely as solvents, propellants and blowing agents in foams.
- As CFC products were used, the gases were released to the atmosphere.
- It was discovered that the CFCs were so inert they did not react in the troposphere. They gradually make their way to the stratosphere where UV energy breaks C-Cl bonds releasing Cl free radicals. Chlorine and related free radicals deplete the ozone layer.
- Halons are fluorocarbons containing bromine. They used to be used extensively in fire extinguishers for electrical fires or to protect computer systems. Fortunately they were never used as extensively as CFCs were.
- Halon use has been drastically reduced because bromine atoms are even more effective than chlorine atoms in the chain reactions that lead to the depletion of the ozone layer.
- The concentration of the chlorine radicals that react with ozone is increased in springtime in the Antarctic with the return to longer periods of sunlight. The rate is reduced by summer when the chlorine is basically used up after the accumulation over winter.

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

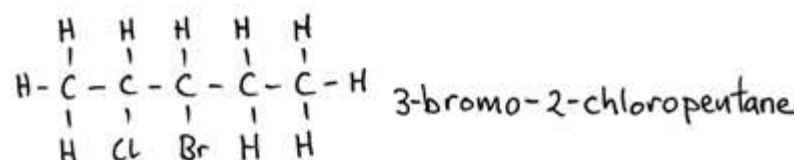
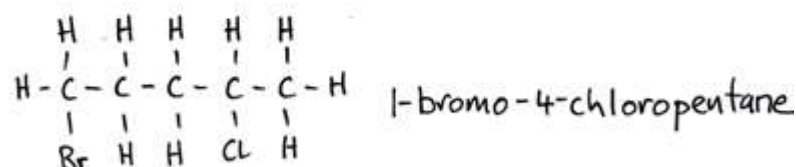
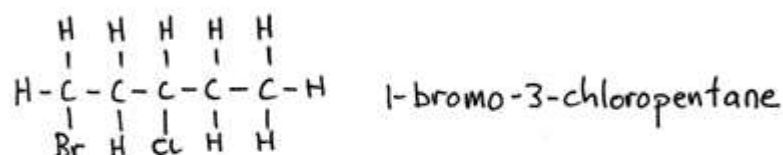
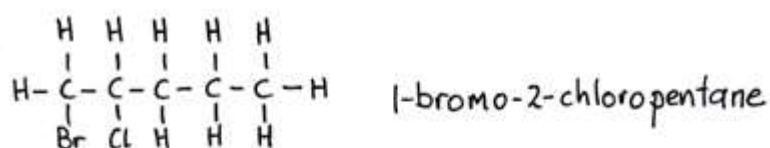
- **Gather** the names and general formulas of some haloalkanes up to eight carbons.
- Determine the possible isomers for these haloalkanes by making models of them or by drawing representations of them. **Present** your isomers as structural formulae. Write the systematic names for each isomer using the IUPAC (International Union of Pure and Applied Chemistry) convention.
- **Process** your representations of isomers and evaluate their validity by comparing them with examples from other secondary sources.

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

- Isomers are molecules with the same molecular formula but different structural formulas (arrangements of atoms). For example, there are a number of isomers for $C_5H_{10}BrCl$. Some are shown below.

Isomers of haloalkanes

Isomers of $C_5H_{10}BrCl$ include the following:



How many isomers are there for $C_2H_3Cl_2F$?

- The longer the carbon chain, the more possible isomers there will be.

Answer:

You should find three isomers for $C_2H_3Cl_2F$. Their names are:

1,1-dichloro-1-fluoroethane

1,1-dichloro-2-fluoroethane

1,2-dichloro-1-fluoroethane

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

History

- CFCs were first used as refrigerants in the 1930s to replace ammonia as a refrigerant, as many deaths were occurring from poisoning by ammonia. The CFCs were considered to be very chemically stable in the troposphere and non-toxic to living things.
- Measurements of the total amount of ozone in a column of atmosphere have been recorded since 1957.
- It was discovered, in the 1970s, that the CFCs were depleting the ozone layer in the stratosphere.
- Paul Crutzen (Holland) investigated the effect of nitrous oxide on the atmosphere in the early 1970s. The source of nitrous oxide was due to the increased use of artificial nitrogen fertilisers and exhausts from supersonic aircraft using the stratosphere. His discovery led to concern over the stability of the ozone layer.
- Investigations by Molina (Mexico) and Rowland (USA) in mid-1970s showed CFCs to be a more significant depleter of ozone.
- Later investigations showed that halons were broken down by UV more readily than CFCs, releasing Br atoms that, like Cl atoms, catalysed decomposition of ozone.
- 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 now exceeds 50%.
- Measurements of ozone levels in the atmosphere can be taken using UV spectrophotometers. Measurements were taken by British scientists in the Antarctic using UV spectrophotometers directed vertically up into the atmosphere.
- UV spectrophotometers could also be directed vertically down. Helium filled balloons were used to carry UV spectrophotometers. Satellites were used to carry a device called a *total ozone mapping spectrophotometer* (TOMS), which proved very efficient in recording changes in ozone levels.

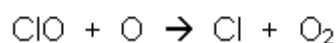
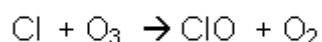
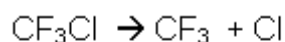
- Scientists recorded the total ozone per unit area as a function of time and noted the changes by season and since their recordings began (a dramatic increase due to increasing use of CFCs).
- Data from NASA satellites can now be seen via the Internet at [Total Ozone Mapping Spectrometer \(TOMS\)](#) ► the official web site for information, data, and images from the Total Ozone Mapping Spectrometer (TOMS) instruments, NASA, USA.

[Changes in the ozone layer and climate](#) ► Roderick Jones, Queens' College Cambridge, UK.

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

- CFCs can undergo photodissociation (reactions using the energy of light to break bonds) to form reactive chlorine atom radicals. The chlorine atom radical then rapidly reacts with an ozone molecule to produce the chlorine oxide molecule, ClO. The chlorine oxide molecule can react with a free oxygen atom (which could have formed O₃ by reaction with O₂) regenerating a Cl atom. This information can be **presented** effectively by the use of a series of chemical equations.

The reactions below represent depletion of the ozone layer in the stratosphere. All species are gases. The CF₃, Cl, ClO and O are free radicals with unpaired electrons and thus are very reactive.



Ozone depletion is more frequent in winter and spring due to more ice particles. These provide a surface to act as a catalyst.

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.

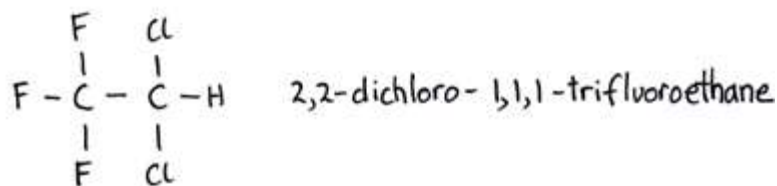
- After gathering appropriate information, **present** a short report to summarise and evaluate the alternatives to CFCs. A sample report is provided below.

Chemical alternatives to CFCs

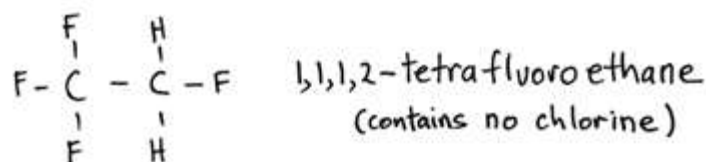
- The alternative chemicals to CFCs include the compounds called *hydrochlorofluorocarbons* (HCFCs) and *hydrofluorocarbons* (HFCs).

Samples of an HCFC and an HFC, indicating structure

HCFC-123 (CF_3CHCl_2)



HFC example: CF_3CFH_2



- The HCFCs, which contain hydrogen atoms and fewer chlorine atoms, can undergo reactions with OH free radicals in the troposphere. However, reaction is slow and many HCFCs will still reach the stratosphere, where they can release chlorine atoms.
- HFCs, which contain no chlorine, are being trialled. They react more readily than HCFCs with OH in the troposphere. Because they do not contain chlorine, they are not expected to produce undesirable radicals in the stratosphere.

[HCFCs and HFCs](#) ▶ CFC Replacements, Maxfields Freeserve, Bristol, UK

[Ozone depletion glossary](#) ▶ US Environmental Protection Agency, USA

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

- The problems associated with CFCs include:
 - depletion of the ozone layer
 - more UV radiation reaching Earth, which increases the chances of cancer in living things (including humans)
 - an increase in the enhanced greenhouse effect.

The enhanced greenhouse effect

The *enhanced greenhouse effect* is caused by gases, released by human activity, absorbing heat rays that come from the Earth's surface, then emitting the heat rays. Many of these heat rays come back to the Earth's surface. This raises the temperature of the atmosphere.

These problems are caused by CFCs moving to the stratosphere where the UV radiation photodissociates the CFCs by breaking C-X bonds. When these bonds break, halogen radicals (X) are formed, which react with an ozone molecule to form new compounds, such as ClO or BrO. A chain reaction occurs and this decreases the ozone concentration allowing more UV to penetrate to the surface of the Earth. The CFCs have a long lifetime and can last up to 150 years.

Steps to reduce the formation of the ozone hole have been taken since its cause was identified. These steps include:

- the Montreal Protocol, an international treaty designed to gain cooperation for the global reduction in the production of CFCs and halons (bromine containing carbon compounds).
- the identification and introduction of alternative chemicals, such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs).
- assistance to less developed countries to phase out the use of CFCs.

The effectiveness of these steps is dependent on a number of actions.

- Global control of production and use of CFCs is needed. If governments do not adhere to the Montreal Protocol it may be difficult to ensure that CFC use is halted and that CFC levels in the atmosphere are actively reduced.

We cannot remove the CFCs already in the stratosphere at this stage of technological development. So some measures are needed to reduce the effects of the problems caused by CFCs, such as high levels of UV radiation. These include:

- people using new sunscreens, as advised by organisations like the Cancer Council.
- the use of UV stabilizers in polymers that are exposed to sunlight to reduce breakdown by UV radiation.

9.4 Chemical monitoring and management: 5. Monitoring and management in water

Extract from *Chemistry Stage 6 Syllabus (Amended October 2002)*. © Board of Studies, NSW.
[Edit: 18 Jun10]

Prior Learning: Preliminary modules **8.2** (8.2.1, 8.2.2, 8.2.3) **8.3** (8.3.2, 8.3.3, 8.3.5), **8.4** (8.4.1, 8.4.3, 8.4.4), **8.5** (8.5.1, 8.5.3); HSC modules **9.2** (9.2.4), **9.3** (9.3.1, 9.3.3, 9.3.4).

Background: Many environmental problems have been generated by humans and their activities. One problem is excess salinity, especially of the Murray Darling Basin. Primary production in this basin makes a major contribution to the economies of both NSW and Victoria. The chemical problems caused by excess salinity will need to have chemical solutions and will require the cooperation of all parties including farmers, the public, state and federal governments and industries that rely on water, either directly or indirectly. Management practices that ensure the sustainability of the environment and long-term viability for all parties using the environment will need to be developed and implemented.

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 metal pollution of water may be caused by the presence of unacceptable levels of the ions of arsenic, cadmium, copper, chromium, mercury, nickel, lead and zinc.

Heavy metal pollution in aquatic sediments ► A transcript of an interview with Stuart Taylor URS Australia Pty Ltd North Sydney NSW, speaking with Robyn Williams on The Science Show, ABC Radio National, March 2007.

Fish Eaters Poisoned ► by Lisa Pryor, Sydney Morning Herald, April 20, 2006

Eutrophication

The process of eutrophication involves the increase in nutrient content of a body of water resulting in excessive growth of plants, which when they die, causes oxygen depletion during the decay process. The oxygen depletion threatens the survival of fish.

- Simple techniques to identify the presence of heavy metals include precipitation and flame testing. Techniques to quantitatively determine heavy metals include volumetric and gravimetric analyses, colorimetry, chromatography and spectroscopy, particularly atomic absorption spectroscopy (AAS) and mass spectroscopy.
- Tests to determine the extent of eutrophication of a waterway involve measurement of dissolved oxygen and nutrients, such as nitrates and phosphates. **Gather information** on the range and chemistry of tests by looking in encyclopaedia, scientific and popular journals and magazines and chemistry textbooks as well as searching the Internet under specific

techniques. If you have access to CD ROMs, such as Encarta or Encyclopaedia Britannica, also search in them under specific techniques.

- **Process** your information making sure you assess its reliability by comparing information from various sources.
- When you **present** information, make sure you select and use appropriate methods to acknowledge sources of information. If a reference is from a book, provide *Author(s), year, book title and publisher*. If a reference is from the Internet, provide *Author (if relevant), Title of item, web site owner, online (date last modified) Available at* (provide URL).

[Water Quality: HSC Chemistry](#) Sydney Catchment Authority

[Water Quality](#) ► Department of Primary Industry, Victoria

[Animation of the process of artificial eutrophication](#) ► Degradation of water quality in a lake is shown in a seven-slide presentation. Mike Docker, The Sixth Form College, Farnborough, UK.

[**perform first-hand investigations**](#) *to use qualitative and quantitative tests to analyse and compare the quality of water samples.*

- A qualitative test shows what (element, compound or ion) is present.
- A quantitative test shows how much (element, compound or ion) is present.
- **Perform** some investigations to determine the quality of water samples by selecting and modifying procedures like those described under the next syllabus point (below) and carrying them out carefully. Be alert to recognise where and when modifications are needed and analyse the effect of any adjustments that you make. Write descriptions of the tests used.

[**identify**](#) *that water quality can be determined by considering:*

concentrations of common ions

total dissolved solids

hardness

turbidity

acidity

dissolved oxygen and biochemical oxygen demand

Water quality

Water quality is commonly defined by its physical, chemical, biological and aesthetic (appearance and smell) characteristics. A healthy environment is one in which the water quality supports a rich and varied community of organisms and protects public health.

[Water Quality: HSC Chemistry](#) Sydney Catchment Authority , 2007

[NSW State of the Environment 2009](#) ► , Department of Environment, Climate Change and Water, NSW, January 2010.

The following tests determine water quality according to a given set of criteria supported by World Health Organisation information.

- The ***concentration of common ions***.
- ***Atomic Absorption Spectrometry (AAS)*** is a common technique used to identify the concentration of metal ions. In testing water quality the concentration of the following cations are usually determined: sodium, magnesium, calcium and potassium.
- ***Gravimetric analysis*** can be used to determine the quantities of both cations and anions, e.g. for chloride ions precipitated and weighed as silver chloride. Common anion concentrations measured include chloride, sulfate, bicarbonate and fluoride ions.

Refer also to subsection 9.4.3 of this module, where a method for the precipitation of barium sulfate from ammonium sulfate fertilizer is described.

Total dissolved solids (TDS)

Total dissolved solids (TDS) are determined by evaporation to dryness of a known volume of a filtered sample. The value is converted to parts per million (ppm) and expressed in mass per volume units, ppm (m/v).

Since most of the dissolved solids are ionic, their presence can be determined by data loggers that have the electrical conductivity probe attached. They can be set up to record continuously if needed.

Hardness

Hardness is due to the presence of calcium and magnesium ions in the water. These form insoluble compounds with soap ions, resulting in a scum on the water surface and around sink basins. This removal of soap ions from solution reduces the ability of soap to lather.

The test for hardness involves precipitating the calcium and magnesium ions from a known volume of the water sample with a solution of sodium carbonate (of known concentration), followed by filtering and drying of the precipitate. Most of the insoluble salt is assumed to be calcium and the concentration of calcium ions is calculated and reported in parts per million (ppm).

Turbidity

This can be one measure of the ability of the water to support life. Turbidity results from the presence of suspended solids in the water. Water with a high turbidity reduces penetration of light and decreases photosynthesis, which in turn reduces the oxygen concentration.

The test for turbidity is conducted using a turbidity tube standing on a white tile. The tube has a black cross marked on the base. The water sample is poured into the tube until the cross just disappears when looking from above.

The use of a turbidity tube is less reliable than a transmittance of light test done with a colorimeter. The lower reliability is due to variations in human eyesight and the intensity of background light during testing.

Acidity (pH)

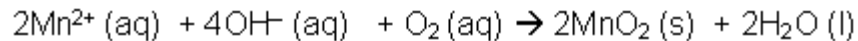
A pH reading below 7 would be expected where there are acid sulfate soils or where there is acid produced by decomposition of organic matter in stagnant situations. The test can be conducted with a data logger and pH probe, universal indicator solution or paper, or a pH meter. If using the universal indicator, comparison with a coloured pH scale provides the pH value. If it is less than 7, the solution is acidic.

Dissolved oxygen (DO)

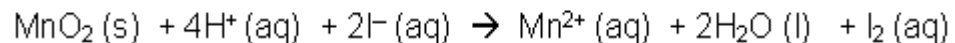
There are several tests for determining the DO in a water sample. The Winkler method *fixes* the amount of dissolved oxygen, which is later determined by titration.

The amount of manganese dioxide produced by adding manganese(II) ions and hydroxide ions is a measure of the DO. Acidified iodide ions are added to cause the manganese dioxide to produce a yellow iodine solution. This is then titrated against a standard sodium thiosulfate solution using starch as the indicator. The indicator turns a blue colour with the iodine and the blue disappears at the endpoint. To conduct the test, no air is to be trapped with the sample and it is to be kept in the dark to reduce algae photosynthesis increasing the DO.

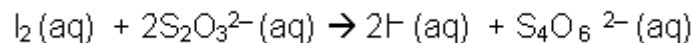
reaction 1:



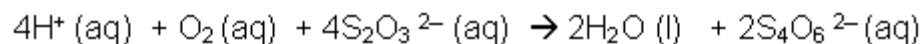
reaction 2:



reaction 3:



The overall reaction can be represented by the equation:



This shows that, for each mole of thiosulfate ($\text{S}_2\text{O}_3^{2-}$) used in the titration, there was 0.25 moles of dissolved oxygen in the original sample.

Biochemical oxygen demand (BOD)

BOD measures the amount of oxygen used by bacteria and other micro-organisms during a five-day period. The sample bottles are held below the water surface and away from the bank. One sample is measured for DO as soon as possible while the other sample is kept in a dark place for 5 days and then tested for DO. The BOD is calculated by subtracting the DO value after 5 days from the initial DO value. The reading is given as milligrams per litre (mg L^{-1}).

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

- Factors include:
 - the frequency of rainfall (floods and droughts),
 - water temperature
 - evaporation rates

- soil type
 - pollution sources, such as the presence of animal faeces and fertiliser usage (leading to eutrophication)
 - land use.
- Farming practices such as the removal of native vegetation or irrigation can increase the salt (NaCl) concentration in rivers.

Earthmoving associated with waterfront developments can expose layers containing sulfide to air. The sulfides are oxidised by oxygen to form sulfates and sulfuric acid, which can kill fish and other living things.

High evaporation rates in the Dead Sea have increased the dissolved salt concentration.

Run-off of water from agricultural land in Queensland, near the Great Barrier Reef, contains ions, such as phosphate, which can affect the growth of organisms.

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

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

- This syllabus point could efficiently be addressed by you working with other students in a group. Assign each member of the group to ***gather*** data about a part of the syllabus requirement. As a whole group, you may need to decide on the structure and components of the final group report so that relevant information is gathered. Many local regional councils and Sydney Water have web sites and some have project officers who can provide information to you on the issues listed above. Before contacting an organisation, you should conduct as much research as you can using published information from the organisation, from books in the school or local library and from the Internet. This will ensure that you are well prepared to discuss relevant chemistry and catchment issues without using an officer's time inappropriately.
- ***Process*** the information gathered by comparing the information from interviews and your secondary sources. This will assist you to evaluate the

validity of all information gathered.

- **Present** your information to other students. Consider using visual aids such as maps, photographs, diagrams, overhead transparencies, graphics or an extract from a video interview. A *Powerpoint* presentation allows each group member to develop materials individually then contribute to the final report. Keep the presentation precise, by only focusing on the information asked for in the syllabus point.

Some useful local NSW web sites:

[Your water](#) ► Sydney Water, Typical Drinking Water Analysis

[Water quality monitoring](#) Sydney Catchment Authority

[Country towns water supply and sewerage program](#) ► Local Government and Shires Association of NSW. The Country Towns Water Supply and Sewerage Program (CTWSSP) is a long standing program which supports councils in country NSW in their provision of water supply and sewerage services.

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

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

flocculation and sedimentation → filtration → sanitisation → pH adjustment

- Water is collected in dams and pumped to a treatment site where the larger solids such as pieces of plastic are removed by screens.
- Fine particles suspended in water have electric charges on their surface that keep the particles from joining together. This stops particles from becoming large enough to settle as sediment. Separation of fine particulate matter suspended in water involves the addition of coagulants, such as iron(III) chloride, FeCl_3 , to the water. The added FeCl_3 neutralises these surface charges so the particles come together. Iron(III) hydroxide is formed by reaction of FeCl_3 with water and precipitates out as a *floc* (flocculant). The floc collects the neutralised particles into large masses that are more easily filtered.
- The chloride ions added with the FeCl_3 remain in the water. They do not have a harmful impact on the water quality as determined by the *Drinking water quality guidelines* (1996), National Health and Medical Research Council (NHMRC).

- In some instances, after flocculation the particle size of suspended solids is too fine for filtration through sand beds and so membrane filters are used. They are more effective than sand filters as they can have a very small pore size. However membrane filtration is more costly than sand bed filtration.
- Sanitising mass water supplies involves disinfecting with chlorine gas, Cl_2 , liquid sodium hypochlorite solution, NaOCl (aq), or solid calcium hypochlorite, $\text{Ca}(\text{OCl})_2$. Sedimentation and filtration removes some harmful organisms, such as bacteria, viruses, cryptosporidium and giardia, but disinfection is needed to ensure concentrations are acceptably low. In some parts of the water distribution system, ammonia, NH_3 , is added to form monochloramine, ClNH_2 , by reaction with chlorine. This is a less reactive disinfectant, but lasts much longer in the distribution system.
- Assessment of the effectiveness of sanitisation methods should involve:
 - microbiological testing of water samples throughout the distribution system, in particular before and after sanitisation processes.
 - public health surveys and reporting by medical doctors of incidences of illnesses that are possibly transmitted through water supplies.
- A few years ago, some water supplies in NSW were contaminated by the micro-organisms, cryptosporidium and giardia. As a result, water supplies are monitored daily at water treatment plants and throughout each catchment during storms or other events that cause a rise in stream water levels and could influence water quality. This is considered effective, as the cost of treatment of all water supplies with membrane filters would make treatment very expensive.

[Managing Drinking Water Quality](#) ► Sydney Water, 2009

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

- Microscopic membrane filters have microscopic pores and the use of appropriate sized filters can avoid the need to chemically treat the water. The filters can be classified as microfiltration, ultrafiltration, nanofiltration or reverse osmosis membranes depending on the size of the pore.
- The membrane is made from synthetic polymers dissolved in a mixture of solvents. Water-soluble powders of a particular size are added. The mixture is spread out over a plate and left for the solvent to dry. The polymer membrane formed, containing particles of water-soluble powder, is then placed in water. Remaining solvent and the powder particles dissolve, leaving a very thin polymer sheet with definite sized microscopic pores where the water-soluble particles were located.
- Semi-permeable membranes used in reverse osmosis are either made of cellulose acetate or a layer of polyamide attached to another polymer. Under

pressure these polymers allow the passage of water molecules but not that of most atoms, ions or other molecules.

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