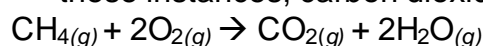


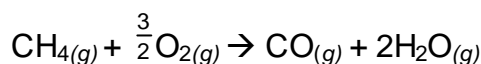
<p align="center">Topic 3</p> <p>Chemical Monitoring & Management</p>	
<p align="center">Focus 1</p> <p>Much of the work of chemists involves monitoring the reactants and products of reactions and managing reaction conditions.</p>	
<ul style="list-style-type: none"> Outline the role of a chemist in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses. 	<p>Role of a Chemist:</p> <p>Industry: Chemical & plastics manufacturing industry.</p> <p>Branch of Chemistry: Analytical Chemistry</p> <p>Components of the Job:</p> <ul style="list-style-type: none"> Monitoring the quality of the product to suit the client's needs. Monitoring waste water & gaseous emissions to satisfy government guidelines. Collaborates with process engineers at the cracking furnace to optimise product yields. Does NOT do the hour to hour monitoring but rather ensures that the equipment is working properly. Most of the analysis involves the use of gas chromatography. <p>Gas Chromatography: Is the process which involves the sample being vaporised into a stream of helium that is passed through a column containing a solid or liquid coated solid.</p>
<ul style="list-style-type: none"> Identify the need for collaboration between chemists as they collect and analyse data. 	<p>Chemists work as part of a team. As chemistry is a very broad subject, chemists are usually highly specialised.</p> <p>To ensure efficient operation of a chemical plant, company or laboratory, collaboration between chemists is essential.</p> <p>Economic viability relies on co-operation between chemists in different fields.</p>
<ul style="list-style-type: none"> Describe an example of a chemical reaction such as combustion, where reactants form 	<p>Combustion of a gas, for example Methane (CH₄) or propane, in a Bunsen burner requires monitoring.</p> <p>Monitoring:</p> <ul style="list-style-type: none"> If a high temperature flame was required, the air hole would need to be fully opened so that sufficient

different products under different conditions and thus would need monitoring.

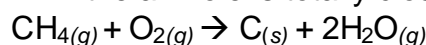
oxygen reaches the gas for complete combustion. In these instances, carbon dioxide is produced.



- If the air hole is only partly open, incomplete combustion occurs and carbon monoxide is produced.



- If the air hole is totally closed, carbon is produced.



Adjusting the fuel to oxygen ratio is important for **combustion** to be successful. The more complete the combustion, the greater the amount of **energy released**.

- **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.**

There are a variety of **chemical occupations** available.

Occupations:

Agricultural Chemistry	Environmental Chemistry
Analytical Chemistry	Food and Flavour
Environmental Chemistry	Chemistry Forensic
Biochemistry	Chemistry
Food and Flavour Chemistry	Geochemistry
Biotechnology	Hazardous Waste
Forensic Chemistry	Management
Catalysis Oil and Petroleum	Inorganic Chemistry
Chemical Education	Materials Science
Chemical Engineering	Medicinal Chemistry
Chemical Information	Organic Chemistry
Specialists	Oil and Petroleum
Chemical Sales	Physical Chemistry
Chemical Technology	Polymer Chemistry
Colloid and Surface	Pulp and Paper Chemistry
Chemistry	R&D Management
Consulting	Science Writing
Consumer Product	Textile Chemistry
Chemistry	Water Chemistry

Specific Occupation – Forensic Chemistry:

A forensic chemist is someone analyses evidence that is brought in from crime scenes. A forensic chemist's job is to identify and characterise the evidence as part of the larger process of solving the crime.

Evidence may include:

- Hair samples
- Paint chips
- Glass fragments
- Blood stains
- Blood samples

Understanding the evidence requires the ability to draw skills

	<p>from various other disciplines of science including:</p> <ul style="list-style-type: none"> • Chemistry • Biology • Materials science • Genetics (DNA analysis) • Toxicology • Gas chromatography <p>Forensic chemists also need to be good public speakers. When cases go to trial, forensic chemists need to give evidence as expert witnesses.</p> <p>Forensic chemists can be employed in:</p> <ul style="list-style-type: none"> • Federal labs • State labs • Local police department labs • Medical examiner's office • Forensic services lab • Branch of FBI • Some private labs <p>Forensic chemists require the following skills:</p> <ul style="list-style-type: none"> • Versatility • Patience • Answer challenges <p>Forensic chemist's salaries start in the high (US)\$30,000 to (US)\$60,000.</p>
<p>Focus 2 Chemical processes in industry require monitoring and management to maximise production.</p>	
<ul style="list-style-type: none"> • Identify and describe the industrial uses of ammonia. 	<p>Uses of Ammonia:</p> <ul style="list-style-type: none"> • Fertilisers • Fibres & plastics. (eg: Nylon, acrylics) • Nitric acid, which is used to make fertiliser, dyes, fibres, plastics and explosives. • Household cleaners and detergents.
<ul style="list-style-type: none"> • Identify that ammonia can be synthesised from its component gases, nitrogen and hydrogen. • Describe that synthesis of ammonia occurs as a reversible reaction that will reach equilibrium. 	<p>Ammonia can be produced from its component gases, nitrogen and hydrogen in the following equation:</p> $\text{N}_{2(g)} + 3\text{H}_{2(g)} \leftrightarrow 2\text{NH}_{3(g)} \quad ?H = -92 \text{ kJ mol}^{-1}.$ <p>Characteristics of this reaction:</p> <ul style="list-style-type: none"> • Equilibrium of this reaction lies well to the left (favours reactants) • The reaction is exothermic, producing 92kJ of energy per mole. • The reaction is a reversible reaction. This is denoted by the double pointed arrow.

<ul style="list-style-type: none"> Identify the reaction of hydrogen with nitrogen as exothermic. 	<p>The reaction is exothermic, producing 92kJ of energy per mole.</p>
<ul style="list-style-type: none"> Explain why the rate of reaction is increased by higher temperatures. 	<p>As the reaction is exothermic, a reduction in temperature will shift the equilibrium right to counteract the change.</p> <p>However, if the temperature is lowered to increase yield, whilst the equilibrium does move to the right, it takes an extremely long time to get there.</p> <p>When the temperature is increased the particles gain more kinetic energy and move faster, hence leading to more collisions.</p> <p>The more collisions, the higher the reaction rate.</p>
<ul style="list-style-type: none"> Explain why the yield in the Haber process is reduced at higher temperatures using Le Chatelier's principle. 	<p>As the reaction is exothermic, an increase in temperature will shift the equilibrium left, reducing the overall yield.</p>
<ul style="list-style-type: none"> Explain why the Haber process is based on a delicate balancing act involving reaction rate, reaction energy and equilibrium. 	<p>For the Haber process to be successful, a combination of reaction rate, reaction energy and equilibrium position must be balanced.</p> <p>A compromise must be made concerning the temperature, whilst an increase in temperature speeds up the reaction rate it does move the equilibrium left, favouring the reactants.</p> <p>For this reason a compromise must be made.</p>
<ul style="list-style-type: none"> Explain that the use of a catalyst will lower the reaction temperature required and identify the catalyst used in the Haber process. 	<p>The equilibrium in the reaction can be reached more quickly if a catalyst is added, with no effect on the position of the equilibrium.</p> <p>It lowers the activation energy, E_A, and allows a reduced temperature without affecting the reaction rate.</p> <p>The catalyst used in the Haber process is a magnetite catalyst, often Fe₃O₄.</p>
<ul style="list-style-type: none"> Analyse the impact of increased pressure on the system involved in the Haber process. 	<p>As the equation is balanced with:</p> <p>4 Moles of Gas \leftrightarrow 2 Moles of Gas</p> <p>An increase in pressure will shift the equilibrium to the right to reduce the effect of the increase, hence favouring the products.</p>
<ul style="list-style-type: none"> Explain why monitoring of the reaction vessel used in the Haber 	<p>Many conditions must be monitored to ensure safe and efficient production of NH₃ using the Haber process. These include:</p> <ul style="list-style-type: none"> Temperature and pressure of the reaction vessel to

<p>process is crucial and discuss the monitoring required.</p>	<p>ensure optimum yields. Also, if the temperature is too high the catalyst can be damaged.</p> <ul style="list-style-type: none"> • The ratio of H₂:N₂ entering the vessel (3:1) • The purity of reactants. If O₂ is present there is a risk of explosion. Also, acidic oxides can damage the catalyst. • The integrity of the vessel operating at high temperatures. 										
<ul style="list-style-type: none"> • 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. 	<p>In 1908, Fritz Haber was the first to develop a process to produce ammonia from its component gases. This development played a significant role in Germany's WWI war effort.</p> <p>In 1914, Carl Bosch converted the Haber process to an industrial scale. Typical conditions of the process are:</p> <ul style="list-style-type: none"> • A temperature of around 700 K (400°C) • A pressure of 2.5 x 10⁴ kPa (250 atmospheres) • Using a magnetite catalyst. <p>These conditions give a yield of around 45%.</p>										
<p>Focus 3 Manufactured products, including food, drugs and household chemicals, are analysed to determine or ensure their chemical composition.</p>											
<ul style="list-style-type: none"> • Deduce the ions present in a sample from the results of tests. 	<p>There are two types of ions:</p> <ul style="list-style-type: none"> • Positively charged cations • Negatively charged anions <p>Each of these can be identified in solution using various tests.</p> <p>Cation Tests:</p> <table border="1" data-bbox="550 1489 1420 2007"> <thead> <tr> <th>Cation</th> <th>Test</th> </tr> </thead> <tbody> <tr> <td>Pb²⁺</td> <td> <ol style="list-style-type: none"> 1. With Cl⁻ forms a white precipitate 2. With I⁻ forms a yellow precipitate. </td> </tr> <tr> <td>Ba²⁺</td> <td> <ol style="list-style-type: none"> 1. With SO₄²⁻ forms a white precipitate (if not too dilute) 2. Gives a pale green flame colour 3. No precipitate with OH⁻ or F⁻ (For Ca²⁺ comparison) </td> </tr> <tr> <td>Ca²⁺</td> <td> <ol style="list-style-type: none"> 1. With SO₄²⁻ forms a white precipitate 2. With F⁻ forms a white precipitate 3. Gives a brick-red flame colour </td> </tr> <tr> <td>Cu²⁺</td> <td> <ol style="list-style-type: none"> 1. With OH⁻ forms blue precipitate 2. This precipitate dissolves in NH₃ to form a deep blue solution </td> </tr> </tbody> </table>	Cation	Test	Pb ²⁺	<ol style="list-style-type: none"> 1. With Cl⁻ forms a white precipitate 2. With I⁻ forms a yellow precipitate. 	Ba ²⁺	<ol style="list-style-type: none"> 1. With SO₄²⁻ forms a white precipitate (if not too dilute) 2. Gives a pale green flame colour 3. No precipitate with OH⁻ or F⁻ (For Ca²⁺ comparison) 	Ca ²⁺	<ol style="list-style-type: none"> 1. With SO₄²⁻ forms a white precipitate 2. With F⁻ forms a white precipitate 3. Gives a brick-red flame colour 	Cu ²⁺	<ol style="list-style-type: none"> 1. With OH⁻ forms blue precipitate 2. This precipitate dissolves in NH₃ to form a deep blue solution
Cation	Test										
Pb ²⁺	<ol style="list-style-type: none"> 1. With Cl⁻ forms a white precipitate 2. With I⁻ forms a yellow precipitate. 										
Ba ²⁺	<ol style="list-style-type: none"> 1. With SO₄²⁻ forms a white precipitate (if not too dilute) 2. Gives a pale green flame colour 3. No precipitate with OH⁻ or F⁻ (For Ca²⁺ comparison) 										
Ca ²⁺	<ol style="list-style-type: none"> 1. With SO₄²⁻ forms a white precipitate 2. With F⁻ forms a white precipitate 3. Gives a brick-red flame colour 										
Cu ²⁺	<ol style="list-style-type: none"> 1. With OH⁻ forms blue precipitate 2. This precipitate dissolves in NH₃ to form a deep blue solution 										

	3. Blue-green flame colour
Fe ²⁺	1. With OH ⁻ forms a white precipitate that quickly turns brown 2. Decolourises acidified dilute KMnO ₄ solution.
Fe ³⁺	1. With OH ⁻ forms a brown precipitate 2. With SCN ⁻ forms a deep red.

Anion Tests:

Anion	Test
Carbonate CO ₃ ²⁻	1. Solution has a pH between 8 & 11 (pH paper suffices.) 2. Addition of dilute HNO ₃ produces bubbles of colourless gas. (CO ₂)
Sulfate SO ₄ ²⁻	1. Addition of Ba(NO ₃) ₂ to an acidified sample of the solution produces a thick white precipitate. 2. Acidification and addition of Pb(NO ₃) ₂ produces a white precipitate.
Chloride Cl ⁻	1. Addition of AgNO ₃ to an acidified sample produces a white precipitate 2. This precipitate dissolves in ammonia solution and darkens in sunlight.
Phosphate PO ₄ ³⁻	1. Addition of ammonia followed by Ba(NO ₃) ₂ produces a white precipitate. 2. Addition of Mg ²⁺ in an ammonia, ammonium nitrate buffer produces a white precipitate of Mg(NH ₄)PO ₄
Nitrate NO ₃ ⁻	1. Addition of FeSO ₄ followed by concentrated H ₂ SO ₄ produces a brown ring at the junction of the two solutions ('brown ring' test)

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

Atomic Absorption Spectroscopy is extremely accurate and is used to determine the **concentration** of **metal ions** in solutions.

The equipment is set up as shown in the diagram and the aqueous solution of the sample is fed into the flame. A lamp is set up that emits **radiation** of a certain **wavelength** (which is characteristic of a particular element). The **element** in the sample **absorbs** some of the **radiation** and the rest passes through it to the **prism** or **monochromator**.

By knowing how much **radiation** would pass if there was no element, and since the amount absorbed by the element is proportional to its concentration, the **concentration** of an **element** in a sample can be calculated.

Each element has its own characteristic absorption spectrum related to its electron energy shells.

	<p>Its development has allowed us to realise the wide variety of substances that contain previously unknown trace elements. Trace elements are elements that are required by living organisms in very small amounts.</p> <p>The need for these elements was recognised when scientists started using AAS for measuring concentrations of elements in soil samples.</p>
<ul style="list-style-type: none"> • Perform first hand investigations to carry out a range of tests, including flame tests, to identify the following ions: <ul style="list-style-type: none"> ○ Phosphate ○ Sulfate ○ Carbonate ○ Chloride ○ Barium ○ Calcium ○ Lead ○ Copper ○ Iron 	<p><u>Experiment:</u></p> <p><u>Aim:</u> To identify anions and cations in solution.</p> <p><u>Method:</u></p> <ol style="list-style-type: none"> 1. Labelled the unknown solutions (A to F) for cations and (A to E) for anions. 2. Followed step by step the procedure below for each unknown cation containing solution, placing solutions in test tubes to conduct tests. 3. Followed step by step the procedure below for each unknown anion containing solution. 4. Recorded results. 5. Was then given a new anion solution (Sample F), which contained 3 anions, and used flowchart to identify anions in that solution. <p><u>Conclusion:</u> The solutions were identified successfully. The only problems that occurred were concerning the combined anion solution, which failed to conclusively prove the presence of nitrate ions.</p>
<ul style="list-style-type: none"> • 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. 	<p>Needs for Monitoring Phosphates: Phosphate often occurs in natural waterways at low concentrations and is essential for normal aquatic plant growth.</p> <p>However, if its concentration becomes too high, it can cause an algal bloom.</p> <p>An algal bloom is an excessive growth of algae that completely covers the surface. By using up all the nutrients, fish die and the health of the waterway suffers.</p> <p>By monitoring the amount of phosphate in the waterways, scientists can guard against algal blooms.</p>
<ul style="list-style-type: none"> • Identify data, plan, select equipment and perform first hand investigations to measure the sulfate content of lawn fertiliser and explain the chemistry involved. 	<p><u>Experiment:</u></p> <p><u>Aim:</u> To calculate the percentage of sulfate in a fertiliser product.</p> <p><u>Method:</u></p> <ol style="list-style-type: none"> 1. Approximately one gram of fertiliser was ground into a fine powder using a mortar and pestle. 2. This was weighed before being dissolved in about 250ml of 0.1 mol L⁻¹ HCl. Stirred to dissolve as much solid as possible. 3. Insoluble material was filtered off. 4. The solution was heated to near boiling, then barium chloride was slowly added from a burette with continuous

stirring. Excess barium chloride was added.

5. The mixture was digested for about 30 minutes with intermittent stirring, then allowed to cool to room temperature. The precipitate was allowed to settle to the bottom.
6. The beaker and contents were then cooled in ice water.
7. A dry piece of filter paper was weighed and put in the Buchner filtering apparatus.
8. The solution was poured through the Buchner filtering apparatus. The solution was washed through first with distilled water, then with ethanol.
9. The filter paper was allowed to dry in an oven overnight and its mass recorded.
10. The percentage of sulfate could then be calculated.

Results:

Mass of fertiliser: 1.08 g

Mass of dried filter paper: 0.68 g

Mass at end: 0.88 g

Calculations:

Mass of precipitate = 0.88 – 0.68 = 0.20 grams

Mass of sulfate in BaSO₄ = $\frac{\text{Molar Mass of Sulfate}}{\text{Molar Mass of BaSO}_4} \times 0.20$

Mass of sulfate in BaSO₄ =

$$\frac{32.1 + 4 \times 16.0}{137.3 + 32.1 + 4 \times 16.0} \times 0.20$$

Mass of sulfate in BaSO₄ = 0.08234 g

Percentage of Sulfate in Fertiliser = $\frac{0.08234}{1.08} \times 100$

Percentage of Sulfate in Fertiliser = 7.62%

Conclusion:

The percentage of sulfate in the fertiliser is 7.62%.

Evaluation:

As the experimentally calculated percentage of 7.62% is well below the printed 17% on the side of the packaging, experimental errors have occurred at some stage throughout the experiment.

The experimentally calculated value has an error percentage of 123% and there are a number of possible reasons for this.

- A loss of barium due to its small but possibly significant solubility
- If the precipitate formed was extremely small, it could have passed through the filter paper.
- Some of the precipitate becoming stuck on the walls of the beaker while transferring the mixture.
- Loss of some precipitate through spillage
- Loss of some precipitate by dissolution while washing it if the volume of wash water is too great.

<ul style="list-style-type: none"> Analyse information to evaluate the reliability of the results of the above investigation and to propose solutions to problems encountered in the procedure. 	<p>Experimental Difficulties:</p> <p><u>Errors that would cause the precipitate to weigh less than it should:</u></p> <ul style="list-style-type: none"> Loss of barium sulfate due to its small but possibly significant solubility. If the precipitate formed was extremely small, it could have passed through the filter paper. Some of the precipitate becoming stuck on the walls of the beaker while transferring the mixture. Loss of some precipitate through spillage Loss of some precipitate by dissolution while washing it if the volume of wash water is too great. <p><u>Errors that would cause the precipitate to weigh more than it should:</u></p> <ul style="list-style-type: none"> Contamination of the precipitate with substances adsorbed from the solution during precipitation. This occurs more severely when the precipitate forms as very small particles as there is more surface area. Incomplete drying of the precipitate so that it still contains water when it is weighed.
<ul style="list-style-type: none"> Gather, process and present information to interpret secondary data from AAS measurements and evaluate the effectiveness of this in pollution control. 	<p>Because AAS can measure extremely small concentrations, it is extremely effective when dealing with pollution control.</p>
<p>Focus 4</p> <p>Human activity has caused changes in the composition and structure of the atmosphere. Chemists monitor these changes so that further damage can be limited.</p>	
<ul style="list-style-type: none"> Describe the composition and layered structure of the atmosphere. 	<p>Starting from ground level, as we go up, temperature decreases from about 15°C at ground level to about -50°C at an altitude of 15km. This region is known as the troposphere. The troposphere is the region of the atmosphere closest to the Earth. From there we enter the stratosphere, where the temperature goes from -50°C to around 0°C. The stratosphere is between the altitudes of 15km and 50km. The mesosphere is next, and once again the temperature decreases, to about -100°C at 85km up.</p>

	<p>We then enter the thermosphere where the temperature continues to increase.</p> <p>The ionosphere is the region above the altitude of 60km.</p>																		
<ul style="list-style-type: none"> Identify the main pollutants found in the lower atmosphere and their sources. 	<p>The biggest source of atmospheric pollution is combustion. Combustion can produce pollutants such as carbon monoxide, sulfur dioxide and oxides of nitrogen.</p> <p>Main Pollutants:</p> <table border="1"> <thead> <tr> <th>Pollutant</th> <th>Source</th> </tr> </thead> <tbody> <tr> <td>Carbon monoxide</td> <td>Motor cars, cigarettes, bush fires, slow combustion stoves</td> </tr> <tr> <td>Oxides of nitrogen</td> <td>Combustion vehicles and power stations</td> </tr> <tr> <td>Hydrocarbons</td> <td>Vehicles and factories using solvents</td> </tr> <tr> <td>Sulfur dioxide</td> <td>Impurities in the fuel during combustion, metal extraction and some chemical manufacturing.</td> </tr> <tr> <td>Fluoride</td> <td>Aluminium smelters</td> </tr> </tbody> </table>	Pollutant	Source	Carbon monoxide	Motor cars, cigarettes, bush fires, slow combustion stoves	Oxides of nitrogen	Combustion vehicles and power stations	Hydrocarbons	Vehicles and factories using solvents	Sulfur dioxide	Impurities in the fuel during combustion, metal extraction and some chemical manufacturing.	Fluoride	Aluminium smelters						
Pollutant	Source																		
Carbon monoxide	Motor cars, cigarettes, bush fires, slow combustion stoves																		
Oxides of nitrogen	Combustion vehicles and power stations																		
Hydrocarbons	Vehicles and factories using solvents																		
Sulfur dioxide	Impurities in the fuel during combustion, metal extraction and some chemical manufacturing.																		
Fluoride	Aluminium smelters																		
<ul style="list-style-type: none"> Describe ozone as a molecule able to act both as an upper atmosphere UV radiation shield and a lower atmosphere pollutant. 	<p>Ozone, O₃, is an allotrope of oxygen. It is a naturally occurring substance.</p> <p>Ozone is poisonous to humans and most other forms of life if they breathe it. Ozone can cause breathing difficulties, headaches and premature fatigue.</p> <p>Yet, this same ozone, when contained in the stratosphere, is able to block harmful UV radiation from reaching us.</p>																		
<ul style="list-style-type: none"> Describe the formation of a coordinate covalent bond. Demonstrate the formation of a coordinate covalent bond using Lewis electron dot structures. 	<p>The most common ozone allotrope, O₂, consists of a pair of oxygen atoms joined by a double covalent bond.</p> <p>Ozone, O₃, is three oxygen atoms joined together. One of the lone pairs of electrons on an oxygen atom of the O₂ molecule forms a new covalent bond with the third oxygen atom. We call this a coordinate covalent bond.</p> <p>A coordinate covalent bond is a covalent bond in which both of the shared electrons come from the one atom. Once formed, a coordinate covalent bond is indistinguishable from a normal covalent bond.</p>																		
<ul style="list-style-type: none"> Compare the properties of the oxygen allotropes O₂ & O₃ and account for them on the basis of molecular structure and bonding. 	<table border="1"> <thead> <tr> <th>Property</th> <th>O₂</th> <th>O₃</th> </tr> </thead> <tbody> <tr> <td>Colour</td> <td>Colourless Gas</td> <td>Blue gas</td> </tr> <tr> <td>Odour</td> <td>Odourless</td> <td>Strong odour (detectable at 0.01ppm)</td> </tr> <tr> <td>Use</td> <td>Essential for life</td> <td>Poisonous to life</td> </tr> <tr> <td>Boiling Point</td> <td>-183°C</td> <td>-111°C</td> </tr> <tr> <td>Density</td> <td>About the same as air</td> <td>1.5 times that of air</td> </tr> </tbody> </table>	Property	O ₂	O ₃	Colour	Colourless Gas	Blue gas	Odour	Odourless	Strong odour (detectable at 0.01ppm)	Use	Essential for life	Poisonous to life	Boiling Point	-183°C	-111°C	Density	About the same as air	1.5 times that of air
Property	O ₂	O ₃																	
Colour	Colourless Gas	Blue gas																	
Odour	Odourless	Strong odour (detectable at 0.01ppm)																	
Use	Essential for life	Poisonous to life																	
Boiling Point	-183°C	-111°C																	
Density	About the same as air	1.5 times that of air																	

	Reactivity	< O ₃	> O ₂
	<p>When O₂ reacts, a double bond must be broken and this requires a significant amount of energy.</p> $\text{O}_{2(g)} \rightarrow 2\text{O}_{(g)} \quad \Delta H = 498 \text{ kJ mol}^{-1}$ <p>However, when O₃ reacts an oxygen atom just slips off leaving a stable O₂ molecule. This reaction requires much less energy and hence O₃ is the more reactive allotrope.</p> $\text{O}_{3(g)} \rightarrow \text{O}_{2(g)} + \text{O}_{(g)} \quad \Delta H = 106 \text{ kJ mol}^{-1}$		
<ul style="list-style-type: none"> Compare the properties of the gaseous forms of oxygen and the oxygen free radical. 	<p>The oxygen free radical (a single oxygen atom) is highly reactive and for this reason they don't normally exist for very long. Their high reactivity means that their concentration is always very low. This high reactivity is due to its incomplete valence shell.</p> <p>Reactivity: O > O₃ > O₂</p> <p>Oxygen atoms readily react with most organic compounds at room temperature. By contrast ozone reacts with organic compounds if they have a double or triple bond and O₂ reacts with organic compounds only at elevated temperatures or during combustion.</p>		
<ul style="list-style-type: none"> Identify the origins of chlorofluorocarbons (CFCs) and halons in the atmosphere. 	<p>Chlorofluorocarbons are compounds containing chlorine, fluorine and carbon only. They contain no hydrogen. They are odourless, non-flammable, non-toxic and very inert.</p> <p>Sources of CFCs:</p> <ul style="list-style-type: none"> Replacement for ammonia in refrigeration Aerosol spray cans Foaming agents in the production of polystyrene Air conditioner units Cleaning circuit boards <p>Halons are compounds of carbon, bromine and other halogens. They are dense, non-flammable liquids that are particularly good at extinguishing fires. They were mainly found in fire extinguishers.</p>		
<ul style="list-style-type: none"> Identify and name examples of isomers (excluding geometrical and optical) of haloalkanes up to 	<p>Rules for Naming Haloalkanes:</p> <ul style="list-style-type: none"> Bromo, chloro, fluoro, iodo, etc, are used as prefixes to the alkane names. The position of the halogen atom (halo) is denoted by a number. If more than one halo atom is present we use di, tri, tetra, etc. 		

<p>eight carbon atoms.</p>	<ul style="list-style-type: none"> • Number from the end of the molecule that leads to the smallest sum of all the numbers • If more than one halo atom is present, then order is decided alphabetically. <p>Isomers are compounds that have the same molecular formula but a different structural formula.</p>
<ul style="list-style-type: none"> • Discuss the problems with CFCs and assess the effectiveness of steps taken to alleviate these problems. 	<p>CFCs were thought to be safe because they were inert, didn't break down in sunlight, were odourless and were non-toxic.</p> <p>However, it is when CFCs come into contact with UV light that they become a problem. When UV light strikes a CFC molecule, a chlorine atom is split off, creating a highly reactive free radical.</p> $\text{CCl}_3\text{F} + \text{UV Light} \rightarrow \text{Cl} + \text{CCl}_2\text{F}$ <p>This free radical, when it comes into contact with ozone, takes an oxygen atom from ozone.</p> $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$ <p>This means that the ozone molecule designed to protect us from the harmful UV rays is destroyed. But the cycle is not yet complete. When an oxygen atom comes in to take the other oxygen from chlorine, all of a sudden the chlorine is free to start again, destroying more ozone.</p> $\text{ClO} + \text{O} \rightarrow \text{O}_2 + \text{Cl}$ <p>This is known as a chain reaction.</p>
<ul style="list-style-type: none"> • Analyse the information available that indicates changes in atmospheric ozone concentrations, describe changes observed and explain how this information was obtained. 	<p>Measuring Stratospheric Ozone: Ozone is measured from ground based instruments, weather balloons and from orbiting satellites. Total ozone per unit area is generally measured in Dobson Units (DU). 1 DU corresponds to 0.01mm thick piece of pure ozone. Normal amounts of ozone recorded are 300 DU.</p> <p>Ground based instruments are UV spectrophotometers pointing vertically upwards towards the sky. They measure the intensity of light received at a wavelength at which ozone absorbs. They also measure the intensity of light on either side of the set of wavelengths that ozone absorbs. By calculating the difference between these intensities, the amount of ozone can be calculated.</p> <p>Total ozone mapping spectrophotometers (TOMS) are used on board satellites to record ozone levels at different</p>

	<p>altitudes.</p> <p>Huge helium-filled weather balloons have also been used to measure concentrations of ozone as a function of altitude.</p>
<ul style="list-style-type: none"> • 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. 	<p>CFC and Ozone Breakdown:</p> $\text{CCl}_3\text{F} + \text{UV Light} \rightarrow \text{Cl} + \text{CCl}_2\text{F}$ $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$ $\text{ClO} + \text{O} \rightarrow \text{O}_2 + \text{Cl}$
<ul style="list-style-type: none"> • Gather, process and present information from secondary sources including simulations, molecular model kits or pictorial representations to model isomers of haloalkanes. 	<p>Use molecular model kits to model isomers of haloalkanes.</p> <p>Did this by following the naming rules above.</p>
<ul style="list-style-type: none"> • 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. 	<p>The Montreal Protocol in 1992 set down a series of guidelines to phase out the use of CFCs for better substitutes.</p> <p>The first substitute used was HCFCs. These are hydrochlorofluorocarbons and undertook reaction in the troposphere and so are decomposed there. Only a small portion of them actually make the stratosphere but while there ozone destroying capacity is small, it is still significant. For that reason, they were seen as a temporary replacement for CFCs.</p> <p>HFCs are now used as the replacement for CFCs. Hydrofluorocarbons are substances containing hydrogen, fluorine and carbon but no chlorine. They undergo some decomposition in the troposphere but most importantly because they have no C – Cl bonds, their ozone destructive power is zero.</p> <p>They are more expensive than CFCs and are less efficient coolers but are now the commonplace for refrigerator units and air conditioners.</p> <p>The most common HFC used is HFC-134a or 1,1,1,2-tetrafluoroethane.</p>

<p>Focus 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.</p>	
<ul style="list-style-type: none"> • Identify that water quality can be determined by considering: <ul style="list-style-type: none"> ○ Concentrations of common ions ○ Total Dissolved solids ○ Hardness ○ Turbidity ○ Acidity ○ Dissolved oxygen and biochemical oxygen demand. 	<p>Good Quality Drinking:</p> <ul style="list-style-type: none"> • Completely colourless and clear • Odourless • Pleasant taste • Relatively low salt content • No pathogens • No poisonous chemicals <p>Criteria for Assessing Water Quality: In good drinking water, ions such as Aluminium, Nitrates and Phosphates need to be kept below guideline figures.</p> <p>Total dissolved solids are the mass of solids in a unit volume of water. It is reported as either mg/L or ppm. Drinking water should have a TDS measurement of under 500 ppm. Realistically, almost all of the TDS in a solution are ionic salt compounds, which is why salt water bodies have high TDS readings. TDS can be calculated by either evaporation or with a TDS conductivity scanner.</p> <p>Hard water is regarded as water that does not lather well. Hardness of water is measured in regards to the concentration of calcium and magnesium ions. Hardness is usually measured in mg/L.</p> <p>Turbidity is a measure of the suspended solids in water. In other words, a lack of transparency. Turbidity is measured in NTU (Nephelometric Turbidity Units) and generally needs to be below 5 NTU for a waterway to be considered healthy.</p> <p>Acidity, or the pH of a water supply, must also be monitored. Ideally the pH should be between 6.5 and 8.5.</p> <p>Dissolved oxygen is a measure of the amount of oxygen dissolved in water and is usually recorded in mg/L or ppm. If the dissolved oxygen levels drop too low, fish and other aquatic organisms will die. Dissolved oxygen is measured using either the Winkler titration method or through electrolysis.</p>

	<p>The biochemical oxygen demand (BOD) 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 aerobic bacteria.</p>
<ul style="list-style-type: none"> Identify factors that affect the concentration of a range of ions in solution in natural bodies of water such as rivers and oceans. 	<p>Factors Affecting Concentrations of Ions:</p> <ul style="list-style-type: none"> The pathway from rain to water body. Since rain contains very few ions, any ions it does contain when it reaches a water body it has picked up somewhere along the way. The pH of rain. Acidic rain is better able to leech certain ions from the soil. The nature and amount of human activity in the catchment. Runoff from highways, agricultural land and housing estates can cause an increased concentration of ions. Effluents discharged into the water bodies. Discharges of effluent into rivers and oceans increase the concentration of ions. Leaching from rubbish dumps. If water flows over from poorly designed rubbish tips, they can pick up many ions before reaching the water body.
<ul style="list-style-type: none"> Describe and assess the effectiveness of methods used to purify and sanitise mass water supplies. 	<p>Two main steps are used for the treatment of water in Australia. The first is flocculation, where suspended solids are grouped together so they can be removed. The second stage is sanitisation, where chlorine and ammonia are added to remove pathogens and bacteria from the water.</p> <p>The process is very effective and like everything it is a compromise between final water quality and cost. In areas that are relatively unaffected by human activity, less processing of the water is needed. Other areas around Australia have high human activity and must have a much more thorough process in place to remove impurities.</p>
<ul style="list-style-type: none"> Describe the design and composition of microscopic membrane filters and explain how they purify contaminated water. 	<p>Membrane filters are essentially a thin film of a synthetic polymer through which there are pores of uniform microscopic size.</p> <p>Advantages:</p> <ul style="list-style-type: none"> They can filter out much smaller particles than sand or paper filters can. They filter out virtually all particles larger than the pore size. They are thin and allow liquids to flow through rapidly. They are strong and can withstand pressure differences across them of 2-5 atmospheres. They can be cleaned (back flushed) and reused.
<ul style="list-style-type: none"> Perform first hand investigations to use qualitative and 	<p><u>Experiment:</u> <u>Aim:</u> To quantitatively test the water quality of a designated</p>

quantitative tests to analyse and compare the quality of water samples.

sample, testing for dissolved oxygen (DO), total dissolved solids (TDS) and turbidity.

Method:

Dissolved Oxygen

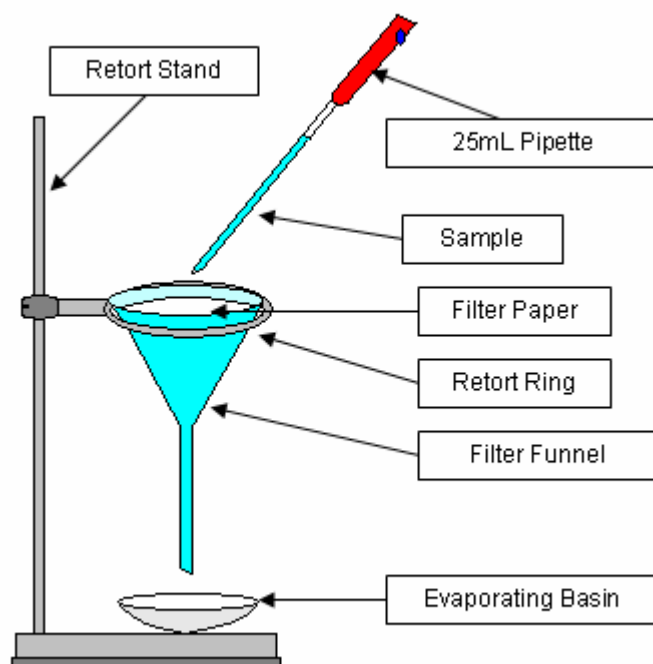
1. Collected the sample from third party supplier and all necessary equipment. The sample of 300mL was collected by a third party in the Schott 300mL Sample Water bottle.
2. Put on safety glasses and gloves.
3. Removed the lid of Schott bottle carefully, taking care not to agitate the water.
4. Added 1mL of Magnesium Sulfate solution (MnSO_4) to the sample water using one of the 1mL pipettes.
5. Added 1mL of Alkali-Iodide-Azide Solution to the sample water using a fresh 1mL pipette. **(SAFETY:** Alkali-Iodide-Azide solution is an alkaline caustic substance. Take extreme care when in use. See Safety Section.)
6. Put the lid back on the Schott bottle and inverted the bottle several times to mix. Allowed a brown precipitate to form.
7. Let the precipitate settle to the bottom half of the Schott bottle. (From this point on, the dissolved oxygen concentration will remain stable for a period of 48 hours unless exposed to intense heat or direct sunlight.)
8. Added 1mL of concentrated sulfuric acid (H_2SO_4) to the sample using a new 1mL pipette. This turned the solution a bright gold colour and dissolved the precipitate. **(SAFETY:** Concentrated Sulfuric Acid is highly acidic and will burn the skin. Take extreme care when in use.)
9. Transferred 201mL of the solution to the 250mL Erlenmeyer flask using the 100mL measuring cylinder. This was done in three transfers.
10. Rinsed the burette using the solution that was to be placed in there, in this case, Sodium Thio-sulfate solution.
11. Set up the retort stand, burette and burette clamp as shown in diagram. Ensured the tap was closed and added approximately 30mL of the Sodium Thio-Sulfate solution to the burette using a filter funnel.
12. Recorded the starting amount of Sodium Thio-Sulfate solution in the burette.
13. Placed a clean, white sheet of paper underneath the tap of the burette and put the Erlenmeyer flask sitting on it, directly underneath the tap. The paper was used so the colour change could be seen more easily.
14. Titrated slowly until the sample water solution in the Erlenmeyer flask turned a pale straw colour. The mixture was continually swirled during titration.
15. Added a few drops of starch solution to the solution in the Erlenmeyer flask using a new 1ml pipette and swirled until

the solution turned a dark blue colour.

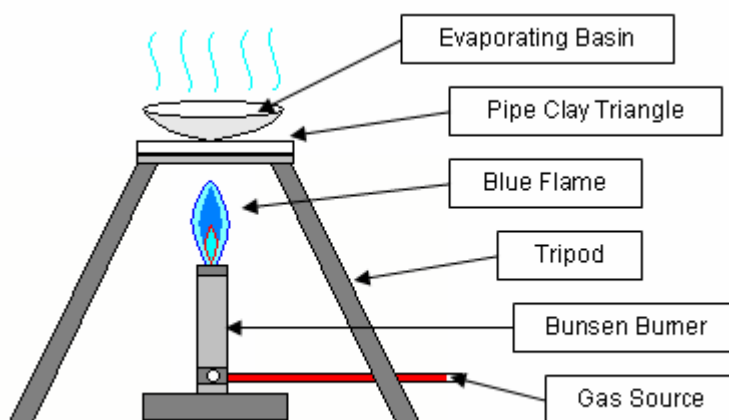
16. Continued to titrate slowly, taking care not to overrun the endpoint. The endpoint was reached when the solution turned clear.
17. Recorded the amount of Sodium Thio-Sulfate solution left in the burette.
18. Transferred the remaining amount of sample solution in the Schott bottle to a clean 250mL Erlenmeyer flask using the measuring cylinder. This was done in two transfers and the exact amount of solution transferred was recorded. Repeated steps 12 to 17 for the new solution in the Erlenmeyer flask.
19. Calculated the concentration of dissolved oxygen for each test and took the average of those values. However, since different amounts were titrated, they had to be calculated differently.
20. For the first test, the amount of millilitres used in the titration equals the concentration of dissolved oxygen in mg/L or ppm.
21. For the second test, the dissolved oxygen concentration was calculated by multiplying the volume of Sodium Thio-Sulfate used by: $\frac{201}{\text{Volume of Sample Used}}$. (For full calculations, using the actual values, see Appendix 2)

Total Dissolved Solids

1. Collected sample from third party supplier and all necessary equipment was gathered.
2. Put on safety glasses and gloves.
3. Rinsed a 250mL beaker using the sample water before adding the sample water to the beaker.
4. Set up retort stand, retort ring, filter funnel and filter paper as shown in diagram.



5. Used the sample water to rinse the 25mL pipette.
6. Saturated filter paper so the sides of it stuck to the filter funnel. This was done so that when the 25mL of sample is filtered later, losses due to absorption by the filter paper can be minimized.
7. A new, clean evaporating basin's mass was recorded using an electronic balance.
8. Placed a clean evaporating basin underneath the filter funnel.
9. Used the 25mL pipette to transfer exactly 25mL of the sample water into the filter funnel and allowed it to slowly filter through.
10. Set up tripod, pipe clay triangle, Bunsen burner and evaporating basin as shown in diagram.



11. Turned on the gas source and lit the Bunsen burner.
12. Slowly heated the evaporating basin using a blue flame to evaporate all the water. This was done slowly to avoid

spitting and losing solids.

13. Once all the liquid had evaporated, allowed the evaporating basin to cool back to room temperature.
14. Re-recorded the mass of evaporating basin and solids.
15. Calculated the mass difference and used this figure to determine the concentration of total dissolved solids. (See appendix 2)
16. Repeated steps 7 to 15 using a fresh 25mL sample and took the average of the two tests.
17. Rinsed a new beaker with distilled water and then half-filled it with distilled water.
18. Calibrated the TDScan10 dissolved solids scanner using the distilled water.
19. Put the TDScan10 into the beaker filled with sample water and recorded the reading on the LCD screen.

Turbidity

1. Collected sample water from third party supplier and gathered all necessary equipment.
2. Put on safety glasses and gloves.
3. Rinsed a clean colorimeter tube (0967) with distilled water.
4. Filled this tube with distilled water to the 10mL line and capped. Wiped with a tissue to remove any fingerprints or dirt.
5. Selected 'Wavelength 1' on the colorimeter.
6. Inserted the tube into the colorimeter chamber and used the 'Set Blank' knob until the screen displayed 100. This was the calibration of the colorimeter.
7. Emptied the tube and rinsed thoroughly with sample water.
8. Filled the tube with sample water to the 10mL line and capped. Wiped with a tissue to remove any fingerprints or dirt.
9. Put the tube back into the colorimeter chamber and recorded the reading on the screen.
10. Consulted calibration table to determine the turbidity.
11. Repeated steps 3 to 10 three more times and took the average of the tests.

A sample of the water was also sent to Richmond Water Laboratories (RWL), Lismore, for analysis. The figures obtained experimentally could be then compared with the actual values obtained by the laboratory.

Conclusion:

The concentration of dissolved oxygen obtained by the experiment was 7.21 ppm and 7.10 ppm by Richmond Water Laboratories.

The concentration of total dissolved solids obtained by the

	<p>experiment was 1190 ppm, and 1175 ppm by Richmond Water Laboratories.</p> <p>The turbidity as calculated by the experiment was 11.78 NTU and the value calculated by Richmond Water Laboratories was 12.5 NTU.</p>
<ul style="list-style-type: none"> • Gather, process and present information on the range and chemistry of the tests used to: <ul style="list-style-type: none"> ○ Identify heavy metal pollution of water. ○ Monitor possible eutrophication of waterways. 	<p><u>Chemical Tests for Heavy Metals</u></p> <p>Atomic Absorption Spectroscopy (AAS) is used to determine the presence and concentration of various heavy metals in the water including lead, iron, silver, copper and cadmium. At Rocky Creek Dam, the biggest problem with heavy metal concentrations is iron due to the nature of the soils as mentioned previously.</p> <p>Also, the graphite furnace can be used to give more accurate concentrations of the presence of mercury, lead and arsenic.</p> <p><u>Monitoring Possible Eutrophication</u></p> <p>Many of the tests mentioned above will test for the presence of substances that could indicate eutrophication. The key is to monitor any sudden changes in concentrations that could lead to possible algal blooms.</p> <p>This includes monitoring the levels of nitrates and phosphates using a discrete analyser. Also being able to recognise algal blooms if it does occur.</p> <p>Water samples are also tested by being kept in an incubator and then viewed under a binocular light microscope to determine whether dangerous bacteria such as giardia are present.</p>
<ul style="list-style-type: none"> • Gather, process and present information on the features of the local town water supply in terms of: <ul style="list-style-type: none"> ○ Catchment area ○ Possible sources of contamination in the 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 	<p><u>Case Study: Rocky Creek Dam</u></p> <p><u>The Catchment Area</u></p> <p>The Rocky Creek Dam catchment area is a 29 km² area once used for logging but is now a pristine catchment environment for the North Coast of New South Wales.</p> <p>The dam itself covers around two square kilometres (478 acres) and can hold about 14,000 mega litres of water when at 100% capacity.</p> <p>The dam wall is 27 metres high and is made up of about 80,000 tonnes of rock, soil, clay and concrete.</p> <p>The dam wall was built in 1949 and Bangalow became the first to begin receiving water from Rocky Creek Dam in 1953.</p> <p><u>Contamination in the Catchment</u></p> <p>As no agricultural farms or properties exist inside the catchment area, Rocky Creek Dam is one of the most pristine catchments in the entire country.</p> <p>However, there are still a number of possible contaminants in the area, mainly due to the natural flora and fauna.</p> <p>Organic runoff from birds and other warm blooded animals can introduce unwanted nutrients into the water, which can cause algal blooms. Also, the soil in the catchment area is a red clay substance, and contains iron, meaning</p>

reasons for the presence of these additives

contamination in regards to iron, must be considered. Also, whilst scarcely used, there are a number of roads in the catchment area due to the old logging days. Runoff from cars and the activities of loggers would also have an impact on the health of the ecosystem.

Purification of Water

Rocky Creek Dam water is treated at the Nightcap Water Treatment Plant, where a number of problem substances are dealt with.

The Nightcap Water Treatment Plant uses a process known as the DAFF process (Dissolved Air, Flotation & Flocculation).

The water is firstly pumped out of Rocky Creek Dam and transported to the Nightcap Water Treatment Plant where it will be treated.

The process begins with the addition of three additives; Alum (Aluminium Sulfate – Al_2SO_4), Lime (Calcium Carbonate – $CaCO_3$) and a long chained chemical known as a poly-electrolyte. These additives are added in the flash mixer.

The addition of the alum and poly-electrolyte allow suspended solids to coagulate so they can be easily removed whilst the lime increases the pH (decreases the acidity) of the water to an ideal level of 6.1 to assist with this process.

This clumping together of solids is called flocculation and can be seen in diagram 3 as the water is mixed with huge stirrers.

The water is then passed into the saturation tank where millions of micro-bubbles are passed through it. It then moves on to the floatation and



filtration tank where these micro-bubbles attach themselves to the clumped solids and float them to the surface. These solids form a floating sludge which can be skimmed off (see diagram 4).

The clean water underneath the sludge is passed through a bed of fine sand so any remaining solids are filtered out.

The dirt and clumped solids is pumped off site and the remaining water contained in the sludge is allowed to evaporate. The sludge can then be used for topsoil.



Following this, more lime is added to increase the pH to between 7.5 and 8.5 so that it meets drinkable standards. This also increases the

hardness of the water. Liquid carbon dioxide is also used for pH correction.

Following this process, chlorine, hypochlorous acid and ammonia are added as disinfectants to kill any remaining pathogens. This water is then transported to a 13 mega litre reservoir where it can be distributed to various towns.

Chemical Additives

As mentioned above, there are a number of chemical additives included in the treatment process. These include aluminium sulfate (Al_2SO_4) and a poly electrolyte, which are added as coagulants that allow the suspended solids to clump together.

Calcium carbonate (CaCO_3) is added to control the pH of the water during flocculation and increase the alkalinity (buffering capacity) of the water. Liquid carbon dioxide is also used to help regulate the pH.

Chlorine, Hypochlorous acid and Ammonia are added to kill pathogens during the disinfection process.

Chemical Tests Used to Identify Contaminants

There are a number of methods used to identify various forms of contaminants and determine the levels of these contaminants.

Turbidity is one of the properties of the water that needs to be monitored. Turbidity is a measure of the suspended solids in a solution and is measured in NTU (Nephelometric Turbidity Units).

Total Dissolved Solids (TDS) are also measured using either evaporation or conductivity measurements. They are expressed as a mass per unit volume.

Salinity is also measured using electrical conductivity tests as salts are ionic compounds which will conduct electricity when in solution.

The hardness of water can be measured by determining the total concentration of calcium and magnesium ions in the water and they are expressed as a result of milligrams of CaCO_3 per litre.

Phosphate is tested for using colour spectroscopy, whilst nitrates, nitrites and ammonia are tested for using the discrete analyser or a flame spectrophotometer.