

Introduction

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Introduction

I have managed to compile up notes from a huge range of different sources (at least 20 different places), I have made my notes as detailed yet concise as possible. Unfortunately I can not disclose the sources where my information is from but please trust me in that they are valid and reliable. However, I did not just copy and paste from different sources. I rewrote almost everything based on a variety of sources to give the best possible answer to each dotpoint in the syllabus. I did copy and paste images, I am not an artist.

-Scott Zhou

HSC Course (Year 12)

9.0 Objective and Outcomes

To be added

9.1 Chemistry Skills

To be added

9.2 Production of Materials

Humans have always exploited their natural environment for all their needs including food, clothing and shelter. As the cultural development of humans continued, they looked for a greater variety of materials to cater for their needs.

The twentieth century saw an explosion in both the use of traditional materials and in the research for development of a wide range of materials to satisfy technological developments. Added to this was a reduction in availability of the traditional resources to supply the increasing world population.

Chemists and chemical engineers continue to play a pivotal role in the search for new sources of traditional materials such as those from the petrochemical industry. As the fossil organic reserves dwindle, new sources of the organic chemicals presently used have to be found. In addition, chemists are continually searching for compounds to be used in the design and production of new materials to replace those that have been deemed no longer satisfactory for needs.

This module increases students' understanding of the implications of chemistry for society and the environment and the current issues, research and developments in chemistry.

9.2.A - Synthetic Polymers

1. Fossil fuels provide both energy and raw materials such as ethylene, for the production of other substances <i>Students learn to:</i> <ul style="list-style-type: none">construct word and balanced formulae equations of chemical reactions as they are encounteredidentify the industrial source of ethylene from the cracking of some of the fractions from the refining of petroleumidentify that ethylene, because of the high reactivity of its double bond, is readily transformed into many useful productsidentify that ethylene serves as a monomer from which polymers are madeidentify polyethylene as an addition polymer and explain the meaning of this termoutline the steps in the production of polyethylene as an example of a commercially and industrially important polymeridentify the following as commercially significant monomers:<ul style="list-style-type: none">vinyl chloridestyreneby both their systematic and common namesdescribe the uses of the polymers made from the above monomers in terms of their properties	<i>Students:</i> <ul style="list-style-type: none">gather and present information from first-hand or secondary sources to write equations to represent all chemical reactions encountered in the HSC courseidentify data, plan and perform a first-hand investigation to compare the reactivities of appropriate alkenes with the corresponding alkanes in bromine wateranalyse information from secondary sources such as computer simulations, molecular model kits or multimedia resources to model the polymerisation process
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9.2.B - Biological Polymers

2. Some scientists research the extraction of materials from biomass to reduce our dependence on fossil fuels <i>Students learn to:</i> <ul style="list-style-type: none">discuss the need for alternative sources of the compounds presently obtained from the petrochemical industryexplain what is meant by a condensation polymerdescribe the reaction involved when a condensation polymer is formeddescribe the structure of cellulose and identify it as an example of a condensation polymer found as a major component of biomassidentify that cellulose contains the basic carbon-chain structures needed to build petrochemicals and discuss its potential as a raw material	<i>Students:</i> <ul style="list-style-type: none">use available evidence to gather and present data from secondary sources and analyse progress in the recent development and use of a named biopolymer. This analysis should name the specific enzyme(s) used or organism used to synthesise the material and an evaluation of the use or potential use of the polymer produced related to its properties
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9.2.C - Ethanol

3. Other resources, such as ethanol, are readily available from renewable resources such as plants <i>Students learn to:</i> <ul style="list-style-type: none">describe the dehydration of ethanol to ethylene and identify the need for a catalyst in this process and the catalyst useddescribe the addition of water to ethylene resulting in the production of ethanol and identify the need for a catalyst in this process and the catalyst useddescribe and account for the many uses of ethanol as a solvent for polar and non-polar substancesoutline the use of ethanol as a fuel and explain why it can be called a renewable resourcedescribe conditions under which fermentation of sugars is promotedsummarise the chemistry of the fermentation processdefine the molar heat of combustion of a compound and calculate the value for ethanol from first-hand dataassess the potential of ethanol as an alternative fuel and discuss the advantages and disadvantages of its useidentify the IUPAC nomenclature for straight-chained alkanols from C1 to C8	<i>Students:</i> <ul style="list-style-type: none">process information from secondary sources such as molecular model kits, digital technologies or computer simulations to model:<ul style="list-style-type: none">the addition of water to ethylenethe dehydration of ethanolprocess information from secondary sources to summarise the processes involved in the industrial production of ethanol from sugar caneprocess information from secondary sources to summarise the use of ethanol as an alternative car fuel, evaluating the success of current usagesolve problems, plan and perform a first-hand investigation to carry out the fermentation of glucose and monitor mass changespresent information from secondary sources by writing a balanced equation for the fermentation of glucose to ethanolidentify data sources, choose resources and perform a first-hand investigation to determine and compare heats of combustion of at least three liquid alkanols per gram and per mole
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9.2.D - Electrochemistry

4. Oxidation-reduction reactions are increasingly important as a source of energy <i>Students learn to:</i> <ul style="list-style-type: none">explain the displacement of metals from solution in terms of transfer of electronsidentify the relationship between displacement of metal ions in solution by other metals to the relative activity of metalsaccount for changes in the oxidation state of species in terms of their loss or gain of electronsdescribe and explain galvanic cells in terms of oxidation/reduction reactionsoutline the construction of galvanic cells and trace the direction of electron flowdefine the terms anode, cathode, electrode and electrolyte to describe galvanic cells	<i>Students:</i> <ul style="list-style-type: none">perform a first-hand investigation to identify the conditions under which a galvanic cell is producedperform a first-hand investigation and gather first-hand information to measure the difference in potential of different combinations of metals in an electrolyte solutiongather and present information on the structure and chemistry of a dry cell or lead-acid cell and evaluate it in comparison to one of the following:<ul style="list-style-type: none">button cellfuel cellvanadium redox celllithium cellliquid junction photovoltaic device (eg the Gratzel cell)in terms of:<ul style="list-style-type: none">chemistrycost and practicalityimpact on society - environmental impactsolve problems and analyse information to calculate the potential requirement of named electrochemical processes using tables of standard potentials and half-equations
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9.2.E - Nuclear Chemistry

5. Nuclear chemistry provides a range of materials <i>Students learn to:</i> <ul style="list-style-type: none">distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable	<i>Students:</i> <ul style="list-style-type: none">process information from secondary sources to describe recent discoveries of elements
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<ul style="list-style-type: none"> • describe how transuranic elements are produced • describe how commercial radioisotopes are produced • identify instruments and processes that can be used to detect radiation • identify one use of a named radioisotope: <ul style="list-style-type: none"> - in industry - in medicine • describe the way in which the above named industrial and medical radioisotopes are used and explain their use in terms of their properties 	<ul style="list-style-type: none"> • use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine
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9.3 The Acidic Environment

Acidic and basic environments exist everywhere. The human body has a slightly acidic skin surface to assist in disease control and digestion occurs in both acidic and basic environments to assist the breakdown of the biopolymers constituting food. In deed, microorganisms found in the digestive system are well adapted to acidic or basic environments.

Many industries use acidic and basic compounds for a wide range of purposes and these compounds are found in daily use within the home. Because of this, an awareness of the properties of acids and bases is important for safe handling of materials. Currently, concerns exist about the increased release of acidic and basic substances into the environment and the impact of these substances on the environment and the organisms within those environments.

This module increases students' understanding of the history, nature and practice of chemistry, the applications and uses of chemistry and implications of chemistry for society and the environment.

9.2.B – Identification

1. Indicators were identified with the observation that the colour of some flowers depends on soil composition <i>Students learn to:</i> <ul style="list-style-type: none"> • classify common substances as acidic, basic or neutral • identify that indicators such as litmus, phenolphthalein, methyl orange and bromothymol blue can be used to determine the acidic or basic nature of a material over a range, and that the range is identified by change in indicator colour • identify and describe some everyday uses of indicators including the testing of soil acidity/basicity 	<i>Students:</i> <ul style="list-style-type: none"> • perform a first-hand investigation to prepare and test a natural indicator • identify data and choose resources to gather information about the colour changes of a range of indicators • solve problems by applying information about the colour changes of indicators to classify some household substances as acidic, neutral or basic
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9.2.A – Synthesis

9.2.C – Equilibrium

2. While we usually think of the air around us as neutral, the atmosphere naturally contains acidic oxides of carbon, nitrogen and sulfur. The concentrations of these acidic oxides have been increasing since the Industrial Revolution <i>Students learn to:</i> <ul style="list-style-type: none"> • identify oxides of non-metals which act as acids and describe the conditions under which they act as acids • analyse the position of these non-metals in the Periodic Table and outline the relationship between position of elements in the Periodic Table and acidity/basicity of oxides • define Le Chatelier's principle • identify factors which can affect the equilibrium in a reversible reaction • describe the solubility of carbon dioxide in water under various conditions as an equilibrium process and explain in terms of Le Chatelier's principle • identify natural and industrial sources of sulfur dioxide and oxides of nitrogen • describe, using equations, examples of chemical reactions which release sulfur dioxide and chemical reactions which release oxides of nitrogen • assess the evidence which indicates increases in atmospheric concentration of oxides of sulfur and nitrogen • calculate volumes of gases given masses of some substances in reactions, and calculate masses of substances given gaseous volumes, in reactions involving gases at 0°C and 100kPa or 25°C and 100kPa • explain the formation and effects of acid rain 	<i>Students:</i> <ul style="list-style-type: none"> • identify data, plan and perform a first-hand investigation to decarbonate soft drink and gather data to measure the mass changes involved and calculate the volume of gas released at 25°C and 100kPa • analyse information from secondary sources to summarise the industrial origins of sulfur dioxide and oxides of nitrogen and evaluate reasons for concern about their release into the environment
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9.2.D – Behaviour

9.2.E – Analysis

3. Acids occur in many foods, drinks and even within our stomachs <i>Students learn to:</i> <ul style="list-style-type: none"> • define acids as proton donors and describe the ionisation of acids in water • identify acids including acetic (ethanoic), citric (2-hydroxypropane-1,2,3-tricarboxylic), hydrochloric and sulfuric acid • describe the use of the pH scale in comparing acids and bases • describe acids and their solutions with the appropriate use of the terms strong, weak, concentrated and dilute • identify pH as $-\log_{10} [\text{H}^+]$ and explain that a change in pH of 1 means a ten-fold change in $[\text{H}^+]$ • compare the relative strengths of equal concentrations of citric, acetic and hydrochloric acids and explain in terms of the degree of ionisation of their molecules • describe the difference between a strong and a weak acid in terms of an equilibrium between the intact molecule and its ions 	<i>Students:</i> <ul style="list-style-type: none"> • solve problems and perform a first-hand investigation to use pH meters/probes and indicators to distinguish between acidic, basic and neutral chemicals • plan and perform a first-hand investigation to measure the pH of identical concentrations of strong and weak acids • gather and process information from secondary sources to write ionic equations to represent the ionisation of acids • use available evidence to model the molecular nature of acids and simulate the ionisation of strong and weak acids • gather and process information from secondary sources to explain the use of acids as food additives • identify data, gather and process information from secondary sources to identify examples of naturally occurring acids and bases and their chemical composition • process information from secondary sources to calculate pH of strong acids given appropriate hydrogen ion concentrations
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4. Because of the prevalence and importance of acids, they have been used and studied for hundreds of years. Over time, the definitions of acid and base have been refined <i>Students learn to:</i> <ul style="list-style-type: none"> • outline the historical development of ideas about acids including those of: <ul style="list-style-type: none"> - Lavoisier - Davy - Arrhenius • outline the Brønsted-Lowry theory of acids and bases • describe the relationship between an acid and its conjugate base and a base and its conjugate acid • identify a range of salts which form acidic, basic or neutral solutions and explain their acidic, neutral or basic nature • identify conjugate acid/base pairs • identify amphiprotic substances and construct equations to describe their behaviour in acidic and basic solutions • identify neutralisation as a proton transfer reaction which is exothermic • describe the correct technique for conducting titrations and preparation of standard solutions • qualitatively describe the effect of buffers with reference to a specific example in a natural system 	<i>Students:</i> <ul style="list-style-type: none"> • gather and process information from secondary sources to trace developments in understanding and describing acid/base reactions • choose equipment and perform a first-hand investigation to identify the pH of a range of salt solutions • perform a first-hand investigation and solve problems using titrations and including the preparation of standard solutions, and use available evidence to quantitatively and qualitatively describe the reaction between selected acids and bases • perform a first-hand investigation to determine the concentration of a domestic acidic substance using computer-based technologies • analyse information from secondary sources to assess the use of neutralisation reactions as a safety measure or to minimise damage in accidents or chemical spills
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9.2.F – Esters

5. Esterification is a naturally occurring process which can be performed in the laboratory <i>Students learn to:</i> <ul style="list-style-type: none"> • describe the differences between the alcohol and alkanolic acid functional groups in carbon compounds • identify the IUPAC nomenclature for describing the esters produced by reactions of straight-chained alkanolic acids from C1 to C8 and straight-chained primary alcohols from C1 to C8 • explain the difference in melting point and boiling point caused by straight-chained alkanolic acid and straight-chained primary alcohol 	<i>Students:</i> <ul style="list-style-type: none"> • identify data, plan, select equipment and perform a first-hand investigation to prepare an ester using reflux • process information from secondary sources to identify and describe the uses of esters as flavours and perfumes in processed foods and cosmetics
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structures	
<ul style="list-style-type: none"> • identify esterification as the reaction between an acid and an alkanol and describe, using equations, examples of esterification • describe the purpose of using acid in esterification for catalysis • explain the need for refluxing during esterification • outline some examples of the occurrence, production and uses of esters 	

9.4 Chemical Monitoring and Management

The state of our environment is an important issue for society. Pollution of air, land and water in urban, rural and wilderness areas is a phenomenon that affects the health and survival of all organisms, including humans. An understanding of the chemical processes involved in interactions in the full range of global environments, including atmosphere and hydrosphere, is indispensable to an understanding of how environments behave and change. It is also vital in understanding how technologies, which in part are the result of chemical research, have affected environments. This module encourages discussion of how chemists can assist in reversing or minimising the environmental problems caused by technology and the human demand for products and services.

Some modern technologies can facilitate the gathering of information about the occurrence of chemicals at $^{\circ}\text{C}$ both those occurring in natural environments and those that are released as a result of human technological activity. Such technologies include systems that have been developed to quantify and compare amounts of substances.

This module increases students' understanding of the nature, practice, applications and uses of chemistry and the implications of chemistry for society and the environment.

9.4.A – Chemical Monitoring

1. Much of the work of chemists involves monitoring the reactants and products of reactions and managing reaction conditions <i>Students learn to:</i> <ul style="list-style-type: none"> • 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 • identify the need for collaboration between chemists as they collect and analyse data • describe an example of a chemical reaction such as combustion, where reactants form different products under different conditions and thus would need monitoring 	<i>Students:</i> <ul style="list-style-type: none"> • gather, process and present information from secondary sources about the work of practising scientists identifying: <ul style="list-style-type: none"> - the variety of chemical occupations - a specific chemical occupation for a more detailed study
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9.4.B – Haber Process

2. Chemical processes in industry require monitoring and management to maximise production <i>Students learn to:</i> <ul style="list-style-type: none"> • identify and describe the industrial uses of ammonia • 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 • identify the reaction of hydrogen with nitrogen as exothermic • explain why the rate of reaction is increased by higher temperatures • explain why the yield of product in the Haber process is reduced at higher temperatures using Le Chatelier's principle • explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate and equilibrium • explain that the use of a catalyst will lower the reaction temperature required and identify the catalyst(s) used in the Haber process • analyse the impact of increased pressure on the system involved in the Haber process • explain why monitoring of the reaction vessel used in the Haber process is crucial and discuss the monitoring required 	<i>Students:</i> <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
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9.4.C – Ions

3. Manufactured products, including food, drugs and household chemicals are analysed to determine or ensure their chemical composition <i>Students learn to:</i> <ul style="list-style-type: none"> • deduce the ions present in a sample from the results of tests. • 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. 	<i>Students:</i> <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 • 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. • identify data, plan, select equipment and perform first-hand investigations to measure the sulfate content of lawn fertiliser and explain the chemistry involved. • analyse information to evaluate the reliability of the results of the above investigation and to propose solutions to problems encountered in the procedure. • gather, process and present information to interpret secondary data from AAS measurements and evaluate the effectiveness of this in pollution control.
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9.4.D – Atmospheric Chemistry

4. Human activity has caused changes in the composition and structure of the atmosphere. Chemists monitor these changes so that further damage can be limited. <i>Students learn to:</i> <ul style="list-style-type: none"> • describe the composition and layered structure of the atmosphere. • identify the main pollutants found in the lower atmosphere and their sources. • describe ozone as a molecule able to act both as an upper atmosphere UV radiation shield and a lower atmosphere pollutant. • describe the formation of a coordinate covalent bond. • demonstrate the formation of coordinate covalent bonds using Lewis electron dot structures. • compare the properties of the oxygen allotropes O₂ and O₃ and account for them on the basis of molecular structure and bonding. • compare the properties of the gaseous forms of oxygen and the oxygen free radical. • identify the origins of chlorofluorocarbons (CFCs) and halons in the atmosphere. • identify and name examples of isomers (excluding geometrical and optical) of haloalkanes up to eight carbon atoms. • discuss the problems associated with the use of CFCs and assess the effectiveness of steps taken to alleviate these problems. • analyse the information available that indicates changes in atmospheric ozone concentrations, describe the changes observed and explain how this information was obtained. 	<i>Students:</i> <ul style="list-style-type: none"> • analyse the information available that indicates changes in atmospheric ozone concentrations, describe the changes observed and explain how this information was obtained. • 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. • gather, process and present information from secondary sources including simulations, molecular model kits or pictorial representations to model isomers of haloalkanes. • 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.
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9.4.E – Water Quality

5. Human activity also impacts on waterways. Chemical monitoring and management assists in providing safe water for humans to use and to protect the habitats of other organisms. <i>Students learn to:</i> <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 	<i>Students:</i> <ul style="list-style-type: none"> • perform first-hand investigations to use qualitative and quantitative tests to analyse and compare the quality of water samples. • 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 • Gather, process and present information on the features of the local town water supply in terms of:
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<ul style="list-style-type: none"> - dissolved oxygen and biochemical oxygen demand • identify factors that affect the concentrations of a range of ions in solution in natural bodies of water such as rivers and oceans. • describe and assess the effectiveness of methods used to purify and sanitise mass water supplies. • describe the design and composition of microscopic membrane filters and explain how they purify contaminated water. 	<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 this catchment - chemical tests available to determine levels and types of contaminants - physical and chemical processes used to purify water - chemical additives in the water and the reasons for the presence of these additives
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9.5 Industrial Chemistry

Industry uses chemical reactions to produce chemicals for use by society. This module develops the ideas that some chemicals have been produced to replace naturally occurring chemicals that are no longer available or are not economically viable. The concepts of qualitative and quantitative equilibrium are further developed.

Industrial chemical processes cover the full range of reactions but concentration on some case studies is sufficient to illustrate the range of reactions and the role of chemists and chemical engineers involved in these processes. This allows some insight into the qualitative and quantitative aspects of the chemical industry and allows a consideration of the analytical processes and monitoring that are necessary for efficient production.

This module increases students' understanding of the history, applications and uses of chemistry, and current issues, research and developments in chemistry.

9.5.A – Replacement Products

9.5.1 Industrial chemistry processes have enabled scientists to develop replacements for natural products	
<i>Students learn to:</i> <ul style="list-style-type: none"> • discuss the issues associated with shrinking world resources with regard to one identified natural product that is not a fossil fuel, identifying the replacement materials used and/or current research in place to find a replacement for the named material 	<i>Students:</i> <ul style="list-style-type: none"> • identify data, gather and process information to identify and discuss the issues associated with the increased need for a natural resource that is not a fossil fuel and evaluate the progress currently being made to solve the problems identified

9.5.B – Quantitative Equilibrium

2. Many industrial processes involve manipulation of equilibrium reactions	
<i>Students learn to:</i> <ul style="list-style-type: none"> • explain the effect of changing the following factors on identified equilibrium reactions <ul style="list-style-type: none"> - pressure - volume - concentration - temperature • interpret the equilibrium constant expression (no units required) from the chemical equation of equilibrium reactions • identify that temperature is the only factor that changes the value of the equilibrium constant (K) for a given equation 	<i>Students:</i> <ul style="list-style-type: none"> • identify data, plan and perform a first-hand investigation to model an equilibrium reaction • choose equipment and perform a first-hand investigation to gather information and qualitatively analyse an equilibrium reaction • process and present information from secondary sources to calculate K from equilibrium conditions

9.5.C – Sulfuric Acid

3. Sulfuric acid is one of the most important industrial chemicals	
<i>Students learn to:</i> <ul style="list-style-type: none"> • outline three uses of sulfuric acid in industry • describe the processes used to extract sulfur from mineral deposits, identifying the properties of sulfur which allow its extraction and analysing potential environmental issues that may be associated with its extraction • outline the steps and conditions necessary for the industrial production of H₂SO₄ from its raw materials • describe the reaction conditions necessary for the production of SO₂ and SO₃ • apply the relationship between rates of reaction and equilibrium conditions to the production of SO₂ and SO₃ • describe, using examples, the reactions of sulfuric acid acting as: <ul style="list-style-type: none"> - an oxidising agent - a dehydrating agent • describe and explain the exothermic nature of sulfuric acid ionisation • identify and describe safety precautions that must be taken when using and diluting concentrated sulfuric acid 	<i>Students:</i> <ul style="list-style-type: none"> • gather, process and present information from secondary sources to describe the steps and chemistry involved in the industrial production of H₂SO₄ and use available evidence to analyse the process to predict ways in which the output of sulfuric acid can be maximised • perform first-hand investigations to observe the reactions of sulfuric acid acting as: <ul style="list-style-type: none"> - an oxidising agent - a dehydrating agent • use available evidence to relate the properties of sulfuric acid to safety precautions necessary for its transport and storage

9.5.D – Sodium Hydroxide

4. The industrial production of sodium hydroxide requires the use of electrolysis	
<i>Students learn to:</i> <ul style="list-style-type: none"> • explain the difference between galvanic cells and electrolytic cells in terms of energy requirements • outline the steps in the industrial production of sodium hydroxide from sodium chloride solution and describe the reaction in terms of net ionic and full formulae equations • distinguish between the three electrolysis methods used to extract sodium hydroxide: <ul style="list-style-type: none"> - mercury process - diaphragm process - membrane process by describing each process and analysing the technical and environmental difficulties involved in each process 	<i>Students:</i> <ul style="list-style-type: none"> • identify data, plan and perform a first-hand investigation to identify the products of the electrolysis of sodium chloride • analyse information from secondary sources to predict and explain the different products of the electrolysis of aqueous and molten sodium chloride

9.5.E – Saponification

5. Saponification is an important organic industrial process	
<i>Students learn to:</i> <ul style="list-style-type: none"> • describe saponification as the conversion in basic solution of fats and oils to glycerol and salts of fatty acids • describe the conditions under which saponification can be performed in the school laboratory and compare these with industrial preparation of soap • account for the cleaning action of soap by describing its structure • explain that soap, water and oil together form an emulsion with the soap acting as an emulsifier • distinguish between soaps and synthetic detergents in terms of: <ul style="list-style-type: none"> - the structure of the molecule - chemical composition - effect in hard water • distinguish between anionic, cationic and non-ionic synthetic detergents in terms of: <ul style="list-style-type: none"> - chemical composition - uses 	<i>Students:</i> <ul style="list-style-type: none"> • perform a first-hand investigation to carry out saponification and test the product • gather, process and present information from secondary sources to identify a range of fats and oils used for soap-making • perform a first-hand investigation to gather information and describe the properties of a named emulsion and relate these properties to its uses • perform a first-hand investigation to demonstrate the effect of soap as an emulsifier • solve problems and use available evidence to discuss, using examples, the environmental impacts of the use of soaps and detergents

9.5.E – Sodium Carbonate

6. The Solvay process has been in use since the 1860s	
<i>Students learn to:</i> <ul style="list-style-type: none"> • identify the raw materials used in the Solvay process and name the products • describe the uses of sodium carbonate • identify, given a flow chart, the sequence of steps used in the Solvay process and describe the chemistry involved in: <ul style="list-style-type: none"> - brine purification - hydrogen carbonate formation - formation of sodium carbonate - ammonia recovery • discuss environmental issues associated with the Solvay process and explain how these issues are addressed 	<i>Students:</i> <ul style="list-style-type: none"> • perform a first-hand investigation to assess risk factors and then carry out a chemical step involved in the Solvay process, identifying any difficulties associated with the laboratory modelling of the step • process information to solve problems and quantitatively analyse the relative quantities of reactants and products in each step of the process • use available evidence to determine the criteria used to locate a chemical industry using the Solvay process as an example

Introduction

Remember: These notes are NOT complete. There are still a few bits missing and have not been edited.

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-Scott Zhou

Contextual Outline

Humans have always exploited their natural environment for all their needs including food, clothing and shelter. As the cultural development of humans continued, they looked for a greater variety of materials to cater for their needs.

The twentieth century saw an explosion in both the use of traditional materials and in the research for development of a wider range of materials to satisfy technological developments. Added to this was a reduction in availability of the traditional resources to supply the increasing world population.

Chemists and chemical engineers continue to play a pivotal role in the search for new sources of traditional materials such as those from the petrochemical industry. As the fossil organic reserves dwindle, new sources of the organic chemicals presently used have to be found. In addition, chemists are continually searching for compounds to be used in the design and production of new materials to replace those that have been deemed no longer satisfactory for needs.

This module increases students' understanding of the implications of chemistry for society and the environment and the current issues, research and developments in chemistry.

*Focus Point 1 - Fossil fuels provide both energy and raw materials such as ethylene, for the production of other substances

Identify the industrial source of ethylene from the cracking of some of the fractions from the refining of petroleum

Ethylene:

- As from year 11, you may remember that a hydrocarbon is an **organic compound** consisting entirely of **hydrogen and carbon**
- Ethylene is such a hydrocarbon
- Ethylene is an important material in the chemical industrial as you will learn. It is the main focus of this Production of materials topic.
- Ethylene has formula $\text{CH}_2=\text{CH}_2$
- It is a gas at room temperature

Note: Ethylene can also be called **ethene**. Some books will use one name, some the other, some will use both. **Both** are acceptable in the HSC.

- Ethylene can be obtained from the naturally occurring substance, **crude oil** (a.k.a. petroleum)
- Ethylene is extracted from the following steps:
 - Fractional **Distillation of Crude Oil** to form **long chain hydrocarbons**
 - Followed by the Thermal or catalytic **cracking** of these long chain hydrocarbons to form shorter chain hydrocarbons e.g. ethylene

Fractional distillation:

- This is a process used to separate mixtures such as petroleum into its components, depending on the components having **different boiling points**.
- This process forms long hydrocarbon chains such as Decane
- These long chains are not useful, they need to undergo cracking to form smaller more useful chains (e.g. ethylene)

Note: You do not need to know about fractional distillation in detail, as it is in the preliminary course.

- However you must remember that Crude Oil is fractionally distilled to form long hydrocarbon chains. Eg. Decane

Cracking:

- This is the step after Fractional Distillation
- Cracking is the breaking down of longer chain hydrocarbons into more useful shorter chain hydrocarbons.
- There are two ways to do this, catalytic cracking and thermal cracking

Note: You are not required to know either types of cracking in detail, rather just the **reaction conditions for both**

Reaction conditions for Catalytic Cracking:

- Zeolite catalysts are used in catalytic cracking
- Recall from year 11 that a catalyst speeds up a reaction but does not participate in the reaction
- A temperature of 500 degrees Celsius
- An Absence of air
- A large atmospheric pressure

- Ethylene is a by-product of this process
- You are required to know an example of catalytic cracking
 - e.g. Catalytic cracking of Decane produces 1 Ethene and 1 Octane
- This is represented by the chemical equation: C

Reaction conditions for Thermal Cracking:

- Thermal cracking is a non-catalytic process, thus catalysts are not required
- Alkane are mixed with steam, through hot metal tubes (700 - 1000 degrees Celsius)
- The pressure is maintained at just above normal atmospheric pressure
- Likewise, you are required to know one example of Thermal cracking
 - e.g. Thermal cracking of Decane produces 2 Ethylenes and 1 Hexane
- This is represented by the chemical equation:

Advantages for using Catalytic cracking over Thermal cracking :

- Even though not strictly stated by the syllabus, there are advantageous for using catalytic cracking:
 - Catalytic cracking saves money, Catalysts lower the energy barrier for reaction. Thus less energy is needed. Meaning less money is needed to buy or produce the energy required
 - Catalytic cracking involves faster reactions - Catalysis provide a surface for the reaction (helps break down the molecule), this saves time

Identify that ethylene, because of the high reactivity of its double bond, is readily transformed into many useful products.

- Now that you have learnt the industrial source of Ethylene, you will begin to learn about its chemistry and why it is useful
- You will encounter the following two terms in this dot-point:

Saturated Hydrocarbon: A hydrocarbon with only single bonds, no more atoms can be added. E.g.. Alkanes

Unsaturated Hydrocarbon: A hydrocarbon containing double or even triple bonds, further atoms can be added. E.g.. Alkenes, Alkynes

- Ethylene being an alkene, is an unsaturated hydrocarbon. It contains a double bond

High reactivity:

- The double bond in alkenes breaks easily to react with substances
 - This is why alkenes such as ethylene are highly reactive
- More specifically, the double bond contain 4 shared electrons between the bonds
- This **high electron density** attracts highly electro negative substances. E.g.. Halogens
- This means that ethylene can form substances with halogens by breaking the double bond and attaching the halogen onto the chain (this is know as a substitution reaction)
- This high electron density also allows addition polymers to be formed through the breaking of the double bond (this is know as an addition reaction)
- Thus, as shown above, Ethylene can undergo addition or substitution reactions.

Addition reaction: Joining of individual monomers without the loss of any atoms. E.g.. Polyethylene: $\text{CH}_2 = \text{CH}_2 \rightarrow (-\text{CH}_2=\text{CH}_2)_n$

Substitution reaction: A reaction where an atom is substituted for another already in the molecule. Light energy may be required

Useful products formed from ethylene:

Product	Formed by	Used for
Vinyl Chloride	Substitution reaction, hydrogen in ethylene is swapped for chlorine	Production of polyvinylchloride
Ethylene glycol	Addition reaction, adding oxygen to ethylene, followed by adding water to the product	Production of anti-freeze, Production of PET, Production of Polyester

Polyethylene	Polymerisation of Ethylene	(see later in "Describe the use of polymers made from the above monomers in terms of their properties.")
Ethanol	Hydration of Ethylene	Solvent, fuel, alcohol (see later in ethanol topic)

Note: Right now you do not need to know each in detail. Later on you will learn the detailed properties / uses of each of these products.

- Hence is the ability for ethylene to form many useful products that makes ethylene a useful building block
- Without the reactivity of the double bonds we wouldn't be able make polymers, neither would we be able to create useful products via substitution such as vinyl chloride.

Identify that ethylene serves as a monomer in which polymers are made

Definitions:

Mono = one
Poly = Many
Mer = unit
Monomer = One Unit
Polymer = Many Unit

Polyethylene is an **addition polymer** made from many ethylene monomers. (See next dotpoint)

Condensation reactions	Addition reactions
Involves monomers joining to form a long chain molecule.	involves monomers joining to form a long chain molecule.
No double bonds necessary.	Monomer has double bond which breaks during polymerisation.
Polymer forms and also another small molecule.	No small molecule produced.

Outline the steps in the production of polyethylene as an example of commercially and industrially important polymer.

- Polyethylene is a commercially and industrially important polymer because it's **two forms, LDPE and HDPE**, are **widely used in everyday society**.
- All plastics begin with a fluid manner. This allows them to be cast or bent into various shapes.
- Thermosoftening plastics:** melt as the temperature rises and can be molded
- Thermosetting plastics:** have a cross-linked 3d structure. You makes these plastics once in a mold.
- Addition polymerisation used in the production of LDPE
- Catalytic polymerisation is used in the production of HDPE

LDPE Properties and production:

- 1 mil g /mole
- Branched
- Shorter
- LDPE is flexible as there is a lot of free space between branched monomers (thus the dispersion forces are very weak).

LDPE	<ul style="list-style-type: none"> Low density Low Melting point Flexible Soft 	<ul style="list-style-type: none"> Wrapping materials Carry bags Milk bottles squeeze bottles
------	--	---

- A initiator is used to initiate the joining of ethylene monomers. E.g. a peroxide containing an o-o bond that breaks easily forming free radicals
- High gas pressure. Approx. 200 atmospheres
- High temperatures. Approx. 300 degrees Celsius.
- Results in molecules with short branches

The Mechanism: The overall process is known as free radical addition

Chain initiation: The chain is initiated by free radicals, produced by reaction between some of the ethene and the oxygen initiator.

Chain propagation: Each time a free radical hits an ethene molecule a new longer free radical is formed

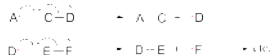
Chain termination: Eventually two free radicals hit each other producing a final molecule. The process stops here because no new free radicals are formed.

- Initiation:** the benzyl peroxide is split into peroxide radicals. This is done by high temperatures (300degrees c) and high pressures.
- Activation (you are required to know this but you can say it is part of 'propagation'):** the peroxide radical grabs the electron dense ethene and grabs an electron to it. The double bond breaks. The radical binds with the ethene.
- Propagation:** the chain grows longer. Each time a monomer unit is added across the double bond, another free radical is formed at the end of the chain on the newly added monomer unit.
- Termination:** two free radicals join together and then the whole process stops. A long molecule is formed. Termination can be also achieved by lowering the temperature or the pressure.

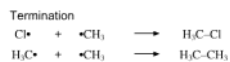
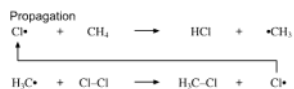
Initiation



Propagation

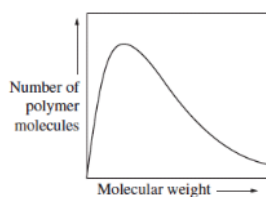


Termination



Randomness / variations:

- Free radical polymerisation (addition polymerisation) produces polymer molecules of **varying molecular weight** as shown in the graph below.
- Because of the large variation in chain length in a reacting system, polymer units will have a variety of carbon chain lengths.
- The somewhat random nature of termination produces polymer molecules with a range of molecular masses.
- The addition of inhibitors or lowering the temperature and pressure can also stop polymerisation so the length of polymer chains can be regulated to some degree.
- Catalytic polymerisation (see below - HDPE properties and production) is another method of producing addition polymers whereby termination can be more tightly controlled.



HDPE Properties and production:

- 3 mil g /mole
- Straight
- Longer
- HDPE is quite strong and tightly packed with less space between monomer 'layers'.

HDPE	<ul style="list-style-type: none"> • High density • High melting point • Hard 	<ul style="list-style-type: none"> • Kitchen Utensils • Toys • Building materials
------	--	--

- Since both density and strength are closely related to the use of commercial polymers, the development of a polymerisation process that could control branching and chain length was of great interest to chemists in the first half of the 20th century
- This led to the development of transition metal catalysts which allowed for **catalytic polymerisation**

- **The Ziegler-Natta process**
- Low gas pressures, approx. 20atm
- Low temperatures, approx. 60 degrees Celsius
- Catalysts used, usually made of transition metals and organometallic compounds
- Catalysts enable more ordered orientation of ethylene to form the long un-branched and aligned molecules of HDPE.
- Physical properties vary with reaction conditions
- Chemical properties are based on the functional groups in their structure.

1. The catalyst, called the metallocene catalyst, has a zirconium ion which breaks double bonds within ethene monomers.
2. Then it attaches the ethene monomers one by one to each other.
3. The chain grows long

Analyse information from secondary sources such as computer simulations, molecular model kits or multimedia resources to model the polymerisation process

Student molymod set (the stupid ball and sticks thing)

Benefits:

- Physical representation of the type and quantity of atoms involved
- Demonstrates the difference between various bonds
- Provides a simple representation to help understanding, someone may understand the simplified model better than the theory.
- Hands on, some people are hands on learners

Limitations:

- Relative sizes, and distances between atoms are unrealistic
- The dynamic nature of various molecules and their bonds is not shown
- Over simplifies the model.
- Not complete, not full picture due to time restraints.

Risks (wtf? I know right...):

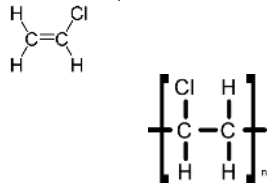
- Swallowing small items can be hazardous and can cause choking which may be life threatening. Exhaust caution, do not put near mouth.
- Falling or tripping on model balls can lead to serious injuries. Do not leave models on floor.
- Damage to eyes from the models. Exhaust caution when handling the models, do not approach face.

Identify the following a commercially significant monomers: vinyl chloride and styrene - by both their systematic and common names.

Common Name	Systematic Name	Chemical Formula
Vinyl Chloride	Chloroethene	C ₂ H ₃ Cl
Styrene	Phenylethene / Ethenylbenzene	C ₆ H ₅ (CH=CH ₂)

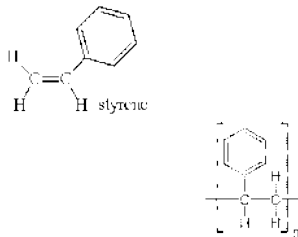
Vinyl Chloride is a monomer used in the production of the polymer, polyvinyl chloride (PVC). This is an **addition polymer** as Cl atoms are simply added in the reaction rather than substituted.

Production of vinyl chloride: 2CH₂=CH₂ + Cl₂ + 1/2 O₂ → (150 degrees Celsius and CuCl₂ catalyst) 2CH₂=CHCl + H₂O



Styrene is the monomer used to make polystyrene. Polystyrene is an **addition polymer** as it is the only product of the reaction.

*When a benzene ring is attached, it is called a **phenyl group**.



Describe the use of polymers made from the above monomers in terms of their properties.

The below is a table of the 4 polymers, their properties, and their use. The properties related to their use is put in brackets().

Polymer	Properties	Use
Polyvinylchloride	<ul style="list-style-type: none"> • Water and flame resistance, • Relatively durable, does not readily react. • Strong and sturdy nature due to larger polar branching and will not let water through • Rigid, strong, nature between powerful C-Cl polar intermolecular bonds • Does not conduct heat or electricity • Large side chain, (chlorine) thus PVC is rigid. • Chemical resistant (caused by chlorine) • Venerable to heat or UV light (the C-Cl bond is weaker compared to C-H) bond 	<ul style="list-style-type: none"> • Insulation for drain pipes (rigid, tough) • Electrical insulation (does not conduct) • Plasticiser needs to be added depending on the use. Plasticiser will change the properties • Shower Curtains (adding plasticiser makes it flexible and not light sensitive) • Rain coats (adding plasticiser makes it resistant to light and UV decay) • Garden Hoses (adding plasticiser makes it flexible and not light sensitive)
Polystyrene	<ul style="list-style-type: none"> • Very large side chain • Extremely rigid • Insoluble (C-H bonds are hydrophobic, do not dissolve in water) • Effective heat, cold and electrical insulator • Not chemically reactive • Strong, rigid and resistance under heat + UV light • Few crystals, can be made transparent which makes it useful. • By blowing air bubbles in the liquid form, it dries to form Styrofoam. • Styrofoam has a cushioning effect. It also has heat insulation. 	<ul style="list-style-type: none"> • Insulator (effective heat cold and electrical insulator) • Cd cases and various containers (can be made transparent) - The large benzene allows it to be seethrough • Car batteries casing(extremely rigid) • Tool handles (rigid) • Packaging (Styrofoam, after blowing air, which changes properties) (cushioning effect) • Plates and foam cups (styrofoam, after blowing air, which changes properties) (heat insulation)
LDPE	<ul style="list-style-type: none"> • Low density • Low Melting point 	<ul style="list-style-type: none"> • Wrapping materials (flexible) (soft) • Carry bags (flexible soft)

	<ul style="list-style-type: none"> • Flexible • Soft • Insoluble (C-H bonds are hydrophobic, do not dissolve in water) • Lower density is highly branched so less can be fit in a certain amount of space • i.e. branches Prevents tight packing • Low density has "lower" average molecular weight 	<ul style="list-style-type: none"> • Milk bottles (low density) • Squeeze bottles (low density) • Rubber ducks (flexible)
HDPE	<ul style="list-style-type: none"> • High density • High melting point (so many chances, a lot of dispersion forces thus more energy required to break bonds) • Hard, high tensile strength (so many chances, a lot of dispersion forces thus more energy required to break bonds) • Insoluble (C-H bonds are hydrophobic, do not dissolve in water) • xHigh density is linear, so a lot more can be fit in it • High density has "higher" average molecular weight 	<ul style="list-style-type: none"> • Kitchen Utensils (high MP) (insoluble) • Cooking Utensils (high MP) (insoluble) • Toys (hard, high tensile strength) • Building materials (hard, high tensile strength) • Garbage bins (hard, high tensile strength) • Wheelie bins (hard, high tensile strength)

- As a result of these **properties and the readily available uses**, Polystyrene, PVC, LDPE and HDPE have become and **integral part of today's commercial and plastics industries**. They are crucial to everyday life.

Factors that effect properties:

- The above unique properties all come from **structures**, nameley the following factors:
 - Length of chain
 - A longer chain leads to more dispersion forces and thus higher tensile strength
 - Arrangement of chains
 - Less chain branching --> Easier packing --> Higher density>> Stronger, harder more brittle
 - Functional groups
 - Polar functional groups (OH, NH2) will increase the dipole-dipole forces, leading to increased hardness
 - Addition of a bigger side group e.g. CH3 , Cl, C5H6 restricts the mobility of chain, makes chain rigid
 - Crosslinking
 - Sulfur bonds between chains, leading to rigid and difficult to melt polymers
 - Additives
 - Improve, extend or change properties
 - E.g. plasticiser is added to PVC
 - Plasticiser can also act as softeners, stabilisers , colour changes or flame resistance

Identify data, plan and perform a first-hand investigation to compare the reactivities of appropriate alkenes with the corresponding alkanes in bromine water

- In this experiment you are comparing an alkene to it's corresponding alkane
- We use either Cyclohexene - Cyclohexane or Hexene - Hexane
- This is because both of them are relatively safe for laboratory use
- I suggest studying the hexene and hexene as their equations are much simpler than the cyclo ones.

Risk assessment:

Identify	Assess	Control
Bromine Water	Toxic upon all routes of exposure	<ul style="list-style-type: none"> • Wear safety glasses and gloves • Perform experiment in a fume cupboard • Use small quantities of chemicals • Avoid Inhalation
Hexene and Hexane	Highly flammable, Toxic upo all routes of exposure	<ul style="list-style-type: none"> • Wear safety glasses and gloves • Perform experiment in a fume cupboard • Use small quantities of chemicals • Avoid Inhalation • Avoid Open flames

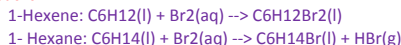
Procedure:

1. Place two clean and dry small test tubes in a test-tube rack.
2. Add 20 drops of bromine water to each tube. Note the initial colour.
3. To the first tube add 20 drops of cyclohexane. Stopper the tube with a rubber bung.
4. Using a new dropper, add to the second tube 20 drops of cyclohexene. Stopper the tube.
5. Gently shape each tube to mix the chemicals. Place the tubes back into the rack and allow the layers to separate. If decolourisation has not occurred fully in the second tube then you may need to add more cyclohexene.
6. Repeat this experiment with hexene and 1-hexene and determine whether the decolourisation of bromine occurs only with the alkene.

Substance	Observation
1 – Hexene	The Bromine water quickly went from brown to colorless, layer of Bromine on top
Hexane	The Bromine water slowly went brown to slightly lighter brown, layer of bromine on top
Cyclohexene	The Bromine water quickly went from brown to colorless layer of bromine on top
Cyclohexane	The Bromine water slowly went from brown to slightly lighter brown, layer of bromine on top

- So Generally unsaturated hydrocarbons (alkenes) will decolourise bromine water
- On the under hand, saturated hydrocarbons (alkanes) will have no reaction

Equations:



Note: You do not need to do both hexene-hexane and cyclohexene-cyclohexane, in the exam I suggest to do the non-cyclo ones as the equations are much easier to remember

Note: It is the **BROMINE WATER** that changes colour, not the alkanes and alkenes themselves.

Note: The experiment should be performed in the **absence of UV light** as this declourises bromine water, effecting the results possibly providing false results

Analyse information from secondary sources such as computer simulations, molecular model kits or multimedia resources to model the polymerisation process

The same Student molymod set (the stupid ball and sticks thing)

Benefits:

- Physical representation of the type and quantity of atoms involved
- Demonstrates the difference between various bonds
- Provides a simple representation to help understanding, someone may understand the simplified model better then the theory.
- Hands on, some people are hands on learners

Limitations:

- Relative sizes, and distances between atoms are unrealistic
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Risks (wtf? I know right...):

- Swallowing small items can be hazardous and can cause choking which may be life threatening. Exhaust caution, do not put near mouth.
- Falling or tripping on model balls can lead to serious injuries. Do not leave models on floor.
- Damage to eyes from the models. Exhaust caution when handling the models, do not approach face.

Scientific terms for this focus point

Term	Meaning
Ethylene	2 Carbon Alkene

Ethane	2 Carbon Alkane
Cracking	Breaking of longer chain hydrocarbons into shorter chain more useful hydrocarbons *catalytic or thermal
Fractions of Petroleum	Components that make up petroleum
High reactivity	Likely to combine with together
Alkenes	C _n H _{2n} has double bond
Alkane	C _n H _{2n+2} has no double bond
Hydrocarbons	Chain of hydrogen +carbon
Octane	8 Carbon alkane, used for fuel
Functional groups	Part of a compound that gives it it's function. I.e. ethanol has the "OH" group.
Addition	Adding of atoms into a molecule with nothing lost
Substitution	Swapping one atom for another i.e. creating vinyl chloride, swapping hydrogen for chlorine
Zeolite catalyst	Used in catalytic cracking
Bromination	Adding bromine into molecules i.e. in the bromine water experiment
Hydration	Adding of water molecules
Styrene (ethylene benzene)	Monomer of ethene, one hydrogen substituted for benzene
VinylChloride (chloroethene)	Monomer of ethene, one hydrogen substituted for Chloride.
Addition polymer	Joining together of monomers without a loss
Polyethylene	Ethylene monomers joint together
High density Polyethelyene	PE that is straight
Low density Polyethelyene	PE that is ranched
Linear Polymer	Straight polymer
Branched Polymer	Polymer with branches
Metallocene catalyst	Helps produce HDPE
Peroxide radical	Starts production of LDPE

*Focus Point 2 - Materials from Biomass

Discuss the need for alternative sources of the compounds presently obtained from the petrochemical industry

- Crude oil is a non renewable resource. (it is produced by high pressures and temperatures over millions of years)
- Modern petrochemical industry and the common society has a huge dependence on the hydrocarbons which are extracted and refined from crude oil. (i.e. ethene)
- From each fraction, we obtain essential fuels lubricants and hydrocarbons of which many are used in the production of polymers and plastics.
- As crude oil runs out of natural supply (non-renewable) scientists are pressured to think of alternative secondary source solutions.
- One solution of the future is the possible development of **using biomass (cellulose) to make ethanol or biopolymers.**

Scarcity / Finite supply of petroleum (limited):

- Alternate sources are required because the current production trends are unsustainable.
- Petrochemical products are derived from non-renewable sources of crude oil.
- Australia will run out of petroleum in 10 years. Thus we need to buy more and more foreign oil which will be more and more expensive.
- Experts place the lifespan of current petroleum sources at 50 year, and natural gas sources within 100 years.

Environmental impact:

- The consumption of fuel has an enormous impact on the environment (high Co₂ emissions).
- Potential fuels from biomass such as ethanol burns much more cleanly than the current relatively unclean petrol which causes environment problems such as the green house effect and acid rain.
- The biodegradability of many products also places strains on our landfills. Plastics which end up in the ocean and are not biodegradable can cause harm to marine life. When plastics such as plastic bags fall into the sea, they do not degrade and last a long time, poisoning the oceans and causing harm to aquatic life.
- These problems can be alleviated with alternate sources of compounds from the petro chemical industry. An alternative source of petrochemicals, such as using biomass can form biodegradable biopolymers.

Use available evidence to gather and present data from secondary sources and analyze progress in the recent development and use of a named biopolymer This analysis should name the specific enzyme(s) used or organism used to synthesis the material and an evaluation of the use or potential use of the polymer produced related to its properties.

Biopolymer is simply a polymer produced by biological substances i.e. enzymes.

Biopol:



Research
Task T4R

PLA:

- Patented in 1954.
- Commercially produced in the 1990s
- Ever increasing amounts produced
- Lactic acid is the monomer. (also occurs in our bodies)
- Polylactic acid is formed by a **condensation reaction**. Water molecules are lost when lactic acid monomers join together.
- Production:
 - First, corn is grown, starch is harvested from corn,
 - Next, Hydrolysis (adding water) to break the bonds in starch to form individual glucose molecules
 - Next, fermentation using either **lactobacillus bacteria** or Rhizopus fungi, this produces 2 lactic acid monomers
 - Next, condensation polymerisation of the lactic acids to form polylactic acid.

Advantages:

- Used for dinner ware, food wraps and other plastic equipment
- PLA has high tensile strength --> allows rigid plastic containers
- PLA has high flexibility and mouldability --> allows plastic bags and garbage bags. Garbage bags need to have high strength and flexible. (Due to the high load it carries)
- PLA is biodegradable --> PLA Garbage bags or food wraps will be broken down. Beneficial to environment, we won't have plastics lying around for thousands of years
- Renewable --> does not run out, grow more corn.

Properties / Uses:

Use	Property
Plastic Container	Rigid, High tensile strength, Durability
Garbage bags	Biodegradable, high tensile strength
Biomedical applications (drug delivery devices)	Biocompatible
Dinnerware	Rigid, High tensile strength, Durability

Limitations:

- High cost of production, however a cheaper production method has been developed (see below)
- Can not be used in plastic cups or coffee cups (melts)
- Use of corn starch --> more land is required, we also have a food shortage so we should use the land and corn for food. In the future it is possible to use food waste.

Future:

- In the future, PLA will be more viable due to lessening costs caused by increase in technology
- PLA will be more easily produced as we find ways for it to be produced from food waste.

Recent Developments:

- In 2009, A team of South Korean scientists and chemical company LG Chem Ltd. developed a new fermentation process
 - It enables polylactic acid polymers and copolymers to be produced in a **single-step direct fermentation process**.
 - Up until now, PLA has been produced using a two-step process of fermentation and chemical polymerization
 - The new process, uses a **metabolically engineered strain of E. coli**.
 - This makes PLA and lactate-containing copolymers **cheaper** and more **commercially viable**.
- Production of PLA and lactate-containing copolymers will become cheaper and more commercially viable through the new process

Evaluation: Currently we are limited by the high cost of production of PLA and its demand for land during production. However, should the se barriers be overcome, PLA has strong potential as it is environmentally friendly (biodegradable) and contains physical properties such as high tensile strength, flexibility and mouldability which are appropriate for creatin g materials (i.e. rubbish bags, dinner ware and food wraps) which are beneficial for human use. It is possible that this barrier will be overcome in then near future due to the 2009 development of single-step direct fermentation.

Explain what is meant by a condensation polymer.

- Monomers combine via a chemical process called condensation
- Monomers join up with the expulsion of small molecules. E.g. water
- E.g.. Cellulose, Polyamides (nylon), Polyesters (terylene) peptides, Starch, Kevlar, Polylactic acid



Describe the reaction involved when a condensation polymer is formed

- Small monomer molecules each release one or more atoms and the molecules join at that point. The released atoms combine to form a new compound.

Requirements for Condensation reactions:

- Monomers need to be present
- Hydroxide present (when condensing water) --> OH on every end of monomer, a OH group must be present at every end, or else they will not join to form polymers.
- Monomers must join at the OH group.

Describe the structure of cellulose and identify it as an example of a condensation polymer found as a major component of bio mass.

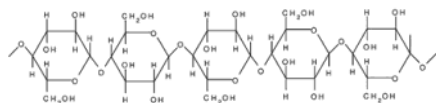
Criteria for biomass:

- For a substance to be considered biomass it must be:
 - Carbon based substance
 - Produced by plants via photosynthesis
 - Biomass is mostly cellulose + linen(wood). Cellulose makes up more than 50% of biomass.
- Thus cellulose fits the criteria of a biomass and is a major component of biomass.

Cellulose:

- Cellulose are polymers formed by beta glucose monomers. (alpha glucose monomers form starch)
- Cellulose is an **example of a condensation polymer** because water is lost during polymerisation
- Remember that the two main properties is that cellulose is **strong / tough** and it is **insoluble in water**
- I have split the notes into these two properties

Structure:



- Repeat units of beta-glucose
- In between every consecutive molecule, a OH hydroxyl group condenses out as a water molecule.
- This leaves a single oxygen linking the two monomers.
- The bonds between each beta-glucose monomer is called a **1,4 beta glycosidic bond** (1, 4 because they always connect on the first and fourth carbon)

Strength / toughness:

- **Alternating monomers are inverted** in the chain. This produces a reasonably linear (straight) molecule, increasing the density and strength of the molecule. Also allows tight packing because less space is needed.
- The formation of the glycosidic bonds between each monomer in alternating angles increases the stress limits of cellulose due to compression and contraction.
- Cellulose polymers line up side by side, this forms strong hydrogen bonds between them. The strong intra-molecular forces between the hydrogen bonding of the external hydroxy groups make cellulose particularly brittle and resistant to elastic forces. They hydrogen bonding allows the toughness for plant walls.

Insolubility in water:

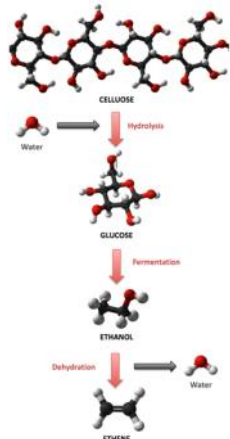
- There are less OH groups than the glucose monomers because OH groups have formed H₂O and have been lost (condensation polymer)
 - Cellulose is thus insoluble in water, (less OH groups). Important because cell walls made of cellulose need to have a good structure and thus should not dissolve in water
 - The OH groups between lines of cellulose are being occupied and this makes cellulose even less soluble.
- Hence due to these factors cellulose is an extremely strong biopolymer.

Identify that cellulose contains the basic carbon-chain structures needed to build petrochemicals and discuss its potential as a raw material.

Remember, Discuss means to argue the for and against, and then coming to a conclusion.

The long chain carbon structure of cellulose makes it a viable replacement for petroleum. It contains the **basic structures needed** to build petrochemicals such as ethanol and ethene. Using biomass such as cellulose, we can make the same petrochemicals (i.e. ethanol, PVC, PS, ethene) as we could using petroleum.

- The following diagram lists the steps which are required to convert cellulose to ethene



Advantages:

- Contains a basic carbon chain structure common to compounds found in petrochemical industry (i.e. can be used as a replacement)
- Readily abundant and renewable - We can just grow more and more.

- Easily produced - Modern bacterial production methods, e.g. E.coli, present many opportunities for the mass production of cellulose-based substances
- Cellulose is biodegradable - and can be used to develop biopolymers such as rayon, cellophane and cellulose acetate..
- It is the formation of ethanol and ethylene from cellulose that gives it the potential as a raw material in the production of petrochemicals.

Disadvantages:

- Currently not economically viable - The processes of converting cellulose to glucose through both acid digestion and enzyme digestion both require a high amount of energy. Due to the strong hydrogen bonds present.
- Distillation after fermentation also requires high energy and high costs
- This is due to the **STRONG hydrogen bonds** formed between water and ethanol
- Loss of arable land, If large areas of land were devoted to the growth of biomass for petrochemicals this would also cause environmental problems such as erosion and deforestation. Also takes up farming land
- Although food crops are readily available, their use would be unethical as many people do not have access to sufficient food reserves.
- Difficult to transport, has its own storage problems.
- Cellulose based biopolymers are relatively costly and are not widely applied.

Biomass to produce energy:

- This is not directly stated on the syllabus but has been asked in a hsc question (2003 question 20)
- Biomass can be used as an alternate source of energy
- This is used in electrical Generation
- If proper methods are developed, we can harness the large energy provided by biomass
- This will alleviate our dependence on the burning of fossil fuels and hence reduce greenhouse gases, an economical concern

Summary: Although the inability to convert cellulose to glucose in an economically viable manner does prevent its use as an alternative source for petrol chemical products and there is insufficient arable land to grow biomass, should these barriers be overcome cellulose has virtually unlimited potential given its abundance and chemical makeup.

Scientific terms for this focus point

Term	Meaning
Condensation reaction	Reaction that results in the loss of water
Condensation polymer	Joining of monomers with the loss of a small molecule
Functional group	Group that gives molecule its function, i.e. OH group
Cellulose	Component of plant cell walls
Biomass	Carbon containing plant products
Fossil Fuels	Energy derived from fossils
Petrochemicals	Chemicals derived from petroleum
Petroleum	Crude oil
Hydroxide	OH group
Amine group	NH ₂ Group
Biopolymer	Polymer produced by something biological e.g. enzymes of organisms
Poly(lactic Acid) (PLA)	Biopolymer made by bacteria
Lactic acid	Monomer of PLA
Lactobacillus bacteria	Bacteria that produces PLA
Fermentation:	Removal of CO ₂ using yeast / bacteria
Hydrolysis	Adding of water molecule
Lignin	Component that makes up wood
Glycosidic bond	Bond between 2 glucose molecules (1, 4, betaglycosidic bond)
Insoluble	Doesn't dissolve
Biodegradable	Degrades naturally

*Focus Point 3 - Ethanol

Describe the dehydration of ethanol to ethylene and identify the need for a catalyst in this process and the catalyst used.

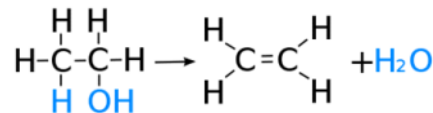
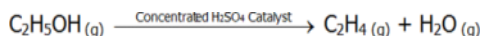
Dehydration: removing water molecules from a substance.

- Catalyst is needed or reaction won't start
- A catalyst lowers the activation energy required for a chemical reaction to take place by providing an alternate pathway for the reaction to occur.
- Catalyst: Concentrated sulfuric acid or Phosphoric acid (for purity) is used.
- A double bond is produced
- $C_2H_5OH(g) \rightarrow (Concentrated\ H_2SO_4)\ C_2H_4(g) + H_2O(g)$

Requirements:

- Dilute sulphuric acid (as a dehydrating agent)
- High temperatures

The dehydration of ethanol means the removal of a water molecule from the original ethanol molecule with the aid of a dehydrating catalyst. The catalyst most commonly used is concentrated sulphuric acid. (H₂SO₄) The dehydration process needs to occur at high temperatures. The acid acts as a **dehydrating agent** to remove the H₂O from the ethanol molecule.



Describe the addition of water to ethylene resulting in the production of ethanol and identify the need for a catalyst in this process and the catalyst used.

Hydration: The addition of water to a substance

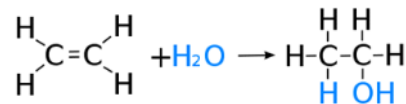
- Catalyst is needed or reaction won't start
- A catalyst lowers the activation energy required for a chemical reaction to take place by providing an alternate pathway for the reaction to occur.

The addition of a water molecule to ethylene is simply the opposite process above for the production of ethylene to ethanol. The use of diluted sulphuric acid is needed as it acts to **hydrate** the ethene which aids to break the double bond in ethylene to form ethanol and attach the water molecule.

Warning: Even though Conc H₂SO₄ is called a dehydrating agent, dilute H₂SO₄ is NOT called a hydrating agent. **There is no such thing as a "hydrating agent".**

Requirements:

- Dilute sulphuric acid (or any other substance that provides H⁺ ions)
- 300°Celsius
- Water



Process information from secondary sources such as molecular model kits, digital technologies or computer simulations to model the addition of water to ethylene and the dehydration to ethanol.

Student moly mod set (that stupid ball and stick thing, again)

Benefits:

- Physical representation of the type and quantity of atoms involved
- Demonstrates the difference between various bonds
- Provides a simple representation to help understanding, someone may understand the simplified model better than the theory.
- Hands on, some people are hands on learners

Limitations:

- Relative sizes, and distances between atoms are unrealistic
- Not complete, not full picture due to time restraints.
- The dynamic nature of various molecules and their bonds is not shown
- Over simplifies the model.

Risks (wtf? I know right...):

- Swallowing small items can be hazardous and can cause choking which may be life threatening. Exhaust caution, do not put near mouth.
- Falling or tripping on model balls can lead to serious injuries. Do not leave models on floor.
- Damage to eyes from the models. Exhaust caution when handling the models, do not approach face.

Process information from secondary sources to summarise the process involved in the industrial production of ethanol from sugar cane.



Research
Task T6R

Steps:

1. Sugar Cane is harvested
2. Sugar cane is crushed into either sucrose juice or bagasse (waste product, not needed)
3. Extraction of sucrose. Sucrose juice from the above step might be only 20% sucrose, in this step we extract the sucrose so it is mostly sucrose.
4. Now we have sucrose molasses (syrupy, quite thick)
5. Acid is added to sucrose molasses, this kills bacteria which can interfere with the fermentation process
6. Then the bacteria free sucrose molasses is placed in a fermentation chamber.
7. It is fermented using yeast (*Saccharomyces cerevisiae*), this turns sucrose into ethanol.
8. The above step produces 10-14% ethanol, this means the rest (86-90%) is water
9. Distillation is used to purify the ethanol (removes the water), which produces about 97% ethanol. Only 3% of water is left. Hydrogen bonds between water and ethanol
 - This process is expensive due to the strong hydrogen bonds
10. We then undergo dehydration to convert from 97% ethanol to 100% ethanol.

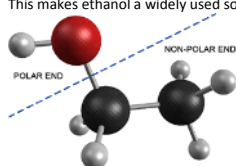
Summary: Harvest and crush sugar cane --> Ferment sucrose --> Distillation to 97% ethanol --> Dehydration to 100% ethanol

Describe and account for the many uses of ethanol as a solvent for polar and non-polar substances.

The structure of ethanol:

- Ethanol is a **liquid at room temperature**. This is a suitable property for it to be used as a solvent.
- Ethanol has many uses because it has **2 ends, 1 polar, 1 non polar**.

- **Polar:**
 - Slightly polar hydroxyl functional group OH allows ethanol to act as solvent for polar substances. Because electronegative species are able to dissolve in dipole-dipole interactions or through hydrogen bonding.
 - Since the hydrocarbon chain in ethanol is relatively short, the polar nature of the -OH group is still "visible" to other molecules. This makes the ethanol molecule polar overall, allowing its solubility in water.
- **Non Polar**
 - Dispersion forces in CH bonds combined with the hydrogen bonding present within the molecule serve to dissolve non polar substances.
 - The dispersion forces formed between the nonpolar end (hydrocarbon chain) and non polar substances allow nonpolar substances to be dissolved.
- Thus, ethanol is the second most important solvent after water. As it can dissolve both non polar and polar substances.
- This makes ethanol a widely used solvent and cleaning agent.



Ethanol as a solvent:

- Cosmetics (otherwise not soluble in water)
- Food coloring and flavorings (otherwise not soluble in water)
- Solvent-based paints, lacquers, inks, household cleaning products, external pharmaceuticals (rubbing alcohol) and perfumes.
- Medical preparations (otherwise not soluble in water)
- Cleaning agents (otherwise not soluble in water)
- Dissolves medicine that is non polar (which water can not) and thus allowing it to be taken as a liquid
- Dissolves ionic substances (polar) and water soluble substances (polar)

Outline the use of ethanol as a fuel and explain why it can be called a renewable resource

Production:

- In cornfields, corn is planted. Both the sugar part (yellow) and the cellulose part (leafy green) of corn can be used to make ethanol. We mainly use the sugar part to make ethanol
- Using CO₂, energy from the sun and water, the corn plants build sugar. (photosynthesis). Using fertilisers and pesticides and water we can grow the corn
- We then ferment the corn into 10-12% ethanol (rest is water)
- We then distill the 10-12% ethanol to 97-100% ethanol. (very little water left)

Use of Ethanol as a fuel:

- However, cars can not use a lot of ethanol or the engines will break. Current motors can accept 10-20 % mixture of ethanol mixed with petrol. We use a blend which is 10% ethanol and 90% unleaded (from petroleum - fossil fuels).
- When transport e.g. cars combust, it releases CO₂ and then it is used again. (see later for carbon neutral)
- Even though some countries use ethanol, its use is still limited due to its disadvantages (see later)
- For more use of ethanol see T7R

- Ethanol can be defined as a renewable resource because it can be produced as a waste product, naturally occurring from plants.
- Ethanol readily burns. Complete combustion. Due to the presence of an oxygen atom within each molecule. Less harmful byproducts are produced.
$$C_2H_6O + 3O_2 \Rightarrow 2CO_2 + 3H_2O + \text{Heat}$$
- Ethanol is easily transportable
- Ethanol has a heat of combustion of 1360 KJ / mol, giving a fairly high energy per mole output.
- Ethanol is renewable - fermented from glucose, sugar cane farming is an effective primary source used to produce ethanol.
- Thus ethanol has great potential
- See later for advantages and disadvantages of using ethanol as a fuel.

Identify the IUPAC nomenclature of straight-chained alkanols from C1 to C8

Stupid dot point, you should know this, or you are like.. Actually fucked. Legit.
General formula for alkanes: C_nH_{2n+2}, General formula for alkanols: C_nH_(2n+1)OH

Carbon Chain	IUPAC Name	Structural formula
--------------	------------	--------------------

C1	Methanol	CH ₃ OH
C2	Ethanol	C ₂ H ₅ OH
C3	Propanol	C ₃ H ₇ OH
C4	Butanol	C ₄ H ₉ OH
C5	Pentanol	C ₅ H ₁₁ OH
C6	Hexanol	C ₆ H ₁₃ OH
C7	Heptanol	C ₇ H ₁₅ OH
C8	Octanol	C ₈ H ₁₇ OH

Define the molar heat of combustion of a compound and calculate the value for ethanol from first -hand data.

Epic definition from crazy guy notes: The molar enthalpy of combustion of a chemical is the enthalpy change (energy released) when 1 mole of the chemical in its normal state at room temperature and pressure is burned in as much oxygen as needed for complete combustion. (you should remember this definition)

- $C_2H_5OH(l) + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O(l)$
- Ethanol's molar heat of combustion is -1367 KJ / Mol

Process information from secondary sources to summarise the use of ethanol as an alternative car fuel, evaluating the success of current usage.



Gary Liang -
Ethanol



T7R Use of
Ethanol

Assess the potential of ethanol as an alternative fuel and discuss the advantages and disadvantages of its use.

For more details check above T7R

Remember, Discuss means to argue the for and against, and then coming to a conclusion.

Advantages:

- Complete combustion (all converted to CO₂, no poisonous CO) much cleaner burning, less greenhouse gas. Environmentally beneficial.
- Renewable resource, corn can be grown. Fossil fuels will soon deplete but corn will not.
- Totally miscible with water. Any major spillages in rivers or oceans will not have an impact, but will simply dilute. Environmentally beneficial.
- Carbon neutral: Photosynthesis + Fermentation + Combustion reactions will result in a balance of carbon dioxide released. (see disadvantage for counter argument)
- Ethanol acts as a solvent. Thus washes away dirt or residue in pipes or storage containers. Makes engine last longer.
- Less volatile, less ready to explode
- Flash point is higher, less ready to explode



• **Carbon Neutral equations:**

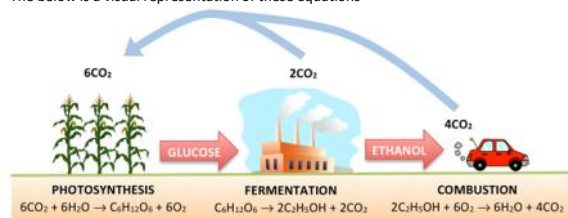
Photosynthesis: $6H_2O + 6CO_2 \Rightarrow C_6H_{12}O_6 + 6O_2$

Fermentation: $C_6H_{12}O_6 \Rightarrow 2C_2H_5OH + 2CO_2$

Combustion: $2C_2H_5OH + 6O_2 \Rightarrow 4CO_2 + 6H_2O$ (this equation has been multiplied by 2)

Input: 6CO₂, Output: 6CO₂

The below is a visual representation of these equations



Disadvantages:

- More expensive. Cost of production higher than petrol. Not economically viable yet.
- Smaller heat of combustion. This means that per liter of ethanol, there will be less energy produced compared to petroleum
- Uses farm land. We would have less land for food crops. We need more food for our growing population. Ethical issue
- Greater engine wear. modifications are required to cars if used in larger compositions than 20%
- Water usage, we need to use a lot of water to grow plants. Especially in Australia we are a dry continent, we must conserve water.
- Disposal of waste fermentation liquors. Waste disposal from the fermentation process can be difficult to keep within environmental regulations. Environmental issue.
- Even though ethanol is "carbon neutral" harvesting crops, fermentation, distillation of the product and transportation of it produces much greenhouse gases.

Assessment: (Summary/Judgement) Ethanol has high potential due to its cleaner burning, renewability, miscibility with water and it being carbon neutral. However, the use of ethanol is still currently impractical because of the demand for farm land, high costs in production and the wear ethanol produces on car engines. In the future it may be possible to use weeds and corn waste to produce ethanol which will decrease the price of ethanol and increase ethanol's potential as an alternate fuel. More research in these fields should be done before ethanol can be used widely as an alternative fuel. Ethanol's potential can be seen in Brazil where vehicles have achieved compatibility with 100% ethanol fuels. It is certainly a possible alternate fuel in the future.

Describe conditions under which fermentation of sugars is promoted.

"Promoted": helped or made to go faster

Fermentation of glucose: The process by which glucose is broken down to form ethanol and carbon dioxide. Several conditions must be satisfied in order for fermentation to successfully take place.

- Ethanol can also be used to make alcohol. Beer can be made from fermenting barley, wine can be made from fermenting grapes.

Ideal Conditions / "Promotion":

- Aqueous carbohydrates (glucose, starch, maltose or sucrose) solution. If a solid containing glucose is used, water must be added to form a solution. Chemical reactions only occur in solution.
- **Ideal** temperature of around 37 degrees Celsius.
Temperature Too high and the yeast / enzymes denatures, there will be no fermentation. Too low, the kinetic energy in the particles is too small and there will be very little successful collisions and thus no reaction.
- Yeast produces enzymes which makes sugars turn into ethanol faster. (Enzymes are biological catalysts)
- Anaerobic conditions, no oxygen. If oxygen is present, then the yeast will instead turn sugar into water. The ethanol produced will also react with oxygen to form vinegar. (acetic acid)

"Bonus conditions" (important but not always present, optional):

- Alcohol tolerant yeast present. alcohol tolerant yeast can go higher than 12-14 % alcohol.
- Slightly acidic conditions. Low PH prevents pathogens from growing and kills bacteria, which can otherwise turn ethanol into vinegar. Which makes our wine taste sour.

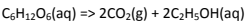


Summarise the chemistry of the fermentation process

Summary: Under the correct conditions for fermentation, any starch or sucrose present are first converted to glucose and/or fructose by enzymes. Fermentation can occur once glucose and/or fructose are present. In fermentation, the

glucose or fructose is converted to ethanol and carbon dioxide by certain enzymes found in yeast:

Fermentation of Glucose: The yeast included in the reaction secretes an enzyme complex known as zymase which catalyses the process of glycolysis, which refers to the conversion of glucose into ethanol and carbon dioxide. An ethanol percentage of 15% can be successfully produced, at which point the yeast will begin to die due to the concentration of ethanol and the reaction will halt. The resulting aqueous solution of ethanol needs to be distilled.

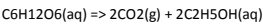


In the lab:



- Yeast is added to mashed grain and water.
- The yeast and other microbes break down the large carbohydrates (e.g. starch or sucrose) into simple sugars (glucose or fructose) which are then fermented.
- sucrose + water → glucose + fructose
- $C_{12}H_{22}O_{11}(aq) + H_2O(l) \rightarrow C_6H_{12}O_6(aq) + C_6H_{12}O_6(aq)$
- In an oxygen-free atmosphere, the yeast use their enzymes to break down the sugars, forming ethanol and CO_2 as products.
- $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$
- When ethanol concentration reaches 15%, the yeast die and fermentation STOPS.
- Distillation is used to obtain higher ethanol concentrations (95-100%).

Present information from secondary sources by writing a balanced equation for the fermentation of glucose to ethanol.



Task1A

Scientific terms for this focus point

Term	Meaning
IUPAC nomenclature	Way to name organic compounds
Straight chain alkanols	$C_nH_{2n+1}OH$ group
Dehydration	Removal of water
Ethanol	2 Carbon alcohol C_2H_5OH
Solvent	Substance that dissolves things
Non - Polar	Few or no possibilities for hydrogen bonding
Polar	Many possibilities for hydrogen bondings
Fermentation	Anaerobic respiration
Renewable	Can be remade
Alternative fuel	Non fossil fuel
Fossil fuel	Fuel / energy derived from petroleum / coal
Molar heat of combustion	Energy produced from combustion of one mole of fuel (see epic definition above)
Complete combustion	Enough oxygen. Only CO_2 is formed. Ethanol undergoes complete combustion
Incomplete combustion	Not enough oxygen CO is formed. CO is quite deadly
Carbon monoxide	Poisonous CO formed by incomplete combustion
Yeast	Biological organism used for fermentation
Enzyme	Biological catalyst. Biological means produced by something biological (enzymes are produced by yeast)
Zymase	Enzyme used for fermentation of glucose to ethanol.

***Focus Point 4 - Redox Reactions (electrochemistry)**

Explain the displacement of metals from solution in terms of transfer of electrons

Element state: In its natural state (no charge, or part of a compound)

Metal Displacement reaction: a reaction where metals are displaced from a solution, a transfer of electrons between a metal and a metal ion.

- This occurs due to the different relative activity of each metal.
- A metal converts the ions of another metal to a neutral atom. (element state)
- As one metal reacts and dissolves, one comes out of solution as a solid deposit.
- Metal displacement reactions are used to generate electricity
- Metal displacement reactions can be used to rank metals in order of their strength as reductants.

Observations during metal displacement:

- Colour fades (due to the loss of ions in solution and thus a less concentrated solution)
- Deposits forming (due to ions converting to solid metal in the element state)

Oxidation is the loss of electrons by a species

Reduction is the gain of electrons by a species.

The Oxidising agent (oxidant) oxidises the other thing

The reducing agent (reductant) reduces the other thing.

Metals generally behave as reductants. (Do not think this way though).

Identify the relationship between displacement of metal ions in solution by other metals to relative activity of metals.

- A more active metal will give away electrons (acts as anode)
- A less active metal will not give away electrons (acts as cathode)
- The **more reactive metal, X, will displace the other metal, Y.**
- This means the less active metal will deposit on the more active metal, electrons will transfer from the more reactive metal X, to the solution Y. Resulting in X becoming a positive ion in solution, and Y turning back into a metal atom.
- Using the fact that a more reactive metal will displace a less reactive metal, we can then conduct tests to rank metals in order of reactivity.
- How reactive a metal is can be measured as how easily it is oxidised. (aka, how strong of a reductant it is)

potassium	most reactive	K
sodium		Na
calcium		Ca
magnesium		Mg
aluminium		Al
carbon		C
zinc		Zn
iron		Fe
tin		Sn
lead		Pb
hydrogen		H
copper		Cu
silver		Ag
gold		Au
platinum	least reactive	Pt

- Oxidants:
 $Au^{3+} > Ag^+ > Cu^{2+} > H^+ > Pb^{2+} > Fe^{2+} > Zn^{2+} > Al^{3+} > Mg^{2+} > Na^+ > Ca^{2+} > K^+$

- Generally: Cations of inactive metals are strong oxidants, cations of active metals are weak oxidants.

Account for the changes in the oxidation state of species in terms of their loss or gain of electrons.

- Oxidation state:** theoretical number of electrons an atom has lost or gained
- Oxidation** is an **increase** in oxidation number, a loss of electrons
- Reduction** is a **reduction** in oxidation number, a gain of electrons
- Oil Rig:** Oxidation is loss, Reduction is gain. (in electrons)
- Changes in the oxidation state of a species can be accounted for in terms of an imagined loss or gain of electrons.
- Reduction and oxidation reactions occur **simultaneously**, rather than independently of each other.
- As such, the electrons lost by one species will be gained by the other.

Category	Oxidation state (OS)	Examples
elements (free)	0	Copper metal: OS(Cu) = 0, chlorine gas: OS(Cl) = 0
simple ions	charge on the ion	Cu ²⁺ ion: OS(Cu ²⁺) = +II, Cl ⁻ ion: OS(Cl ⁻) = -I
polyatomic ions	sum of the oxidation states of each element must sum to the charge on the ion	sulfate ion (SO ₄ ²⁻): OS(S) = +VI, OS(O) = -II, [(+VI)+4(-II)] = 2-
molecular compounds	sum of the oxidation states of each element must sum to zero	sulfur dioxide (SO ₂): OS(S) = +IV, OS(O) = -II, [(+IV)+2(-II)] = 0

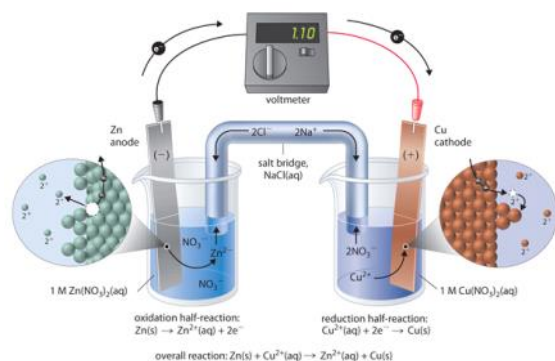
- Oxygen has an oxidation state of -2 unless in the form of peroxides where it is -1 and in F₂O (aka OF₂, oxygen difluoride) where it equals +2
- Hydrogen has an oxidation state of +1 unless in the form of metal hydride (-1) (e.g. AlH₃, aluminum hydride)

Describe and explain galvanic cells in terms of oxidation / reduction reactions.

Outline the construction of galvanic cells and trace the direction of electric flow

Define the term anode, cathode, electrode and electrolyte to describe galvanic cells.

THE ZN²⁺ SHOULD BE ZN²⁺ IN THE BELOW DIAGRAM



Redox reactions can generate electricity through separated oxidation and reduction reactions.

Galvanic cell: an arrangement of electrodes and electrolytes in which redox reaction cause a flow of electricity; also called an electrochemical cell

Half-cell: either the oxidation or reduction half of an electrochemical cell

Electrode: the metallic conducting plates of a galvanic cell

Anode: the electrode at which oxidation takes place. This electrode is negative in a galvanic cell

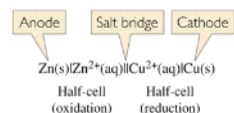
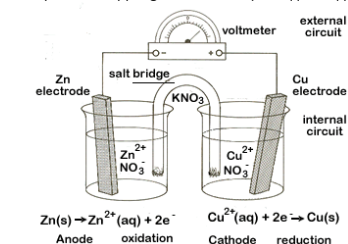
Cathode: the electrode at which reduction takes place. The electrode is positive in a galvanic cell.

Electrolyte: a substance that release ions when in solution or when melted and that carries an electric current.

Salt bridge: an electrolyte to electrolyte gel that joins two half-cells in a galvanic cell and allows movement of ions to maintain a balance of charges. Also called an ion bridge.

- Anode is the site of oxidation - loss of e-
- Cathode is the site of reduction - gain of e-
- I.e., **Electrons move from the anode to the cathode.** (Theoretically current moves in the opposite direction).
- We can write a simplified form of the galvanic cell

Example: Zinc Copper galvanic cell. Zn | Zn²⁺ || Cu²⁺ | Cu



How does it actually work? (using zinc and copper as an example):

- Electrons move from the zinc electrode towards the copper electrode
- This means that a zinc atom which lost the electrons would become a zinc ion (Zn²⁺)
- This ion will then fall into the electrolyte, but now there is an uneven distribution of charge within the electrolyte due to the extra Zn²⁺ ion
- Thus now the NO₃⁻ ions from the salt bridge will move into the electrolyte to balance the charges
- Meanwhile the electrons have hit the copper electrode, travelled to the bottom, and attracted a copper ion (Cu²⁺) which needs 2 electrons
- The copper ion grabs the 2 electrons and turns into copper metal, depositing on the copper electrode.
- However now there is an uneven distribution of charge within the electrolyte due to the loss of a copper ion (Cu²⁺).
- Now the K⁺ ion from the salt bridge will move into the electrolyte to balance this charge.
- The process repeats continuously
- If the salt bridge runs out of ions, the galvanic cell will stop working because the charges in the electrolytes can not be balanced.
- Eventually the large deposit on the electrode prevents the electrode to come in contact with the solution it is submerged in. When that happens the reaction stops and the battery dies.
- We can use the electrons which pass through the wire, make them pass through out devices. This is the electricity we use. E.g. the voltmeter

Solve problems and analyse information to calculate the potential requirement of electrochemical processes using tables of standard potentials and half equations.

Redox table - list of reduction potentials measured under standard conditions (25 °C, 1 atmosphere pressure, 1 mol/L solution)		REDUCING AGENTS (Reductants) (strongest reducing agent)
OXIDISING AGENTS (Oxidants) (weakest oxidising agent)		
$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li(s)}$	3.04 V	
$\text{K}^+ + \text{e}^- \rightleftharpoons \text{K(s)}$	-2.92 V	
$\text{Ba}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ba(s)}$	-2.90 V	
$\text{Ca}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ca(s)}$	-2.87 V	
$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na(s)}$	-2.71 V	
$\text{Hg}_2^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg(l)}$	0.26 V	
$\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al(s)}$	-1.66 V	
$\text{Cr}^{3+} + 3\text{e}^- \rightleftharpoons \text{Cr(s)}$	-0.75 V	
$\text{Fe}^{2+} + 2\text{e}^- \rightleftharpoons \text{Fe(s)}$	-0.44 V	
$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn(s)}$	-0.14 V	
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb(s)}$	0.13 V	
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77 V	
$\text{H}^+ + \text{e}^- \rightleftharpoons \frac{1}{2}\text{H}_2(\text{g})$	0.00 V	
$\frac{1}{2}\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O(l)}$	+1.23 V	
$\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu(s)}$	0.34 V	
$\frac{1}{2}\text{Cl}_2(\text{g}) + \text{e}^- \rightleftharpoons \text{Cl}^-$	0.54 V	
$\frac{1}{2}\text{I}_2(\text{s}) + \text{e}^- \rightleftharpoons \text{I}^-$	0.54 V	
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	0.77 V	
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag(s)}$	0.80 V	
$\frac{1}{2}\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}$	1.23 V	
$\frac{1}{2}\text{Cl}_2(\text{g}) + \text{e}^- \rightleftharpoons \text{Cl}^-$	1.35 V	
$\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1.51 V	
$\frac{1}{2}\text{F}_2(\text{g}) + \text{e}^- \rightleftharpoons \text{F}^-$	2.87 V	
The higher the reduction potential, (e.g. F_2), the more easily the substance is reduced (and thus the greater its oxidising power).		

Example: Zinc Copper galvanic cell. $\text{Zn}|\text{Zn}^{2+}||\text{Cu}^{2+}||\text{Cu}$

- $E^\circ_{\text{total}} = E^\circ_{\text{reduction}} + E^\circ_{\text{oxidation}}$
- The list of standard potentials is a list of **REDUCTION** potentials
- From list zinc is -0.76v, copper is 0.34v
- Zinc is **oxidised**, therefore the **OXIDATION** potential is - (-0.76)v = (+0.76v)
- Copper is being **reduced**, the **REDUCTION** potential from list is 0.34v
- Therefore the total potential is 0.34v+0.76v = 1.1v
- Short cut method, lower one on list minus higher one on list. I.e. Oxidant - Reducant. Ie Copper - Zinc, 0.34 - (-0.76) = 1.1 1.1v

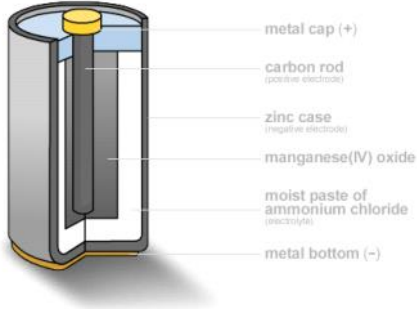
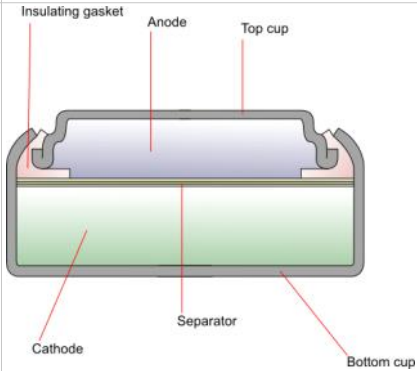
Full working:

- $E^\circ_{\text{total}} = E^\circ_{\text{reduction}} + E^\circ_{\text{oxidation}}$
 $= (\text{Cu}^{2+}|\text{Cu}) + (\text{Zn}|\text{Zn}^{2+})$
 $= 0.34 + 0.76$
 $= +1.1\text{v}$

Gather and present information on the structure and chemistry of a dry cell or lead acid cell and evaluate it in comparison with one of the following: button cell, fuel cell, vanadium redox cell, lithium cell, liquid junction photovoltaic device (eg the gratzel cell) in terms of : chemistry, cost and practicality, impact on society, environmental impact.

Study: http://support.radioshack.com/support_tutorials/batteries/bated-B01.htm

BE SURE TO LEARN EVERYTHING **ESPECIALLY THE HALF CELL EQUATIONS**

	The Dry Cell (Leclanche Cell)	Silver Oxide Cell
Diagram		
Anode (oxidation) Equation	<ul style="list-style-type: none"> Anode: Zinc casing Oxidation reaction: $\text{Zn(s)} \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$ 	<ul style="list-style-type: none"> Anode: Zinc (powdered) Oxidation reaction: $\text{Zn(s)} + 2\text{OH}^- \rightarrow \text{ZnO(s)} + \text{H}_2\text{O} + 2\text{e}^-$
Cathode (reduction) Equation	<ul style="list-style-type: none"> Cathode: Graphite (carbon) rod Reduction reaction: $2\text{NH}_4^+(\text{aq}) + 2\text{MnO}_2(\text{s}) + 2\text{e}^- \rightarrow \text{Mn}_2\text{O}_3(\text{s}) + \text{H}_2\text{O} + 2\text{NH}_3(\text{aq})$ Carbon / Manganese dioxide is reduced 	<ul style="list-style-type: none"> Cathode: Silver Oxide (paste) Reduction reaction: $\text{Ag}_2\text{O(s)} + \text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow 2\text{Ag(s)} + 2\text{OH}^-$
Electrolyte	Paste of ammonium chloride and zinc chloride	Potassium hydroxide KOH / Zn(OH)_2 (aq)
Uses of Cells	Torches, TV remotes, portable CD players, alarm clocks etc	Pacemakers, hearing aids, watches, small appliances
Relative Cost	Very cheap	Silver is an expensive metal, making the cell reasonably more expensive than dry cells.
Practicality	<ul style="list-style-type: none"> Readily available, e.g. in supermarkets. Can not be recharged, have a short life. Big and bulky compared to the button cell, however small and light compared to other batteries such as the lead-acid battery. 	<ul style="list-style-type: none"> Very small and light Relatively long life (A tiny button cell will keep a watch running 24 hours per day for 3 to 5 years.) Constant output voltage, allows for medical use such as pacemakers or hearing aids Non-rechargeable
Impact on environment	<ul style="list-style-type: none"> If used continuously, ammonia produced may expand and cause the cell to burst. The ammonia is dangerous to the environment if it ends up in waterways The batteries are non rechargeable, when they are thrown out they might end up in landfill 	<ul style="list-style-type: none"> Have to be discarded/recycled after one use Expensive silver must be recycled Potassium hydroxide electrolyte is caustic No highly toxic materials that will harm the environment
Impact on Society	<ul style="list-style-type: none"> Relatively small and light, can be used in portable appliances This is a great impact on society, e.g. portable radios can be readily available to be used anywhere which allows the communication of news. Relatively cheap, meaning the general society can afford 	<ul style="list-style-type: none"> Small size has allowed for miniature electric appliances Non-toxic nature has allowed for use inside the body Benefits society in it's medical uses such as hearing aids or peace makers
Extra Info	<p>Chemical Reaction: $2\text{MnO}_2 + 2\text{NH}_4\text{Cl} + \text{Zn} \rightarrow \text{ZnCl}_2 + 2\text{NH}_3 + \text{H}_2\text{O} + \text{Mn}_2\text{O}_3$</p> <p>Operating Temperature: 20° F to 130° F (-6° C to 54.4° C). Low temperature drastically reduces service capacity./</p> <p>Recommended for: Toys, radios, flashlights, amplifiers, and lighting.</p> <p>Initial Voltage: Varies</p> <p>Capacity: Lowest capacity of the primary battery types. These batteries do not have a standard capacity rating; see the Capacity heading for a full explanation.</p> <p>Discharge Rate: Sloping.</p>	<p>Type: Primary</p> <p>Chemical Reaction: $\text{Zn} + \text{Ag}_2\text{O} \xrightarrow{\text{KOH}} \text{ZnO} + 2\text{Ag}$ or $\text{Zn} + \text{Ag}_2\text{O} \xrightarrow{\text{NaOH}} \text{ZnO} + 2\text{Ag}$</p> <p>Operating Temperature: 32° F to 130° F (0° C to 54.4° C) with KOH electrolyte. NaOH electrolyte operates less well at low temperatures.</p> <p>Recommended for: Hearing aids, watches, calculators, photoelectric exposure meters, instruments, and pagers.</p> <p>Initial Voltage: 1.45 volts</p> <p>Capacity: Varies</p>

Internal Resistance	Very low; it increases with usage, storage or at low temperature.	Discharge Rate	Flat
Impedance	Low.	Internal Resistance	Low internal resistance. KOH electrolyte is lower than with NaOH electrolyte.
Storage Life	Up to 18 months	Impedance	Very low.
Storage Temperature	-40° F to 120° F (-40° C to 48.9° C)	Storage Life	Loses less than 10% after 5 years.
Disposal	Not recyclable; check with your local authority (city/county/parish) for proper disposal.	Storage Temperature	-40° F to 150° F (-40° to 60° C)
Source: < http://support.radioshack.com/support_tutorials/batteries/bt-cazi-main.htm >		Disposal	Not recyclable; check with your local authority (city/county/parish) for proper disposal.
		Source: < http://support.radioshack.com/support_tutorials/batteries/bt-siox-main.htm >	

Evaluation: Both batteries have it's advantages which allow it to be used for its purpose. The dry cell is relatively cheap and can be us ed in a wide range of everyday appliances, on the other hand the silver button cell produces a relatively long and stable current, it is also small, allowing it to be used in medical appliances such as pacemakers and hearing aids. Both batteries also have their disadvantages, the dry cell can not be recharged and does not last relatively long. On the other hand the silver button cell is relatively expensive. Thus it can be concluded that neither battery is better than t he other or can serve as a replacement for the other, both batteries have its disadvantages and advantages suitable for its purpose and both batteries have made a very large impact on society.

Scientific terms for this focus point:

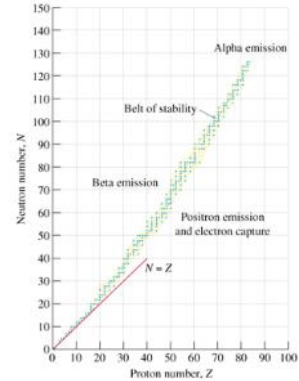
Term	Meaning
Displacement	Metal being replace by ion
Activity of metals	How likely a metal is to lose electrons
Oxidation state	Theoretical number of electrons a particle has gained or lost
Half - Equation	Equation at a half cell. I.e. Zn --> ZN2+ + 2e-, Cu2+ + 2e- --> Cu
Reduction	lowering o/f oxidation number, gain of electrons
Oxidation	Increase in oxidation number, loss of electrons
Oil Rig	Acronym, oxidation is loss, reduction is gain
Reduced	Same as reduction
Oxidised	Same as oxidation
Galvanic cell	an arrangement of electrodes and electrolytes in which redox reaction cause a flow of electricity; also called an electrochemical cell
Electrode	Conducting metal of galvanic cell
Anode	Electrode where oxidation occurs
Cathode	Electrode where reduction occurs
Salt bridge	Salt soaked paper that completes the circuit
Half-Cell	Electrode, electrolyte of one cell
Electrolyte	Solution of metal ions
Cell potential E°	How fast electrons flow (measured in voltage)
Reduction potential	Likelihood of an element to gain electrons (+)
Dry cell battery	AA or AAA battery
Button cell battery	Batteries used in watches, the small ones that look like buttons
Ion	Atom or gained or lost electrons
Element state	Neutral, no loss of gain of electrons. 0 oxidation number.

***Focus Point 5 - Nuclear Chemistry**

Distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable. (fix this when ms manolios hands back the 10 minute test)

Isotope: an atom with the same number of protons, but a different number of neutrons.
Radioactive isotopes: an unstable nucleus due to the particular number of neutrons they have

Stability of the isotope is related to the strength of the forces that hold the nucleus particles together.
Instability occurs if:
 The atomic number is greater then 82. (Z > lead)
 The neutron proton ratio lies outside the zone of stability.
Zone of stability: 1:1 (Z< and equals 20), 1.5:1 (Z 73-83)d



Property	Alpha	Beta	Gamma
Identity	helium nucleus	electron	gamma photon
Symbol	${}^4_2\text{He}$	${}^0_{-1}\text{e}$	γ
Charge	+2	-1	0
Mass	large	Small (negligible)	no mass
Pentrating Ability	stopped by a sheet of paper	stopped by a sheet of aluminium	stopped by a thick sheet of lead
Ionising Ability	high	medium	low
Example	${}^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^4_2\text{He}$	${}^{97}_{40}\text{Zr} \rightarrow {}^{97}_{41}\text{Nb} + {}^0_{-1}\text{e}$	${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^0_{-1}\text{e} + \gamma$
Nuclear Process	Two neutrons and two protons are ejected from the nucleus	A neutron is converted to a proton and electron and the electron is ejected from the nucleus.	Gamma decay usually accompanies beta decay and some of the excess energy of the nucleus is released as a gamma photon

Process information from secondary sources to describe recent discoveries of elements



Research
Task T15R

Not recent:

- The very first transuranic elements, Neptunium (Z=93) and Plutonium (Z=94) was discovered by Glenn Seaborg in the early 1940s (not recent though, dotpoint says recent)
- Glenn Seaborg and his team then continued to discover more transuranic elements between 1944 and 1953. Most between (Z95-101) were discovered by his team.
- The team found these at hydrogen bomb testing sites

More recent:

- Elements 102-109 were discovered post 1950s by ion accelerators. The reason they were discovered later was because they needed ion accelerators which were not invented before.

Most recent:

- Elements 110-118 are extremely short lived.
- We have named and discovered 110,111,112,114,116
- See research task T15R for details on each. **REMEMBER THE EQUATIONS AND HOW THEY ARE MADE.**

Describe how transuranic elements are produced

- Transuranic elements:** Elements above atomic number 92 (above uranium). These are all manmade elements.
- All transuranic elements are artificially produced
- The process of changing one element into another is called transmutation. The two main ways that a transuranic nuclei can be produced are by bombarding a nucleus with ions or neutrons. These ions or neutrons can be captured by the target nucleus and produce heavier nuclei.
- Produced by bombarding a certain nuclei with neutrons.
- Some isotopes will 'split' when hit by the neutrons in a process known as fission, while others will 'absorb' the neutrons, resulting in a larger atomic weight.
- All transuranic elements are radioactive.

Nuclear Reactor (Neutron bombardment and Alpha particle bombardment):

- A nuclear reactor can be used to produce elements 93-95. (they have a "long" half life, a few hours, compared to the other transuranic elements)
- There are two types of bombardments in a nuclear reactor, neutron bombardment and alpha particle bombardment.
- Neutron Bombardment (In nuclear reactor):
 - Produces the smaller transuranic elements
 - High speed neutrons hits target particle
 - Neutrons are slowed down with a moderator material, such as Boron
 - Some slow neutrons pass very close to the atomic nuclei and are captured.
 - Ed up with radioisotopes, too many neutrons to be stable.
 - I.e. $^{238}_{92}\text{U} + {}^1_0\text{n} \rightarrow {}^{239}_{92}\text{U} \rightarrow {}^{239}_{93}\text{NP} + \text{e}^-$
- Alpha particle Bombardment (in nuclear reactor):
 - Produces the smaller transuranic elements
 - Alpha particles move very fast to avoid change in direction.
 - Once it hits its target, the target will change.
 - High speed helium nucleus (4HE^+) hits target particle
 - I.e. $^{239}_{94}\text{Pu} + {}^4_2\text{He} \rightarrow {}^{242}_{96}\text{Cm} + {}^1_0\text{n}$

Particle Accelerator:

- Produces the larger transuranic elements
- Elements greater than $Z = 96$ are produced in a particle accelerator. They have a short half-life (milliseconds - 3seconds)
- High speed ion hits target particle. The ion almost reaches the speed of light.
- i.e. $^{64}_{28}\text{Ni} + {}^{209}_{83}\text{Bi} \rightarrow {}^{272}_{111}\text{Rg} + {}^1_0\text{n}$
- A particle accelerator has magnets on both sides. Electricity and magnetism both combine to speed up the particle, which hits a target at almost light speed.

Describe how commercial radioisotopes are produced

Commercial radioisotopes: The difference between commercial isotopes and transuranic isotopes is that transuranic isotopes have a shorter half-life and are useless, whilst commercial radioisotopes have longer half-lives and are extremely useful.

- While most commercial and medical radioisotopes are made in nuclear reactors, a few are made in smaller particle accelerators called cyclotrons or synchrotrons.
- Commercial radioisotopes usually have an atomic number below 84 (has a longer half-life, which means we have some time to use it)
- Neutron Bombardment is often used, often produced in a nuclear reactor
- e.g. $^{59}_{27}\text{Co} + {}^1_0\text{n} \rightarrow {}^{60}_{27}\text{Co}$ (production of cobalt-60, a commercial radioisotope)
- $^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + \text{e}^- + \text{gamma radiation}$ (the gamma radiation is used to check metals for flaws)
- Another example:
 $^{98}_{42}\text{Mo} + {}^1_0\text{n} \rightarrow {}^{99}_{42}\text{Mo}$ (production of technium-99, a commercial radioisotope used to scan for tumors)
 $^{99}_{42}\text{Mo} \rightarrow {}^{99}_{43}\text{Tc} + \text{e}^-$ (production of technium-99, a commercial radioisotope used to scan for tumors)
- Proton bombardment can be used
- e.g. Iodine-123 is produced by proton bombardment
- Sometimes alpha particle bombardment is also used.

Identify instruments and processes that can be used to detect radiation

- The dot point says Identify, so you **would not need this much information**
- There are many different ways of detecting radiation, radiation can be detected through the use of electronically or physically operated devices although ALL devices rely on the principle that radiation is ionising. Some devices can differentiate between radiation types some measure both amounts.

Instrument	Description	Diagram
Photographic Film:	<ul style="list-style-type: none"> Radiation will darken photographic film Photographic film can therefore be used to detect exposure With care, the film can be used to give a quantitative measure of activity. The greater the extent of exposure to the radiation, the darker the area of the developed negative. People who work with radioactive substances carry film badges to record the extent of their exposure to radiation. There are different thicknesses of observers, there are fast absorbing and slow absorbing films. So if the fast absorbing film changes color, there is a small dose, and if the slow absorbing film changes color it's a high dose. So not only does it detect radiation, it can only differentiate how much radiation is present 	
Cloud Chamber:	<ul style="list-style-type: none"> Instrument contains a super saturated vapor of water or alcohol When radiation passes through, it ionises some air, the ions formed act as nuclei upon which droplets of water form. This way the path of radiation is visible. I.e. the ionisation has led to condensation of alcohol in the air Alpha particles form straight dense tracks Beta particles form less dense zigzag tracks Gamma rays generate even fainter tracks This way, it is possible to determine the type of radiation the cloud chamber is being exposed to. 	
Geiger-Muller counter:	<ul style="list-style-type: none"> The operation of a Geiger counter is based on the ionisation of matter by radiation. Radiation causes argon atoms inside the GM tube to become ionised. The ions and electrons produced by the ionising radiation permit conduction of an electric current. The counter consists of a metal tube filled with gas. It has a cylinder that can be penetrated by radiation. In the centre of the tube is a wire connected to one terminal of a source of direct current. The metal cylinder is attached to the other terminal. Current flows between the wire and the metal cylinder when ions are produced by entering radiation. The current pulse created when radiation enters the tube is amplified; each pulse is counted as a measure of the amount of radiation. 	

	<ul style="list-style-type: none"> • "Click click click" 	
Scintillation counter:	<ul style="list-style-type: none"> • Works by the radiation striking a suitable material (such as Sodium Iodide), and producing a tiny flash of light. • This is amplified by a "photomultiplier tube" which results in a burst of electrons large enough to be detected. • Scintillation detectors form the basis of the hand-held instruments used to monitor contamination in nuclear power stations. • They can recognise the difference between a, b and g radiation, and make different noises (such as bleeps or clicks) accordingly. 	

Identify one use of a named radioisotope in industry and in medicine

Describe the way in which the above named industrial and medical radioisotopes are used and explain their use in terms of their chemical properties.

General uses for industry:

- Energy production (plutonium is used instead of coal)
- Detect flaws in metal objects
- Prevent food spoilage, gamma radiation can destroy pathogens
- Asses the thickness of steel
- Detect leaks in pipes

General uses for medicine:

- Often to do with detection of problems
- Detect cancer
- Detect thyroid disease (using iodine-123)/
- Detect blood disorders (using technetium-99m)
- Detect disease in vital organs. We can see if organs are still working at their best ability.

Named Industry:

- Cobalt-60 (Co-60) is used in a process called industrial radiography, to inspect metal parts and welds for defects.
 - Gamma radiation from Cobalt 60 passes through thick metals which gamma radiation should not be able to pass through
 - There is a film badge on the other side of the metal
 - However if there are flaws (holes) within the metal, then the film badge will change color
 - This tells us there are flaws because if flaws are not present, radiation would not be able to penetrate (due to the thickness of the metal) and thus no change in color.
 - This will tell us the metal is flawed and the extent of the flaw (from the extent of the darkening on the film badge, see above)
- Technetium-99m (Tc-99m) is used in the production of a wide range of biologically active chemicals

Named Medicine:

- Technetium-99m (Tc-99m) is used in a wide range of medical applications, such as pinpointing brain tumours, medical imaging of the body, detect the health of various organs and tracing blood flow.
 - Technetium-99m can be put in our circulation. It is a radioactive isotope so we can scan, trace where it is at any time.
 - If everything is normal, it will look like its flowing normally
 - If there are bumps or problems then the Technetium-99m will not be moving properly
- Cobalt-60 (Co-60) is used for cancer treatment and to sterilise surgical instruments.

Name	How it is used	Chemical property related to this use
Co-60 (Industrial)	<ul style="list-style-type: none"> • Beams of radiation from Co-60 (from decay) are directed at the object to be tested. • Radioactive film on the other side detects radiation when there are cracks or breaks. • Examining the film can help pinpoint structural problems. (see above for more details) • Prevent food spoilage 	<ul style="list-style-type: none"> • Gamma emitter, will penetrate metal parts. (see above) • Half-life of 5.3 years so it enables the equipment to have a long lifetime. • Cobalt 60 has properties similar to metals, so it can be moved around in a solid form, making detecting flaws a lot easier. • The gamma radiation can be actually used to kill pathogens
Co-60 (medical)	<ul style="list-style-type: none"> • Cancer treatment • Sterilise medical equipment 	<ul style="list-style-type: none"> • The gamma rays it produces emits enough energy to kill certain biological molecules, and has a suitable half life for this purpose. • The strong gamma radiation kills pathogens and bacteria.
Tc-99m (medical)	<ul style="list-style-type: none"> • Used for applications such as pinpointing brain tumours, by binding to haemoglobin in red blood cells therefore allowing blood flow to be monitored throughout the body. • Technetium-99m can be put in our circulation. It is a radioactive isotope so we can scan, trace where it is at any time. • If everything is normal, it will look like its flowing normally • If there are bumps or problems then the Technetium-99m will not be moving properly 	<ul style="list-style-type: none"> • Very short half life (6 hours), therefore minimises exposure to the body emits low energy gamma radiation which minimises tissue damage but can still be detected; it is quickly eliminated from the body. • Emits visible photons that produce good scanning image (allows the scanning of bodies), We can see the organs clearly. • The gamma radiation is quite weak. This means it is non deadly. Good property for medical use, otherwise we would die. • Flows well in circulatory system, allows us to check our bloodstream. • Forms compounds, which allows clear images when scanning
Tc-99m (industrial)	<ul style="list-style-type: none"> • Production of a wide range of biologically active chemicals. 	<ul style="list-style-type: none"> • Can be changed to a number of oxidation states

Use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine.



Research
Task T16R

Name	Benefits	Problems
Radioisotopes in general	<ul style="list-style-type: none"> • Detection of disease, e.g. cancer (early detection is vital) • Dating of fossils for paleontology, which allows us to estimate the age of the earth • Tracing, used to find out problems in organs • Detection of leaks in pipes, can detect holes we may not be visible • Industrial benefits include the ability to make monitoring equipment that is more sensitive, precise and reliable than previously possible. It allows for more efficient processes (such as sterilisation and food irradiation) and previously impossible things (examining faults in construction and machinery) • Medical benefits include a new wide range of non-invasive diagnostic techniques that would not be possible on sensitive organs • Radiation therapy is also a greatly positive new treatment. 	<ul style="list-style-type: none"> • Health problems, radiation is harmful to the body • Nuclear waste, there is no way of disposing safely and lasts thousands of years. Waste is placed in shielded containers, we dump them into the sea which may lead to harm in marine life. • Chance of nuclear meltdown • Nuclear technicians and other workers must be continually protected and avoid any form of irradiation, as disease such as cancer or radiation poisoning can result from this.
Co-60	<ul style="list-style-type: none"> • Can be used for cancer therapy • Cost effective due to long half-life (5 years) 	<ul style="list-style-type: none"> • Radiation is harmful to the body
Tc-99m	<ul style="list-style-type: none"> • The big advantage of technetium-99m (half-life six hours) is that it is produced by decay from the much longer lived isotope molybdenum-99 (half-life 67 hours). • This means molybdenum-99 can be stored in the hospital and the technetium-99m isolated for patient use when necessary. 	<ul style="list-style-type: none"> • The tracer procedure produces waste in the form of technetium-99 (the ground or unexcited state of technetium-99m) which has to be immobilised to prevent harm to the environment.

• Technetium-99m is a good isotope to use as a radioactive tracer because it doesn't harm the body too much, and the single gamma ray it emits enables doctors to get a very good picture of where the isotope is in the body.

The short half life means that they can not be easily transported long distances. Thus most places/hospitals need to have their own particle accelerators

Scientific terms for this focus point

Term	Meaning
Isotopes	Version of element with different number of neutrons
Radioactive isotopes	Too high / low ratio of P:N , unstable, can emit radiation
Nucleus	Center of atom , protons + neutrons
Atomic number	Z, number of protons
Atomic mass	Mass of atom , Protons + neutrons, the mass of electrons are negligible
Gamma - Ray	Release of energy
Alpha - radiation	Release of He nucleus
Beta - radiation	Change of N into P + release of electron
Radiation	Accompanies decay of radioisotopes
Geiger meter / counter	Radiation detection through ionisation of argon
Film badge	Detect beta and gamma radiation
Cloud chamber	Detects radiation (see notes)
Neutron bombardment	High speed neutron
Alpha bombardment	High speed helium nuclei
Ion / particle accelerators	Causes collisions of 2 ions at close to the speed of light, achieved through the combination of electric fields and magnetic fields
Transuranic elements	Elements with Z greater than 92, greater than uranium. All artificial , manmade
Cobalt 60	Radioisotope used to detect flaws in metal objects
Technetium 99m	Radioisotope used to detect disease in organs
Half - life	Time it takes for half the molecules of a radioisotope to have decayed
Industry	Area of manufacture and trade
Medicine	Area of health and disease

Introduction

Remember: These notes are NOT complete. There are still a few bits missing and have not been edited.

I have managed to compile up notes from a huge range of different sources (at least 20 different places), I have made my notes as detailed yet concise as possible. Unfortunately I can not disclose the sources where my information is from but please trust me in that they are valid and reliable. However, I did not just copy and paste from different sources. I rewrote almost everything based on a variety of sources to give the best possible answer to each dotpoint in the syllabus. I did copy and paste images, I am not an artist.

-Scott Zhou

Contextual Outline

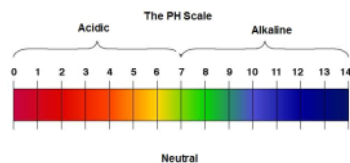
Acidic and basic environments exist everywhere. The human body has a slightly acidic skin surface to assist in disease control and digestion occurs in both acidic and basic environments to assist the breakdown of the biopolymers constituting food. Indeed, microorganisms found in the digestive system are well adapted to acidic or basic environments.

Many industries use acidic and basic compounds for a wide range of purposes and these compounds are found in daily use within the home. Because of this, an awareness of the properties of acids and bases is important for safe handling of materials. Currently, concerns exist about the increased release of acidic and basic substances into the environment and the impact of these substances on the environment and the organisms within those environments.

This module increases students' understanding of the history, nature and practice of chemistry, the applications and uses of chemistry and implications of chemistry for society and the environment.

*Focus Point 1 - Indicators

Classify common substances as acidic basic or neutral



pH: pH is a measure of the activity of the (solvated) hydrogen ion

- pH is **NOT** a measure of acid concentration
- pH is **NOT** a measure of acid strength
- pH is a measure of **hydrogen ion concentration**, which can be affected by **BOTH** of the above

Acidic:

- High concentrations of hydrogen ions (H^+),
- $pH < 7$
- Sour taste
- Stings / burns on skin
- Conducts electricity in solution
- Will corrode metal
- Turns blue litmus paper red
- Releases H^+ ions into solution
- e.g. $HCl(g) \rightarrow H^+ + Cl^-$

Neutral:

- $pH 7$ (around 6-8)
- Neutral taste
- No real harmful effect
- Does not conduct electricity
- Does not change color of litmus paper

Basic:

- Low concentration of Hydrogen ions (H^+)
- $pH > 7$
- Bitter taste
- Soapy/slippery feel
- Can irritate eyes (e.g. getting shampoo into your eyes)
- Stronger concentrations can also give a burning sensation when in contact with skin
- Conducts electricity in solution
- Turns red litmus paper blue
- Release OH^- ions into solution
- E.g. $NaOH(l) \rightarrow Na^+ + OH^-$

Words for classifying:

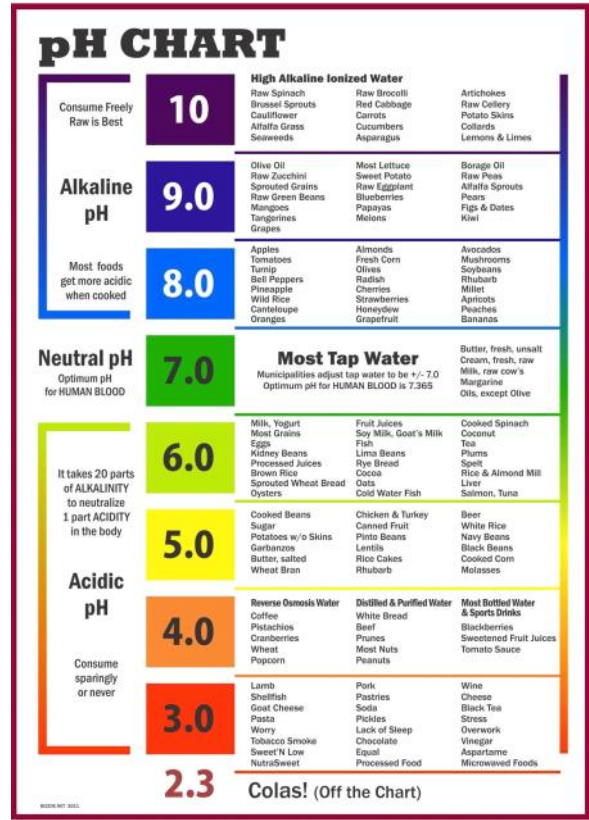
- Weakly: 8-10, 6-4
- Moderately: 10-12, 4-2
- Strongly: 12-14, 2-0

pH 0	Battery Acid
pH 1	Stomach Acid
pH 2	Lemon Juice, Vinegar
pH 3	Orange Juice, Soda, Some Dental Rinses
pH 4	Tomato Juice, Beer
pH 5	Black Coffee
pH 6	Saliva, Cow's Milk
pH 7	Pure Water
pH 8	Sea Water, pH-Neutralizing Dental Rinses
pH 9	Baking Soda
pH 10	Antacids
pH 11	Antacids, Dental Treatment Rinses
pH 12	Soapy Water

Common Substances:

Acidic	Neutral	Basic
Rain Water (pH 5-5.6)	Tap water (pH7)	Washing Soda (pH9)

Milk (pH 6-6.5)	Soap (pH7)	Ocean Water (pH8.5)
Neutral when fresh but bacteria breaks down things in milk to acidic. Bacteria forms lactic acid.	Soap is manufactured to be neutral so it is safe to touch	
Shampoo (pH 6-7)	Salt Solution	Lime (CaO) (pH9)
Soft Drink (pH6)	Sugar Solution	Lime water
Fruit Juice (pH6)	Pure alcohol	Antacid tablets
White Vinegar		Cloudy Ammonia (pH10) (cleaner)
Soda Water		Ammonia Solution
Lemon Juice		Baking Soda
Aspirin		Blood (pH7.4)
Vitamin C		Drain Cleaners (e.g. lye)
Car batteries		Oven Cleaner (pH12)
		Bleach



Common acids and bases:

Common Acid	Common Base
Hydrochloric acid HCl	Sodium hydroxide NaOH
Nitric acid HNO3	Potassium hydroxide KOH
Sulfuric acid H2SO4	Ammonium hydroxide NH4OH
Acetic acid CH3COOH	Barium hydroxide Ba(OH)2
Carbonic acid H2CO3	Calcium hydroxide Ca(OH)2

Identify that indicators such as litmus, phenolphthalein, methyl orange and bromothymol blue can be used to determine the acidic or basic nature of a material over a range, and that the range is identified by change in indicator colour

Acid-Base Indicator: A substance, when in solution, will changes color depending on the pH of the solution.

- Indicators can be either **natural** or **synthetic**
 - An indicator is a chemical compound that is added in small amounts to a solution so that the pH (acidity or basicity) of the solution can be determined visually.
 - Indicators are chemical detectors for hydrogen (hydronium) ions (H^+ / H_3O^+). Normally, the indicator causes the colour of the solution to change depending on the pH.
 - All pH indicators, such as litmus paper, change colours depending upon whether they donate or accept protons, (acids are proton donors and bases are proton acceptors). (see later for Bronsted-Lowry theory)
 - Therefore, pH indicators are themselves acids or bases.
- We use a **range of indicators** to figure out a substance because each indicator has their own uses. E.g. Phenolphthalein is only useful for showing how basic a substance is.
 - The indicators **only shows a range** of possible pHs, it will not be exact.
 - Generally, chemists would use a variety of indicators in conjunction with one another to work out a more accurate pH value for a substance.
 - Universal indicator is a mixture of many indicators and can give a more precise pH value.

Limitations of indicators (source: manolios):

- Only shows a range, not exact
- Destructive testing (partially destroy substance, reacted)
- If something already has color, then it is hard to tell what color the indicator is showing. A pH probe should be used. -alternatively, the solution being tested can be diluted until no color is visible, and then the indicator can be added

Range: Each indicator has a specific range

Indicator	Colour Change Range	pH Range	Colour Change
Methyl orange	Acidic	3.1 - 4.4	red to yellow
Bromothymol blue	Neutral	6.0 - 7.6	yellow to blue
Phenolphthalein	Basic	8.3 - 10.0	colourless to pink
Litmus paper	Neutral	5.0 - 8.0	red to blue

- A combination of these indicators have to be used in order to narrow down the range of the pH

Identify data and choose resources to gather information about the colour changes of a range of indicators (experiment)

How do indicators work? (not in syllabus):

- Indicators change color based on the equation
- $\text{Hind} \leftrightarrow \text{H}^+ + \text{Ind}^-$ (not in syllabus)
- Color 1 Color 2
- There is an acidic form of an indicator with one color, and an alkaline form of an indicator with another color
- Le Chatelier's principle can be used to explain the color changes of indicators
- Adding acids and bases will shift the equilibrium, according to Le Chatelier, one side of the equilibrium will be favoured
- This side favoured is a certain color. (above equation)
- The amount of indicator added is significant. Too little, the indicator is not concentrated and the color can not be seen
- Adding too much will lead to destructive testing, ie too much H^+ ions (check this)

pH Probe (not in syllabus)

- The pH probe actually measures voltage, it measures the conductivity of the solution
- The probe we used only has a single point calibration
- This means that the results will not be as accurate compared to a two point or three point calibration

Identify and describe some everyday uses of indicators including the testing of soil acidity/basicity

Dot point only says you need to know the "testing" of acidity / basicity, not the changing / monitoring of it.

Soil testing:

- Different plants only grow in certain pH values.
- Some flower colors are also determined by the pH of the soil
- Therefore the pH of soil must be monitored to ensure the successful growth of plants. (optimum growth)
- e.g. apple trees need a pH of 5.8-6.8 for optimum growth
- e.g. some need slightly basic soil and some need slightly acidic soil
- We use a soil testing kit, which has a range of indicators to make sure we have very fine measurements.
- Soil is collected and placed in the soil testing kit. Barium sulphate is added (in order for color change to not be masked by the soil color) The color change is then observed.
- This color is then compared to the color labels on the kit. The comparison allows to narrow the pH down to a certain range.
- Alternatively a pH probe can be used.
- We can use ground limestone to raise the pH of soil
- We can use some fertilisers (ammonium sulfate, urea and ammonium nitrate) to lower the pH. They create an acid reaction in the soil)
- To rapidly lower the pH. Sulfur is used. (sulfuric acid forms when sulfur is added to the soil)

Swimming pools:

- If the pH of the pool is too low, the metal of the pool will be attacked and thus the pool will break
- If the pH of the pool water is too high, the swimmers eyes will irritate
- A pH of around 7 is ideal, and thus we must check the pH of the pool water with indicators and appropriately monitor it.
- pH can be measured by taking a sample of water and testing with indicator solution or indicator paper
- We use Sodium hypochloride (NaOCl) added to pools to kill bacteria.
- However, NaOCl reacts with water forming hydroxides which increases the pH, making it more basic; $\text{NaOCl} + \text{H}_2\text{O} \rightarrow \text{Na}^+ + \text{HOCl} + \text{OH}^-$.
- This can irritate and sting eyes and
- Thus, dilute HCl is added to neutralise the OH^- . This neutralises the basic pool water.
- We use Phenol red indicator.
- If too low, Phenol red will turn yellow.
- If too high Phenol red will turn red-purple
- If it stays pink / orange then the pH is ideal (close to neutral)

Testing pH of industrial sewage:

- Industry often uses lots of bases and acids to make products
- The problem is that the sewage will go into the water supply.
- If the sewage waste water from the industrial plant is too high or too low, it can contaminate the water supply which causes harm to marine life.
- The waste water must also not be too acidic so that it will not corrode sinks, drains and sewerage pipes.
- The sewage from the industrial plant therefore, needs to have its pH monitored.
- It is ideal, the sewage waste water is neutral

Fish tanks:

- Fish can only survive in an optimal pH range, otherwise they would die
- Fish produce waste material, which affects the pH of the water.
- Thus the pH of water in fish tanks needs to be monitored and controlled
- There are test kits, which allow for pH monitoring
- Subsequently, chemicals can be added to control the pH.

Laboratory testing

- We use indicators in school labs and science labs
- E.g. in titration, pH indicators need to be used to see if something is basic or acidic. (see later for titration)
- In schools, it is also recommended that indicators are used to determine if chemical solutions are neutral before disposal down drains.

*Focus Point 2 - Acid oxides in the atmosphere

Identify oxides of non-metals which act as acids, and describe the conditions under which they act as acids.

Oxide: An oxide is a chemical compound that contains at least one oxygen atom and one other element in its chemical formula.

- e.g. substance A + Oxygen \rightarrow SubstanceAOxide
- Non-metals (excluding noble gases) produce acidic oxides
- The condition is that the nonmetal oxide reacts with water. (dissolves)
- This can be tested:
 - A soluble nonmetal oxide can be put into water to form hydrogen ions, we can then use a pH meter to test the acidity
 - A non soluble nonmetal oxide can be put into a strong base solution, this will form salt and water in a neutralisation reaction.
- Metals produce basic oxides
- This can be tested:
 - Soluble metal oxides + water will produce hydroxides (the metal gives off electrons to the water)
 - Non soluble metal oxides (basic) + HCl (acidic) will produce a salt and water in a neutralisation reaction

Common Acids:

- CO_2
- SO_3
- SO_2
- NO_2

Analyse the position of these non-metals in the Periodic Table and outline the relationship between position of elements in the Periodic Table and acidity/basicity of oxides

- Metal oxides are **mostly basic (when dissolved in water)**
- Metals tend to lose electrons, this means the electrons will be accepted by water and thus hydroxide ions are produced. (basic)
- **Non metal oxides are mostly acidic (when dissolved in water)**
- Non metals tend to gain electrons, producing hydrogen ions (acidic)
- Oxides of the five elements close to the borderline of metals and non-metals are **amphoteric**, they show both acidic and basic properties
- This is illustrated in the picture below

	1	2	13	14	15	16	17
2	Li ₂ O	BeO	B ₂ O ₃	CO ₂	N ₂ O ₃ N ₂ O ₅	O	OF ₂
3	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₃ P ₂ O ₅	SO ₂ SO ₃	Cl ₂ O ₇
4	K ₂ O	CaO	Ga ₂ O ₃	GeO ₂	As ₂ O ₃ As ₂ O ₅	SeO ₂ SeO ₃	Br ₂ O
5	Rb ₂ O	SrO	In ₂ O ₃	SnO ₂	Sb ₂ O ₃	TeO ₃	I ₂ O ₅
6	Cs ₂ O	BaO	Tl ₂ O ₃	PbO ₂	Bi ₂ O ₃	Po	At

basic oxide amphoteric oxide acidic oxide

- **Acids** become **stronger** towards the **top right** of the periodic table
- Generally, Acidity of oxides increase across the period (electronegativity increases across a period)
- Generally, Acidity of oxides decrease down a group (electronegativity decreases down a group)
- **Bases** become **stronger** towards the **left** of the periodic table
- Generally, Basicity of oxides decrease across the period (electro positivity decrease across a period)
- Generally, Basicity of oxides increase down a group (electrons are easily lost due to the size of the atom, less force holding the electrons)
- The basic trend in oxide acidity across the rows of the periodic table is: Basic → Amphoteric → Acidic

	1A (1)	2A (2)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1								
2	Li ₂ O	BeO	B ₂ O ₃	CO ₂	N ₂ O ₃ N ₂ O ₅	O	OF ₂	
3	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₃ P ₂ O ₅	SO ₂ SO ₃	Cl ₂ O ₇	
4	K ₂ O	CaO	Ga ₂ O ₃	GeO ₂	As ₂ O ₃ As ₂ O ₅	SeO ₂ SeO ₃	Br ₂ O	
5	Rb ₂ O	SrO	In ₂ O ₃	SnO ₂	Sb ₂ O ₃	TeO ₃	I ₂ O ₅	
6	Cs ₂ O	BaO	Tl ₂ O ₃	PbO ₂	Bi ₂ O ₃	PoO ₂		
7	Fr ₂ O	RaO						

Strongly basic Weakly basic Amphoteric Strongly acidic Moderately acidic Weakly acidic

Answering long response questions:

- If you are answering a long response question, then make sure you **use equations** to show whether oxides are acidic or basic
- e.g. $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$, this forms hydroxide ions, meaning sodium oxide is basic.
- e.g. $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3 + \text{O}_2 \rightarrow \text{H}_2\text{SO}_4$, meaning sulphur dioxide is acidic
- e.g. $\text{Al}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaAlO}_2 + \text{H}_2\text{O}$, this is an amphoteric acid acting as acidic
- e.g. $\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$, this is an amphoteric acid acting as basic
- Chose key equations to show there are weakly acidic strongly basic, amphoteric, weakly acidic, strongly acidic.

Amphoteric oxides:

- Oxides that can act as an acid or a base.
- These oxides react as acids when reacted with a base and act as bases when reacted with an acid.

Neutral oxides:

- Oxides which do not react with either acids or bases
- E.g. CO, N₂O, NO

Define Le Chatelier's principle

Reactions that go to completion: Non reversible reaction

Reversible reaction: A forward and backward reaction which can be reversed.

- A reversible reaction can reach **equilibrium**
- I.e. Carbon-dioxide + water \rightleftharpoons Carbonic acid (in soft drink).
- When the bottle is opened, the carbonic acid converts back into Carbon-dioxide and water. (the fizz that occurs is the CO₂)
- Reversible reactions can reach **dynamic equilibrium**
- **Dynamic** means that the reacts and products constantly convert to each other at the same speed (not static)
- I.e. **The rate of forward reaction = The rate of reverse reaction**

Requirements for dynamic equilibrium:

- Closed system (an open system will cause reaction to go to completion)
- Constant macro properties (gas pressure, temperature, color kept constant)
- Concentration of reactants and products are kept the same
- The forward and reverse reaction are equal (in terms of rate (speed))
- The only thing equal in equilibrium is the rate of reactions. Concentration of products and reactants is **NOT NECESSARILY the same**, rather the concentrations are not changing, constant.

Position of equilibrium: The proportion of products to reactants determines the position of equilibrium.

Consider: $\text{A} + \text{B} \rightleftharpoons 2\text{C} + \text{D}$

- The position of equilibrium lays to the left if the conversion of A and B into C and D is small.
- The position of equilibrium lays to the right if the conversion of A and B into C and D is large.
- Initially when 1 mole of A and 1 mole of B are mixed, the reaction proceeds quickly in the forward direction to produce 2 moles of C and 1 mole of D.
- As soon as C and D are produced, the reaction starts to proceed in the backward direction slowly at first but then speeds up as more C and D become available
- In this way the reaction goes backwards and forwards until equilibrium is established.
- It does not matter from which side (reactants or products) the equilibrium is approached - the position of equilibrium will always be the same.
- if the equilibrium favours the reactants rather than the products, this produces only a small amount of the desired product (a low yield).
- Le Chatelier worked out how to manipulate equilibrium systems to increase the yield (example is seen in esterification, but also in industrial chemistry)

Le Chatelier's principle:

- In 1885, the French chemist, Le Chatelier, put forward a principle for predicting the effect of change on reversible reactions:
- **In any chemical system in equilibrium is subjected to a change in pressure, volume, concentration or temperature, then the system will react in the direction to minimise that change**
- I.e. A system will be kept at equilibrium even if there is a **disturbance**
- Disturbances include a **change in temperature, pressure, volume and concentration**
- The system will go back to dynamic equilibrium (it does not reach equilibrium but minimises the disturbance)





(Random picture of him for lols)

In an exam:

- Write down the **equation**
- State what the **disturbance** is (i.e. adding more temperature or more concentration of reactant)
- Refer to **Le Chateliers principle** and equilibrium disturbed
- State that the system will oppose or **minimise the disturbance** / change
- State the **system reaction** (i.e. attempt to decrease temp, make more moles of gas)
- State the direction the system will thus react in, **where the equilibrium lies**. Refer to **equation**.
- If temperature question, mention **exothermic and endothermic** (forwards / backwards reaction).
- If pressure question, mention the **number of moles** on each side.
- State the **Results**. (thus more of ____ is produced, and less of ____)
- Refer to **rates of reaction** or **yield of products** if necessary.

Identify factors which can affect the equilibrium in a reversible reaction

Note: Favoring the forward/backward reaction means that the forward/backward reaction rate will increase. (react faster)

Concentration:

- When a substance is more concentrated in the reaction, the reaction will shift to reduce this concentration
- If the **reactants** are more concentrated, then the rate of **forward reaction** will increase
- If the **products** are more concentrated, then the rate of the **reverse reaction** will increase

Pressure:

NOTE: In an exam, **DO NOT** talk about volume, explain in terms of pressure. (unless asked otherwise)

- Volume is only used here so it is easier to understand, **DO NOT** use volume in an exam.
- When there is **more volume** in a system and thus **less pressure**, the reaction will shift to **spread out** into the new volume
- When there is **less volume** in a system and thus **more pressure**, the reaction will shift to **compact into** the new volume
- Consider $A+B \rightleftharpoons 2C + D$ (assume all are gases)
- If the volume is increased (pressure decreased), more molecules are required to fill up this space
- Thus a forward reaction is favored because this forms 3 moles of gas compared to 2 moles in a reverse reaction (**more moles = more space taken**)
- Similarly, if the volume is decreased (pressure increased), molecules need to fill up a smaller space and thus there should be less molecules
- Thus a reverse reaction is favored because this forms 2 moles of gas compared to 3 moles in a forward reaction (**less moles = less space taken**)

Temperature:

- Consider the reaction $A+B \rightleftharpoons C + D + \text{Heat}$
- The reaction is exothermic, meaning as A and B convert into C and D, heat is released, raising the temperature of the whole system
- If an **increase** of temperature was applied, Le Chateliers principle states that the system will try to **cool itself down**
- This is done by favoring the reverse reaction, as it is endothermic (the reverse of an exothermic reaction is endothermic, vice versa), the excess heat is absorbed and stored into chemical energy (the system is cooler now)
- If a **decrease** of temperature was applied, Le Chateliers principle states that the system will try to **warm itself up**
- This is done by favoring the forward reaction, as it is exothermic (the reverse of an exothermic reaction is endothermic, vice versa), the heat required is released from chemical energy as a reactant, in order to heat the system (the system is warmer now)

Remember: the ionisation of acids are exothermic, any dissolution of gas in water is exothermic

e.g. $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$ Delta H is negative

Solubility (adding salt)

- Some salts are more soluble than the reactants.
- Thus these compete over the reactants to dissolve in the water
- Thus there will be more un-dissolved reactants and less products
- According to Le Chateliers principle this will shift the reaction forward to increase the concentration of the products

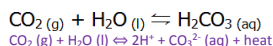
Catalyst:

- The equilibrium **DO NOT CHANGE** when a catalyst is added.
- When a catalyst is added, it **lowers the activation energy** for **both the forward and backward reactions**.
- Therefore the rate of reaction is **increased equally**, the **equilibrium DOES NOT SHIFT**.
- The **RATE** of reaction changes

Remember: If a system is NOT CLOSED, it will NEVER REACH EQUILIBRIUM

Describe the solubility of carbon dioxide in water under various conditions as an equilibrium process and explain in terms of Le Chatelier's principle

- A soft drink is a closed system which has reached dynamic equilibrium
- An example of this is coca cola



- The system will behave according to Le Chateliers principle
- We can describe the solubility of carbon dioxide in water with 3 main steps:
 - $CO_2(g) \rightleftharpoons CO_2(aq)$
 - $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$
 - $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$
 - $HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$
- As it can be seen, the last step produces **H⁺ ions** which makes the soft drink acidic.
- When soft drink is opened, (pressure released), CO_2 will be able to escape from the system. This results in less CO_2 molecules.
- This results a shift from right to left. (the reverse reaction), meaning more and more CO_2 will be formed and consequently released. (**degassed**)
- An equilibrium shift to the left or right in any of the equations above leads to a change in the concentration of the reactants and products in that reaction
- This influences the concentrations in the other three reactions causing the equilibrium in those reactions to also shift to the left or right respectively.
- If we increase the pressure, following the steps of the equation, the drink will be more acidic. (more H^+ ions released)
- If you add more soluble products then CO_2 , such as $NaCl$, then the salt will compete over the CO_2 to dissolve.
- Be careful, mass is also increased when $NaCl$ is added to the bottle.
- Increasing the concentration of water, has no direct effect on the equilibrium.

A warm contain of soft drink, when opened will be more bubbly

- This is because the equilibrium concentration of dissolved CO_2 is lower at a high temperature
- i.e. CO_2 is less soluble at higher temperatures
- Thus there is more CO_2 to escape.

Identify natural and industrial sources of sulfur dioxide and oxides of nitrogen

	SO ₂	NO	NO ₂	N ₂ O
Industrial	<ul style="list-style-type: none"> Burning of fossil fuels, the Sulphur in fossil fuels reacts with oxygen under high temperatures Use of a metal sulfide smelter 	<ul style="list-style-type: none"> Combustion chambers The high temperatures in combustion chambers breaks the bonds within N₂ and O₂ This allows the chemicals to react, forming NO 		
Natural	<ul style="list-style-type: none"> Geothermal Hot Springs The high temperature allows the formation of SO₂ 	<ul style="list-style-type: none"> Lightning Lightning strikes with sufficient amount of energy to break bonds within N₂ and O₂ This allows the chemicals to react, forming NO 	<ul style="list-style-type: none"> Forms from NO gradually reacting with O₂ in the air. 	<ul style="list-style-type: none"> Formed by bacteria from soil or ammonia containing soil fertilisers.

Describe, using equations, examples of chemical reactions which release sulfur dioxide and chemical reactions which release oxides of nitrogen

- In a metal sulfide smelter, the ore is heated in air and converts to a metal oxide, releasing sulfur dioxide.

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$
- When coal, petroleum or natural gas are burnt, sulfur in sulfur compounds is converted to sulfur dioxide.

$$S + O_2 \rightarrow SO_2$$
- Lightning strikes cause reaction between the two most common gases in the atmosphere.

$$N_2 + O_2 \rightarrow 2NO$$
- High temperature combustion reactions in furnaces and internal combustion engines produce significant amounts of NO [called nitrogen monoxide, nitric oxide or nitrogen(II) oxide] above 1300°C.

$$N_2 + O_2 \rightarrow 2NO$$
- Colourless, neutral nitrogen monoxide reacts with oxygen in the air to form brown, acidic nitrogen dioxide [nitrogen(IV) oxide].

$$2NO + O_2 \rightarrow 2NO_2$$

Assess the evidence which indicates increases in atmospheric concentration of oxides of sulfur and nitrogen

<<INSERT HERE research task>>

There is relatively little data that provides solid direct evidence for increases in concentration of sulfur dioxide and oxides of nitrogen, because it is hard to measure the concentration of gas in the entire atmosphere.

Some evidence includes:

Ice core Samples

Ice core samples from Antarctica provide a measure of atmospheric gases trapped in the ice over hundreds of years. These are able to show concentration of gases at different times of history, due to different amounts of gas absorbed.

Samples have shown the concentration of dinitrogen monoxide has increased by about 10%

Damage:

There is increased damage to infrastructure, forests and aquatic life, these provide indirect evidence of increasing acid rain. This means there is more sulfur dioxide and nitrogen oxides in the air. Examples would be the Black forest in Germany or the Taj Mahal in India.

There have been increased incidences of petrochemical smog, which has caused but the presence of nitrogen dioxide.

There are also higher atmospheric concentrations of these oxides in industrial areas than in non-industrial areas, suggesting that it is indeed industry causing emissions of these oxides.

Difficulties in obtaining evidence:

Sulphuric dioxide and the oxides of nitrogen are gases that are only present in small concentrations, and instruments capable of measuring these small concentrations have only been available since the 1970s

Sulfur dioxide and nitrogen dioxide form sulfate and nitrate ions, which are soluble in water. The validity of measurements can be questioned because they are easily dissolved in water.

Explain the formation and effects of acid rain

Formation:

- Acid rain is rain that has pH <5
- Acid Rain is formed non-metal oxides such as Sulfur dioxide, nitrogen dioxide and carbon dioxide dissolving
- Formation of carbonic acid - $CO_2(g) + H_2O \rightleftharpoons H_2CO_3(aq)$
- Formation of sulfurous acid - $SO_2(g) + H_2O \rightleftharpoons H_2SO_3(aq)$
- Formation of sulfuric acid from oxidation of sulfurous acid - $2H_2SO_3(aq) + O_2(g) \rightarrow 2H_2SO_4(aq)$
- Formation of nitrous acid and nitric acid - $2NO_2(g) + H_2O(l) \rightarrow HNO_2(aq) + HNO_3(aq)$
- Formation of nitric acid from the oxidation of nitrous acid - $2HNO_2(aq) + O_2 \rightarrow 2HNO_3(aq)$

Effects:

- Environmental damage:
 - Acid rain effects **plant growth**. It causes defoliation and stunted growth
 - Acid rain weakens trees and plant life by damaging their leaves. This loss of nutrients in their foliage makes trees more susceptible to damage by other environmental factors, particularly cold winter weather.
 - Acid rain flows to streams and rivers, directly into aquatic habitats. This decreases the pH of the water bodies which is directly harmful to **marine life**
 - Soluble compounds in nature become soluble in acid rain. E.g. $Al_2(SO_4)_3$, releasing toxic aluminum ions which are washed into lakes and streams, toxic to fish. Combined with the acidity of the rain, this can kill fish.
- Damage to human society:
 - Acid rain can cause damage to automobile coatings. This problem is not universal, effective protective coating exists.
 - Acid rain contributes to the **corrosion of metals** and the deterioration of paint and stone. This reduces the value of certain structures
 - Buildings made from **limestone**, e.g. statues, will be damaged as limestone is basic. The acidic rain undergoes a destructive neutralisation reaction with the basic limestone.
 - $CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$
 - $Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(s) + H_2(g)$

Analyse information from secondary sources to summarise the industrial origins of sulfur dioxide and oxides of nitrogen and evaluate reasons for concern about their release into the environment



Research
Task T5R

*Focus point 3 - Acids

Define acids as proton donors and describe the ionisation of acids in water

- An acid can be defined as a **proton donor**
- This is the **Lowry-Bronsted theory** (learn in next focus point)
- A proton is also a **hydrogen ion**
- When an acid molecule is placed in water, it can **ionise**, releasing a proton and forming a negative ion.
- The proton, H^+ , can attach to a water molecule, H_2O , forming what is called a hydrated hydrogen ion or hydronium ion, H_3O^+ .
- E.g. $HCl(g) + H_2O(l) \rightarrow H^+ + Cl^-$
- The hydrochloric acid is donating a hydrogen ion, or proton, to the water molecule.
- The donated hydrogen ion reacts with the water molecule to form the **hydronium ion** H_3O^+
- The above reaction can also be written as:
- $HCl(g) + H_2O(l) \rightarrow H_3O^+ + Cl^-$



Difference between dissociation and ionisation:

	Dissociation	Ionisation
Definition	Breaking of chemical bond Without reference to whether the products are ions or neutral fragments	Breaking of chemical bond Products are charged species (ions)
Force	Force from within atom	Force from outside atom
Ions present before?	Yes. Ionic compounds dissociate.	No. Covalent compounds ionise.
Need water?	Not Necessarily	Not Necessarily
Example	$NaCl \rightarrow Na + Cl^-$	$HCl \rightarrow H^+ + Cl^-$

Reason we do not write hydronium ion (been a past HSC question):

- The structure, such as the hydronium ion, is not important
- We want to focus on the proton donation part, the way it is written is adequate enough for a **simple description**.
- It is also **easier and simpler** sometimes to not write the hydronium ion.

Classifying acids:

- We can classify acids based on their **potential for proton donation per molecule**
- Monoprotic acids:** release one hydrogen ion per molecule
- Diprotic acids:** release two hydrogen ions per molecule
- Triprotic acids:** release three hydrogen ions per molecule
- This relates to the strength of the acids: monoprotic < diprotic < triprotic (see later for strength of acids)

Common ionisation equations:

- Hydrochloric acid: $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- Sulfuric acid: $H_2SO_4 + 2H_2O \rightarrow 2H_3O^+ + HSO_4^-$
- Ethanoic acid: $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$
- Citric acid: $C_6H_8O_7 + 3H_2O \rightleftharpoons C_6H_5O_7^{3-} + 3H_3O^+$

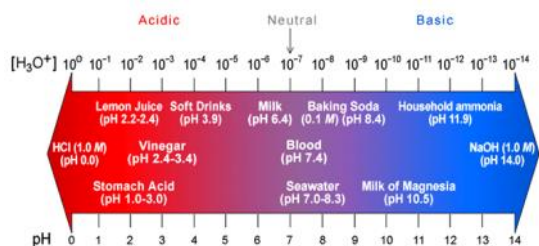
Identify acids including acetic (ethanoic), citric (2-hydroxypropane-1,2,3-tricarboxylic), hydrochloric and sulfuric acid

Systematic Name	Common Names	Ionisation Equation	Structural diagram	Relative Strength (ranked 1-4)
Hydrochloric Acid HCl	Muriatic acid	Monoprotic 100% ionisation $HCl + H_2O \rightarrow H_3O^+ + Cl^-$	H-Cl	2
Sulfuric Acid H ₂ SO ₄	Sulfuric Acid, Battery acid	Diprotic 100% ionisation $H_2SO_4 + 2H_2O \rightarrow 2H_3O^+ + HSO_4^-$		1
Ethanoic Acid CH ₃ COOH	Acetic Acid, Vinegar	Monoprotic 2% ionisation $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$		4
2-hydroxypropane-1,2,3-tricarboxylic acid (REMEMBER THIS) C ₆ H ₈ O ₇	Citric Acid C ₆ H ₈ O ₇	Triprotic 11% ionisation $C_6H_8O_7 + 3H_2O \rightleftharpoons C_6H_5O_7^{3-} + 3H_3O^+$		3

Describe the use of the pH scale in comparing acids and bases

Identify pH as $-\log_{10} [H^+]$ and explain that a change in pH of 1 means a ten-fold change in $[H^+]$

- The pH scale is a scale used by chemists in order to **compare the relative strengths** of acids or bases.
- pH uses a **logarithmic scale** to determine the concentration of hydrogen ions there are, given a substance.
- An **increase of 1 pH** corresponds to a **ten times less** in hydrogen ions
- Similarly, a **decrease of 1 pH** corresponds to a **ten times more** hydrogen ions
- pH can be defined as: $-\log_{10}(H^+)$
- E.g. pH of 7 indicates there are 10^{-7} hydronium ions in concentration within the solution.



Describe acids and their solutions with the appropriate use of the terms strong, weak, concentrated and dilute. Compare the relative strengths of equal concentrations of citric, acetic and hydrochloric acids and explain in terms of the degree of ionisation of their molecules.

Describe the difference between a strong and a weak acid in terms of an equilibrium between the intact molecule and its ions.

Strength:

- The strength of an acid is defined by the degree to which the covalent acid molecules are ionised when dissolved in water.
- This is known as the **degree of ionisation**.
- Strong acids ionise completely**.
- This means there are no intact molecules.
 - This is represented by the one way arrow in an equation \rightarrow .
 - Equilibrium lies to the **right**.
 - e.g. HCl , H_2SO_4 , HNO_3 , HBr , HI .
- Weak acids partially ionise in water**.
- This means there are more intact molecules than ions.
 - This is represented as the reversible arrow in an equation \leftrightarrow .
 - Equilibrium lies to the **left**.
 - e.g. CH_3COOH , $\text{C}_6\text{H}_8\text{O}_7$.
- Strength has **NOTHING** to do with concentration.

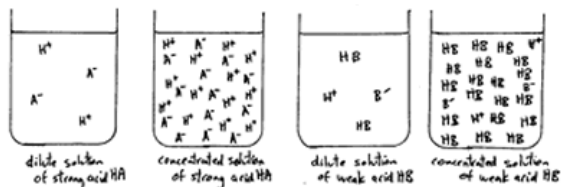
Acid	Chemical Formula	Classification	Percentage Ionisation (%)
Hydrochloric acid	HCl	Strong	100
Sulfuric acid	H_2SO_4	Strong	100
Nitric acid	HNO_3	Strong	100
Hydrogen sulfate ion	HSO_4^-	Weak	38
Phosphoric acid	H_3PO_4	Weak	32
Citric acid	$\text{C}_6\text{H}_8\text{O}_7$	Weak	11
Hydrofluoric acid	HF	Weak	8
Ethanoic acid	CH_3COOH	Weak	2
Dihydrogen phosphate ion	H_2PO_4^-	Weak	0.3
Carbonic acid	H_2CO_3	Weak	0.1
Hydrogen carbonate ion	HCO_3^-	Weak	0.003
Monohydrogen phosphate ion	HPO_4^{2-}	Weak	0.0002

Concentration:

- The concentration is the amount of the acid in the aqueous solution.
- For example, the amount of HCl in an aqueous solution (mixed with water).
- This can be represented by mol/L or M for short.
- 10m Hydrochloric acid is more concentrated than 0.1 M hydrochloric acid.
- Concentration has **NOTHING** to do with strength.

Visual representation

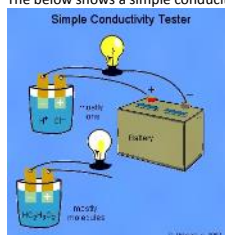
LEARN TO DRAW THESE



Note: A model MUST have a **KEY**.

Electrical conductivity:

- Electrical conductivity is related to the amount of ions.
- Thus Strong acids are stronger electrical conductors.
- Weak acids are weaker electrical conductors.
- The below shows a simple conductivity experiment (probably not on syllabus).



Note:

- pH is not a representation of strength of an acid, or concentration of an acid.
- Rather it is a measure of H^+ ions which is dependent on **BOTH** strength and concentration.
- Therefore just knowing the pH, we can not quantify the strength or concentration of an unknown acid.
- "Potency" (not a chemistry word) or danger or how much harm the acid can cause, is a **measure of H^+ ions**.
- This can be quantified with pH, and this is dependent on **BOTH** strength and concentration.

Why do we compare with equal concentrations?:

- pH is a measure of the concentration of hydrogen ions.
- This can be affected by either the strength of the acid or the concentration of the acid.
- Thus if we use the same concentration of acids, we can compare their **relative strengths**.

Gather and process information from secondary sources to explain the use of acids as food additives



Research
Task T10DP

Flavouring

- Acids taste sour
- This can be used to make foods taste sour
- Acids such as acetic or citric acid is added to food to make it sour

Nutrition

- Vitamin C (L-ascorbic acid), can be added to foods for nutrition purposes
- E.g. Vitamin C in oranges are added to mixed fruit juice for the nutrition

Perservatives

- Acids such as citric or ethanoic acids can act as preservatives.
- When added to food, they provide an acidic environment
- This environment is not suitable for the growth of microorganisms such as bacteria.
- Thus the food will last longer.

Anti-oxidants

- An antioxidant stops a substance from oxidising.
- E.g. Citric acid can be added to an apple, to stop it from oxidising with the air and turning brown.
- Ascorbic acid also acts as an antioxidant

Leavening agents

- Makes cake rise

Acid(s)	Foods	Purpose
Citric acid, tartaric acid	Jams	Provide a sharp taste
Citric acid	Canned and jarred foods	Antioxidant, preventing microbe growth
Fumaric acid, citric acid, phosphoric acid	Packaged biscuit and cake mixes	Leavening agents (react with sodium hydrogen carbonate to release carbon dioxide)
Acetic acid (vinegar)	Pickles and chutneys	Preserving agent
Phosphoric acid	Soft drinks	Provides a sharp taste

Identify data, gather and process information from secondary sources to identify examples of naturally occurring acids and bases and their chemical composition

<INSERT RESEARCH TASK HERE>>

Natural Acid	Produced by / used for:	Natural Bases	Produced by / Use for:
Hydrochloric Acid (HCl) (Gastric acid contains HCl)	Stomach Acid is used to digest food in stomach.	Ammonia (NH ₃)	Produced in some species of urine. Not in fresh urine
Citric Acid (2-hydroxypropane-1,2,3-tricarboxylic) (C ₆ H ₈ O ₇)	Naturally found in lemons, limes, oranges and other citrus fruits	Potassium Hydroxide (KOH)	Produced by leaching of certain wood ashes
Acetic Acid (CH ₃ COOH)	Produced when alcohol is mixed by bacteria	Calcium Carbonate (CaCO ₃) / Magnesium carbonate (MgCO ₃)	Found in limestone and dolomites
Lactic Acid (2-hydroxypropanoic acid) (C ₃ H ₆ O ₃).	produced within body by muscles. Also produced by bacteria in milk.		
Formic or methanoic acid (HCOOH):	Produced in the stings of ants and bee		

- You now understand why this topic is called the acidic environment and not the basic environment

Random Calculation Stuff

Equation:

pOH = -log[OH⁻]
pH = 14 - pOH
E.g.
11.9 = 14 - pOH
pOH = 2.1
[OH⁻] = 10^{-2.1}

How to derive it: (not in syllabus)

Ionisation of water:
H₂O ↔ H⁺ + OH⁻
K = [Products]/[Reactants]
K_w = [H⁺][OH⁻]
K_w = 10⁻⁷ × 10⁻⁷
= 10⁻¹⁴

Find pH of 0.1M NaOH
10⁻¹⁴ = -4 [H⁺][OH⁻]
[H⁺] = 10⁻¹⁴ / 0.1
= 10⁻¹³
pH = 13

*Focus point 4 - Theories / Conjugates / Buffers/ Titration

Outline the historical development of ideas about acids including those of:

- Lavoisier
- Davy
- Arrhenius

- It was first noticed that certain substances produced a sharp taste when placed on the tongue.

Timeline:

Person	Theory	Holes in theory (wrong)
Robert Boyle (not on syllabus but should know) 1661	<ul style="list-style-type: none"> • Came up with observations only, no theory. -Acids sour taste, bases bitter taste -Acids corrosive in nature -Acids and bases change colour of natural dye -Acids and bases neutralise to produce salts 	<ul style="list-style-type: none"> • No theory, just observations.
Antoine Lavoisier 1780s	<ul style="list-style-type: none"> • Found that non-metal oxides reacted with water forming acidic solutions. 	<p>Disadvantage:</p> <ul style="list-style-type: none"> • Why were metals of oxides not acidic? (if they have

	<ul style="list-style-type: none"> Concluded that an acid must contain oxygen. (Thought the above was linked to oxygen) He defined an acid as a non-metal compound containing oxygen. 	oxygen)
Humphry Davy 1815	<ul style="list-style-type: none"> Showed that hydrogen chloride had acidic properties and contained no oxygen This went against Lavoisier's theory (see above) Put HCL in water. $\text{HCL(g)} + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{Cl}^-$ $\text{H}^+ + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ Used electrolysis to pass through the solution (shown above) The hydrogen ions were electrolysed into hydrogen gas. (shown above) He observed that hydrogen was evolved when acids reacted with active metals such as magnesium. Leibic (Syllabus says Davy) redefined an acid as a substance that contained replaceable hydrogen atoms 	Disadvantage: <ul style="list-style-type: none"> Methane contains hydrogen. Why is it not acidic? (Answer: methane has no replaceable hydrogen)
Leibic	<ul style="list-style-type: none"> Redefined that an acid contains replaceable hydrogen 	Disadvantage: <ul style="list-style-type: none"> HSC does not acknowledge him.
Svante Arrhenius	<ul style="list-style-type: none"> Extended Davy's theory. Arrhenius looked at Davy's experiment, he conclude it was the electrolysis which produced the H_2 Gas. Arrhenius was saying hydrogen ions H^+ make things acidic, rather than H_2 Gas. Arrhenius proposed that: <ul style="list-style-type: none"> An acid produced hydrogen ions H^+ when dissolved in water. A base produced hydroxide ions OH^- when dissolved in water. NOTE: When talking arrhenius do not use the word "ionise", he said "disassociated". Benefits: <ul style="list-style-type: none"> This contributed to the pH scale, which used the concentration of hydrogen ions. It was arrhenius who came up with the relation between strength and ionisation He also explained that neutralisation can by a reaction between OH^- and H^+ ions. 	Disadvantage: <ul style="list-style-type: none"> Acid base reactions can occur without water. Arrhenius could not explain this. Could not explain why carbonates and metal oxides had basic properties and why some salt solutions could be acidic and basic. Exception: <ul style="list-style-type: none"> $\text{HCL(g)} + \text{NH}_3(\text{g}) \rightarrow \text{NH}_4\text{CL(s)}$ (Neutralisation reaction, but no hydroxides) Arrhenius can not explain this.

Example question:

H_2SO_4 , explain how the different scientists will call this an acid.

Lavoisier - has oxygen must be acid

Davy - $\text{H}_2\text{SO}_4 + \text{Mg} \rightarrow \text{H}_2(\text{g}) + \text{MgSO}_4(\text{aq})$ This is a replaceable hydrogen, thus acid

Arrhenius - Placed in water, $\text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ + \text{SO}_4^{2-}$ (forms H^+ ions must be acid)

Outline the Brønsted-Lowry theory of acids and bases

- The theory is based on **proton transfer**
- Independently outlined in 1923 by the Danish chemist, Johannes Bronsted, and the British chemist, Thomas Lowry.
- Acid is a **proton donor**
- Base is a **proton acceptor**
- If a substance has a greater tendency to donate protons than a particular solvent, then in that solvent it will be an acid.
- If a substance has a greater tendency to accept protons than a particular solvent, then in that solvent it will be a base.

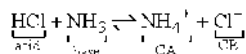
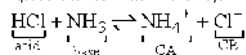


- In the diagram, HCl acts as a **Brønsted-Lowry acid** and water is acting as the base.

Describe the relationship between an acid and its conjugate base and a base and its conjugate acid

- Acids and bases must come in what are called **conjugate acid-base pairs**.
- After the **acid has lost** its proton it becomes a **conjugate base**.
- After the **base has accepted** the proton, it becomes an **conjugate acid**.

- To find the conjugate base of an acid, take away a hydrogen and - 1 to the charge
- To find the conjugate acid of a base, add a hydrogen and + 1 to the charge
- Equations can be written in two ways.



Self ionisation of water:



- Water is acting as both an acid and a base, forming a conjugate base and a conjugate acid
- Shows water's amphiprotic

Identify a range of salts which form acidic, basic or neutral solutions and explain their acidic, neutral or basic nature

Determining pH of salts:

- E.g. CH_3COONa
- 1. CH_3COO^- is derived from the weak acid CH_3COOH
- Na^+ is derived from a strong base NaOH
- $\text{CH}_3\text{COONa(s)} \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{Na}^+$
- CH_3COO^- is the conjugate of the weak acid and will react with water.
- Na^+ does not react with water
- 2. $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{CH}_3\text{COOH}$
- The presence of OH^- ions in solution will make this salt basic. The presence of CH_3COOH , a weak acid, will not significantly lower the

pH.

DO NOT write down these in an exam. But you can do it mentally:

- Weak acid + Strong base --> Basic salt + Water
- Strong acid + Weak base --> Acidic Salt + Water
- Strong acid + Strong base --> Neutral Salt + Water
- Weak acid + Weak base --> Neutral Salt + Water

Full worked example:

Identify conjugate acid/base pairs

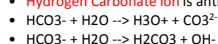
Common acids and conjugate bases:

Acid	Formula	Conjugate Base	Formula
Phosphoric Acid	H ₃ PO ₄	Dihydrogen Phosphate	H ₂ PO ₄ ⁻
Acetic Acid	CH ₃ COOH	Acetate	CH ₃ COO ⁻
Carbonic Acid	H ₂ CO ₃	Hydrogen Carbonate	HCO ₃ ⁻
Dihydrogen Sulfide	H ₂ S	Hydrogen Sulfide	HS ⁻
Hydrogen Sulfide	HSO ₃ ⁻	Sulfite	SO ₃ ²⁻
Dihydrogenphosphate	H ₂ PO ₄ ⁻	Hydrogen Phosphate	HPO ₄ ²⁻
Ammonium	NH ₄ ⁺	Ammonia	NH ₃
Hydrogen Carbonate	HCO ₃ ⁻	Carbonate	CO ₃ ²⁻

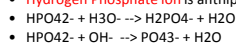
Identify amphiprotic substances and construct equations to describe their behaviour in acidic and basic solutions

- An Amphiprotic substance is one which can both **donate and accept a proton**
- This refers to the Bronsted-Lowry theory only.

- **Hydrogen Carbonate ion** is amphiprotic:



- **Hydrogen Phosphate ion** is amphiprotic:



- Water is also amphiprotic:
- $\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$ (self ionisation of water, see above)

Identify neutralisation as a proton transfer reaction which is exothermic

- Neutralisation is an **exothermic reaction**
 - Energy is released in neutralisation reactions
 - Delta H is negative
- The enthalpy change (ΔH) is approximately -57 kJ/mol,
 - Although this is dependant upon the strength of the acid and base, as well as the concentration of the solutions involved.
- The reason we use **dilute acids and bases** for neutralisation is to **minimise this energy released**.
 - Thus there will be less boiling and it will be **safer**
- E.g. $\text{HCl} + \text{NaOH} \rightarrow \text{Na} + \text{H}_2\text{O}$
 - The HCl is donating a proton to NaOH, forming neutral water
 - This is the **proton transfer**
- The net ionic equation for reaction is:
 $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ or
 $\text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}$

Describe the correct technique for conducting titrations and preparation of standard solutions

Perform a first-hand investigation and solve problems using titrations and including the preparation of standard solutions, and use available evidence to quantitatively and qualitatively describe the reaction between selected acids and bases

Overview:

Obtain primary standard --> Prepare primary standard solution --> Obtain / prepare stock solution of titration (of known concentration) --> Standardise stock solution with standard solution to produce 2ndary standard solution. (accurately known concentration) --> Use secondary standard as titrant to perform many titrations

NOTE: Make sure you know what is classified as **volumetric glassware** and what isn't.

Titration Terms:

Term	Meaning / Use
Titration	<ul style="list-style-type: none">• Also called volumetric analysis• Common laboratory method of quantitative chemical analysis.<ul style="list-style-type: none">- often used to determine the unknown concentration of an acid or a base using a neutralisation reaction.
Pipette	<ul style="list-style-type: none">• A volumetric glassware laboratory tool used to transport a measured volume of liquid.
Burette	<ul style="list-style-type: none">• A burette is a vertical cylindrical piece of laboratory volumetric glassware with a volumetric graduation etched permanently on its full length and a precision tap, or stopcock with plug and bore, on the bottom.
Titrate	<ul style="list-style-type: none">• The action of titrating (see titration above)
Aliquot	<ul style="list-style-type: none">• The known volume of one of the reactants, always placed in conical flask- The little bit in the flask
Titre	<ul style="list-style-type: none">• The volume of solution delivered from the burette that achieves an end point
Deliquescent	<ul style="list-style-type: none">• Unstable mass, absorbs water from the air
Titrant	<ul style="list-style-type: none">• The solution of known concentration
Equivalence Point	<ul style="list-style-type: none">• Point at which all the base and acids have reacted together
End Point	<ul style="list-style-type: none">• Point where indicator changes colour.- Could be different to equivalence point if wrong indicator is used
Standard Solution	<ul style="list-style-type: none">• A solution of known concentration
Primary Standard Solution	<p>A standard solution with the following requirements:</p> <ul style="list-style-type: none">• Obtainable in pure form, have a known formula/ formula mass (e.g. a compound)• Have a stable mass.<ul style="list-style-type: none">- If deliquescent like NaOH, then the mass is not stable.- Must not decompose on heating- Does not react with air- Carbon dioxide does not dissolve in substance- Not volatile• Relatively high formula mass- Weighing errors are minimised

	<ul style="list-style-type: none"> - Reduces error, increases accuracy • Solid, CAN FORM SOLUTION - Easily weighed, easily transported and soluble, can make a solution <p>Common examples: Na₂CO₃ (Anhydrous), H₂C₂O₄·2H₂O (Hydrated Oxalic Acid)</p> <p>The substance to make the primary standard solution is called the primary standard.</p>
Secondary Standard Solution	<ul style="list-style-type: none"> • A standard solution whose concentration has been accurately determined by titration against a primary standard (When titration is done) - Readily Available / Cheap
Distilled Water	
Desiccator	
"Rough" titration	
Indicator	<ul style="list-style-type: none"> • a substance that changes colour depending on the pH of a solution.

Preparation of Primary Standard:

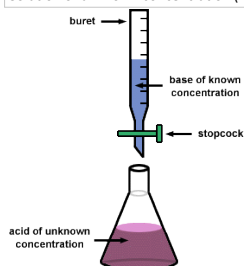
Equipment	Use	Picture
Pipette		
Small 50mL Beaker		
Electronic scales		
Funnel		
Distilled water		
Stopper		
Plastic pipette		
Wash bottle		
Sodium Carbonate or Hydrated Oxalic Acid Note: read requirements on right column	<ul style="list-style-type: none"> • Obtainable in pure form, have a known formula/ formula mass (e.g. a compound) • Have a stable mass. - If deliquescent like NaOH, then the mass is not stable. - Must not decompose on heating - Does not react with air - Carbon dioxide does not dissolve in substance - Not volatile • Relatively high formula mass - Weighing errors are minimised - Reduces error, increases accuracy • Solid - Easier to transport, easier to handle 	

Using Sodium Carbonate as an example

- Calculate the mass of substance required, which from now on we will assume is sodium carbonate.
 - For example, the preparation of 500mL of a 0.0500 mol/L standard solution of sodium carbonate:
 - $n(\text{Na}_2\text{CO}_3) = cv = 0.05 \times 0.5 = 0.025$
 - $n(\text{Na}_2\text{CO}_3) = \frac{m}{\text{FM}} \rightarrow m = 0.025 \times (2 \times 22.99 + 12.01 + 3 \times 16.00) = 2.650\text{g}$
- Heat the sodium carbonate in an oven at 270°C and cool in a desiccator.
 - This is to remove any traces of moisture which might be present.
- Clean equipment with distilled water and allow them to dry by themselves.
 - This is so that there is no contamination of other substances, including the paper used to dry it.
 - Tap water has dissolved salts that may affect the accuracy and validity of titration.
- Tare the small dry beaker on the electronic scales and then added the calculated mass of sodium carbonate.
- Dissolve the powder in distilled water and pour into the 500mL volumetric flask with a funnel.
- Wash the bottle and funnel with distilled water from wash bottle, pour into volumetric flask. Repeat this several times
 - This is to ensure complete transfer of the sodium carbonate into the volumetric flask.
- Add distilled water until the solution reaches the neck of the flask.
- Add distilled water using a plastic pipette, drop by drop, until the bottom of the meniscus reaches the calibrated mark.
 - This is to ensure accuracy, so that extra water is not accidentally added.
 - Avoid parallax error by looking at it level with the mark.
- Stopper the bottle and shake.
 - This is to ensure that the sodium carbonate is fully dissolved throughout the solution.

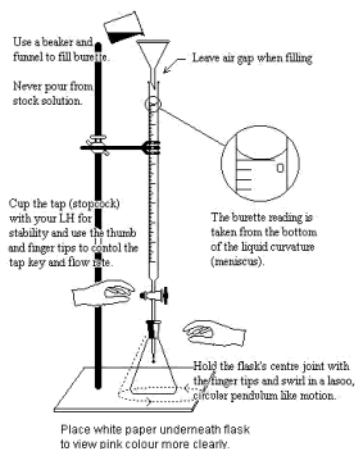
Preparation of Secondary Standard (titration):

Standard solution	
4 conical flasks	
Beaker	
Distilled water	
Pipette	
Burette	
Retort stand	
Funnel	
Burette Clamp	
Indicators (Methyl orange, phenolphthalein, bromothymol blue)	
Solution of unknown concentration (HCl)	



- Clean all equipment with distilled water.
 - Contamination from previous experiments with the equipment may affect the results.
- Rinse pipette with the sodium carbonate standard solution and burette with the HCl solution.
 - This can be done the other way around, depending on which is chosen as the titrant.
 - This is so that the concentrations of the solutions in the pipette and the burette are not diluted.
 - The conical flask does not need to be washed with solution, because this would change the number of moles.
- Transfer a 25mL aliquot (**the independent variable**) into a conical flask and repeat 4 times.
- Add three drops of methyl orange to each flask and swirl.
 - Methyl orange is chosen because the **equivalence point** lies in an acidic pH range.
 - The titration of a strong base and a strong acid has an equivalence point with a pH of 7.

- i. Bromothymol blue, because it changes colour from 6.0 to 7.6.
- The titration of a strong base and a weak acid has an equivalence point of pH > 7.
- i. Phenolphthalein, because it changes colour from 8.3 to 10.0.
- The titration of a weak base and a strong acid has an equivalence point of pH < 7.
- i. Methyl orange, because it changes colour from 3.1 to 4.4.
- The titration of a weak base and a weak acid has no clear equivalence point and is not performed.
- 5. Clamp burette to the retort stand.
- 6. Using a funnel, fill the burette with the hydrochloric acid, above the calibrated mark.
- 7. Open the tap and run acid into waste beaker until base of the meniscus is on the calibrated mark.
 - This is to ensure accuracy. Avoid parallax error.
 - Ensure that the acid has **filled the space below the tap** and that there are no bubbles.
- 8. Place conical flask underneath the burette and add acid slowly, swirling the flask, until a colour change occurs or the **end point** is reached.
 - This is to ensure that the solutions are fully mixed.
 - The reason for using conical flasks is because they can be swirled.
- 9. After the 'rough' titration, perform 3 more accurate titrations by releasing the acid drop by drop, recording the volume of acid required to reach end point (**the dependent variable**).
- 10. The average of the three accurate titrations is used to calculate the concentration of the acid.



Reliability:

- If the results are more than 0.1ml off each other, it is unreliable (quote from manolios)
- E.g. if the results were 13.1ml, 13.0ml and 13.3, the 13.3ml will be an outlier

Possible error:

- Forgot to use incubator,
- Cleaning with paper, not letting it dry itself
- Use wash bottle to fully transfer
- Clean everything with distilled water. Not water.
- Rinse pipette and burette and flask with correct solutions
- Chose the right indicator
- Make sure the standard solution goes up to the mark
- Ensure there are NO BUBBLES in the burette
- Make sure swirl conical flask properly

Example results table:

- Draw it like this in the exam

Results

	Rough	1st	2nd	3rd	Average
Initial volume (mL)	0	12	23.5	35	11.5
Final volume (mL)	12	23.5	35	46.5	
Titre (mL)	12	11.5	11.5	11.5	

Qualitatively describe the effect of buffers with reference to a specific example in a natural system

- Buffers are substances that resist change in pH.
- This is a solution of a **weak acid** and its **conjugate base**.
- Buffers are sensitive and only work within certain limits.
- If the influx of hydronium or hydroxide ions into a system is too large, the buffer will not be able to restore the pH.

Buffers in Blood:

- In our body, our **blood pH (7.4)** must be maintained.
- This is so enzymes can work at an optimum temperature (or else they denature)
- This is done by the $\text{H}_2\text{CO}_3/\text{HCO}_3^-$ buffer



- Explain the buffer with **LE CHATELIER'S PRINCIPLE**

Too acidic:

- When our blood is too acidic, there will be excess H_3O^+ ions.
- According to Le Chatelier's principle, the equilibrium will shift to the left to oppose the excess H_3O^+ ions
- This means the reverse reaction will be favoured, more H_2CO_3 will be formed and thus the excess H_3O^+ used up.
- Now there is no more excess H_3O^+ , meaning the pH will return back to normal (7.4)
- The excess H_2CO_3 , according to Le Chatelier in the top equation, will shift the equilibrium to the left.
- This means the reverse reaction is favored, more H_2CO_3 will be used up to form CO_2
- This means we breathe out more CO_2
- This is what happens when we huff and puff (during exercise)
- It is evident that the presence of the buffer solution has kept the pH constant

Too basic:

Buffers in freshwater lakes and rivers:

- The same $\text{H}_2\text{CO}_3/\text{HCO}_3^-$ buffer occurs in freshwater lakes and rivers
- This is only the case if there is a source of HCO_3^- , e.g. carbonate rocks

Buffer used in home swimming pool:

- The same $\text{H}_2\text{CO}_3/\text{HCO}_3^-$ buffer is used in home swimming pools
- Sodium hydrogen carbonate is added to increase the pools buffering capacity

Buffers in cells:

- The $\text{H}_2\text{PO}_4^-/\text{HPO}_4^{2-}$ buffer is used to maintain pH within cells.

Analyse information from secondary sources to assess the use of neutralisation reactions as a safety measure or to minimise damage in accidents or chemical spills

<<Insert Research Task>>

In the laboratory:

- When chemicals are spilt, it is important to neutralise them, because many acids and bases are **corrosive**.
- Sand or vermiculite should be added to isolate the acid or base in one place.
- We **DO NOT add water** to attempt to dilute the spill
- The water will react, in an **exothermic reaction** and this will cause **boiling**
- Never use strong or concentrated acids or bases to neutralise.
- This will also cause boiling, or even splattering

- When choosing an appropriate substance, the following must be considered:
 - speed of the reaction of neutralisation
 - The need for a reagent that has no harmful effects if excess is added
 - Safety in handling and storing the reagent
 - Cost of the reagent
 - The possibility for the reagent to be able to neutralise both acid and alkali spills

Sodium hydrogen carbonate:

- (sodium bicarbonate) is widely used to neutralise acid spills. This is because:
 - It is easily transported (unreactive white solid)
 - Safe to handle (unreactive)
 - Cheap
 - If too much is used, there is less danger from excess sodium hydroxide or lime (Calcium carbonate)
 - Amphiprotic (can both donate and accept protons, meaning it can neutralise both acid and basic spills)
 - Therefore, if the spill is unknown, adding Sodium Hydrogen carbonate would be good.

Neutralisation of an acid: $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{NaCl}$

Neutralisation of a base: $\text{NaHCO}_3 + \text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$

- Neutralisation reactions can also be used in sewers to make sure its effluences are neither acidic or basic.

*Focus point 5 - Esterification

Describe the differences between the alkanol and alkanolic acid functional groups in carbon compounds

Substance	Description	General Formula	Structural Formula
Alkaonl	An alkane which contains an OH (alcohol functional group) in place of a H.	$\text{C}_n\text{H}_{2n+1}\text{OH}$	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{C}-\text{O}-\text{H} \\ \\ \text{H} \end{array}$
Alkanoic Acid	An alkane containing -COOH group (carboxylic acid functional group) in place of 3 hydrogens.	$\text{C}_n\text{H}_{2n-1}\text{COOH}$ (CHECK THIS)	$\begin{array}{c} \text{O} \\ // \\ \text{R}-\text{C} \\ \backslash \\ \text{O}-\text{H} \end{array}$

Note: R is used to denote a carbon chain of any length

Functional group: An atom or a group of atoms that reacts in a characteristic way when in different carbon compounds.

Primary Alkaonl: Hydroxyl group attached to first carbon

Secondary Alkaonl: Hydroxyl group not attached to first carbon.

Difference between Alkaonl and Alcohol:

- An alkaonl is a subset of Alcohol
- Alcohol is a compound which contains OH group attached to a C atom that only has C or H atoms attached to it. (**But can have other branched out atoms**)
- Alkaonl must have **only OH C and H**
- E.g. $\text{CCl}_3\text{-CH}_2\text{-OH}$ is an alcohol because the main chain has only C and H, and it has an OH
- However it is not an alkaonl because it has Cl in it.

Identify the IUPAC nomenclature for describing the esters produced by reactions of straight-chained alkanolic acids from C1 to C8 and straight-chained primary alkanols from C1 to C8

No. Carbon Atoms	Alkanols		Alkanoic Acids	
	Name	Formula	Name	Formula
R	hydroxyl group	$\text{R-CH}_2\text{-OH}$	carboxyl group	R-COOH
1	methanol	$\text{CH}_3\text{-OH}$	methanoic acid	HCOOH
2	ethanol	$\text{CH}_3\text{-CH}_2\text{-OH}$	ethanoic acid	$\text{CH}_3\text{-COOH}$
3	propan-1-ol	$\text{CH}_3\text{-(CH}_2\text{)}_2\text{-OH}$	propanoic acid	$\text{CH}_3\text{-CH}_2\text{COOH}$
4	butan-1-ol	$\text{CH}_3\text{-(CH}_2\text{)}_3\text{-OH}$	butanoic acid	$\text{CH}_3\text{-(CH}_2\text{)}_2\text{-COOH}$
5	pentan-1-ol	$\text{CH}_3\text{-(CH}_2\text{)}_4\text{-OH}$	pentanoic acid	$\text{CH}_3\text{-(CH}_2\text{)}_3\text{-COOH}$
6	hexan-1-ol	$\text{CH}_3\text{-(CH}_2\text{)}_5\text{-OH}$	hexanoic acid	$\text{CH}_3\text{-(CH}_2\text{)}_4\text{-COOH}$
7	heptan-1-ol	$\text{CH}_3\text{-(CH}_2\text{)}_6\text{-OH}$	heptanoic acid	$\text{CH}_3\text{-(CH}_2\text{)}_5\text{-COOH}$
8	octan-1-ol	$\text{CH}_3\text{-(CH}_2\text{)}_7\text{-OH}$	octanoic acid	$\text{CH}_3\text{-(CH}_2\text{)}_6\text{-COOH}$

Explain the difference in melting point and boiling point caused by straight-chained alkanolic acid and straight-chained primary alkanol structures

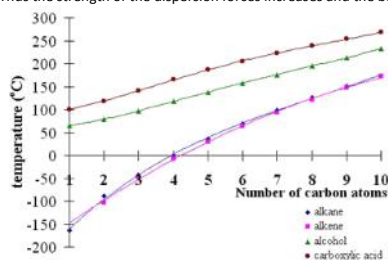
Physical Properties (not all on syllabus)

Esters are Volatile:

- E.g. in perfumes or fragrance sprays

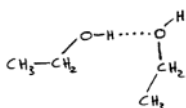
Boiling Point :

- Increasing with Chain length
- intermolecular dispersion forces increase with the number of electrons in a molecule.
- Thus the strength of the dispersion forces increases and the boiling point increases.



- (BP of Alkanoic Acid > BP of Alkanol > BP of Alkane)
- Alkanoic Acids and Alkanols both have hydrogen bonding between their molecules, whilst Alkanes just have dispersion forces
- There are more "places" where Alkanoic acid can form hydrogen bonding
- The presence of two hydrogen bonds per molecule accounts for the higher boiling point of the alkanoic acids.
- This is illustrated in the below diagrams (dotted lines represent hydrogen bonding)

Hydrogen Bonding in Alkanols:



Hydrogen Bonding in Alkanoic Acids

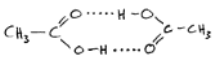


TABLE 5.7 Boiling points for alkanes, alkanols and alkanoic acids of similar molecular weights

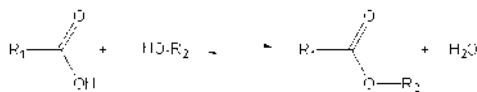
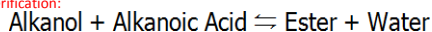
Molecular weights ^a	Alkane	Boiling point (°C)	Alkanol	Boiling point (°C)	Alkanoic acid	Boiling point (°C)
16	methane	-162				
30, 32	ethane	-89	methanol	65		
44, 46	propane	-42	ethanol	78	methanoic	100
58, 60	butane	-0.5	1-propanol	97	ethanoic	118
72, 74	pentane	36	1-butanol	117	propanoic	141
86, 88	hexane	69	1-pentanol	138	butanoic	164
100, 102	heptane	98	1-hexanol	157	pentanoic	186

Identify esterification as the reaction between an acid and an alkanol and describe, using equations, examples of esterification

Esters: sweet smelling chemical compounds usually derived by reacting an alkanoic acid with a hydroxyl compound such as an alkanol.

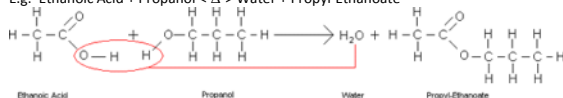
- Esters are **polar**, due to the presence of C=O and C-O bonds
- However, they are not strongly polar compared to the OH bonds.
- They **lack hydrogen bonding**.
- Thus they are **much less soluble** in water and have **low boiling points (volatile)**

Esterification:



- This is a **condensation reaction**. Water is condensed.
- This is an **equilibrium reaction**
- To name an Ester, simply add yl to whatever alkanol and oate to whatever alkanoic acid.
- E.g. Ethanol + Ethanoic acid is called Ethyl Ethanoate
- Note: Ethanoate is also referred to as acetate.
- The reaction requires a **H2SO4 catalyst** (not shown in diagram) (see later)
- All states of all reactants and products are **LIQUID, NOT AQUEOUS**.
- Draw a Δ on the double arrow to represent heating

E.g. Ethanoic Acid + Propanol <-Δ> Water + Propyl-Ethanoate



The hydroxyl group from the ethanoic acid and the hydrogen from the propanol are removed and they bond together to make a molecule of water.

- Note: The above diagram is false because there is no **double arrow**. Esterification is an **EQUILIBRIUM REACTION**
- The reaction requires a **H2SO4 catalyst (not shown in diagram)** (see below)
- All states of all reactants and products are **LIQUID, NOT AQUEOUS**.

Describe the purpose of using acid in esterification for catalysis

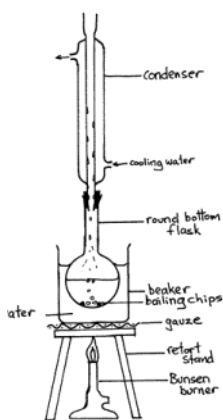
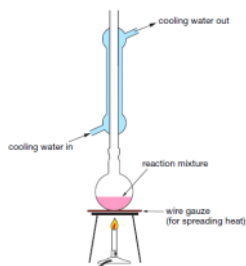
- Esterification is a **slow process** at room temperature, it is also an equilibrium reaction, it does not go to completion.
- To speed up reaction, **concentrated H2SO4** is used as a **catalyst**
- H2SO4, being a dehydrating agent, can also absorb water.
- According to Le Chatelier the system will try to oppose this change by producing more water
- Thus the equilibrium will shift to the right, producing more water and Ester, thus **we gain more yield**.
- Conc H2SO4 also acts as a catalyst, this **decreases the activation energy** of the reaction and thus **increases the rate of reaction**

Explain the need for refluxing during esterification

- **Refluxing:** The process of heating a reaction mixture in a vessel with a cooling condenser attached in order to prevent loss of any volatile reactant or product
- Refluxing refers to the process which involves **both** heating the system and using a condensor
- **Note:** Refluxing is not just using a condenser! The heating is also part of refluxing.
- Refluxing is used to :
 - prevent loss of **volatile** reactant or product (meaning, refluxing provides a closed system), this **MAINTAINS THE EQUILIBRIUM**
 - **Speed up** the reaction, as heating the reaction increases the kinetic energy of the particles, more **collisions** and faster reactions
- Thus reflux **improves the speed** of the experiment
- Reflux is necessary because it allows :
 - The reaction to proceed at high temperatures, **speeding it up**
 - Prevents the loss of volatile products (meaning, refluxing provides a closed system) and reacts, to **MAINTAIN THE EQUILIBRIUM**

Water Bath:

- The water bath is indeed safer because the reactants= and products are flammable
- However, the water bath can only achieve temperatures of 100 degrees Celsius
- This slower than the boiling point of the products
- This means the product will react in liquid form which is a lot slower



Note: DO NOT draw the diagram with a bunsen. Use a heating jacket or water bath.

Justification of process (past HSC Question):

Outline some examples of the occurrence, production and uses of esters

Examples of Esters:

Ester	Smell
Methyl butanoate	Pineapple
Ethyl methanoate	Raspberry
Propyl ethanoate	Pears
Pentyl ethanoate	Banana (52 bananas)
Pentyl pentanoate	Apple
Pentyl butanoate	Pear or Apricot
Octyl ethanoate	Orange (82 oranges)

- As evident in the table, many Esters have **distinct odours**
- This has led to their **widespread use** as **artificial flavoring** and **fragrances**

Production:

- Never use a flame because alkanols are flammable, use a water bath or a hotplate

Use

- Esters are used in artificial food flavouring and smells such as ice-cream, bubblegum,
- There are more than one ester in each fruit
- Thus, cheap artificial substances such as bubblegum does not smell or taste like the real fruit
- You can tell the difference if a substance has the real fruit in it rather than one ester.

Process information from secondary sources to identify and describe the uses of esters as flavours and perfumes in processed foods and cosmetics

<<Insert Research Task>>

Chemical Monitoring and Management

Thursday, 18 April 2013 2:11 PM

Introduction

Remember: These notes are NOT complete. There are still a few bits missing and have not been edited.

I have managed to compile up notes from a huge range of different sources (at least 20 different places), I have made my notes as detailed yet concise as possible. Unfortunately I can not disclose the sources where my information is from but please trust me in that they are valid and reliable. However, I did not just copy and paste from different sources. I rewrote almost everything based on a variety of sources to give the best possible answer to each dotpoint in the syllabus. I did copy and paste images, I am not an artist.

-Scott Zhou

*Focus Point 1 - Stupid focus point that is very short and common sense.

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

Note: Do **NOT** use a teacher. They have specified before, not a teacher.

General Information:

- There are numerous different **branches of chemistry**
- All chemists have basically fundamental understanding of chemistry.
 - e.g. Classification of matter, states of matter, solutions, energy effects
- Chemists **specialise** in their individual expertise.

General roles:

Research Chemist	Development Chemist	Production Chemist	Chemical Engineer	Quality control and quality analysis
Has in depth knowledge of theory Comes up with ideas and products	Produce safe industrial procedures Maximises production efficiency	Supervise production processes Makes sure processes comply with environmental regulations	Produces chemical equipment	Test substances (e.g. titration) to see if they meet standards. Feedback to development chemist.

General Branches:



Random analogy:



- The chemist in the back is a **developmental chemist**
 - E.g. designed nuclear power plant melt down procedures
- Homer, however is only supervising (supposed to be supervising), and is a **production chemist**
- Technically they both do physics, not chemistry.

Specific chemist in specific industry:

- See research task below (last dot point of this focus)

Role of Chemist	Named Industry (e.g. NSW EPA)	Branch of Chemistry	Principle used
Production Chemist	Boss polymer technologies	Polymer chemistry	Addition polymerisation

Note: Do **NOT** use a teacher. They have specified before, not a teacher.

- See research task (below)

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

- Scientists do not work alone
- They work in teams, they collaborate
 - Scientists only get funded for **publishing reports**, thus collaborating with people overseas or in the same country who work on the same project is important.

Collaboration

- Exchange of information and communication
- There are many types of branches and roles Thus one person can not possibly do everything.
- There needs to be collaboration and teamwork between chemists to ensure everything runs smoothly.
- No one is an expert at everything, collaborating makes it more efficient.
- Working together **reduces costs, sharing resources, helps funding**
- Collaboration (working in groups, having meetings) allows results to be achieved more **efficiently**

Example - Producing a new drug:

1. Research chemists researches the new drug.
2. The research chemist communicates with the developmental chemists.
3. The Developmental chemist comes up with the procedure to produce the drug
4. Production chemist overlooks production of the drug.
5. The production chemist communicates with the developmental chemist, if a procedure needs to be changed.

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

Need for monitoring:

- Efficiency, economical or environmental. Energy control
- Products formed may be toxic, or polluting. Pollution control.
- Certain conditions may change the **yield of the product**

Combustion of car fuels:

- We monitor the combustion of car fuels because:
 - Incomplete combustion causes **Carbon monoxide pollution**, which is poisonous
 - **More energy** is gained through complete combustion, compared to incomplete
- Complete combustion of Octane: $\text{C}_8\text{H}_{18} (\text{l}) + 25/2 \text{O}_2 (\text{g}) \Rightarrow 8\text{CO}_2 (\text{g}) + 9\text{H}_2\text{O} (\text{l})$
- Incomplete combustion of octane (not enough oxygen): $\text{C}_8\text{H}_{18} (\text{l}) + 17/2 \text{O}_2 (\text{g}) \Rightarrow 8\text{CO} (\text{g}) + 9\text{H}_2\text{O} (\text{l})$
- Incomplete combustion of octane (even less oxygen): $\text{C}_8\text{H}_{18} (\text{l}) + 9/2 \text{O}_2 (\text{g}) \Rightarrow 8\text{C} (\text{s}) + 9\text{H}_2\text{O} (\text{l})$
- For 1 mole of octane, if the amount of oxygen is between 17/2 moles and 25/2 moles, then you get a mix of both CO_2 and CO
- For 1 mole of Octane, if the amount of oxygen is between 17/2 moles and 9/2 moles, then you get a mix of both C and CO
- For 1 mole of Octane, if the amount of oxygen is $< 9/2$ moles then there is just carbon. (possibly also unburnt fuel)

Why we monitor:

- Carbon is a **pollutant** because it is black soot.
 - It irritates lungs, blocking airways
 - If landed on plants, it stops them from photosynthesising
 - It also attacks asthma sufferers
 - Thus it needs monitoring to effectively control
- Carbon monoxide is a pollutant because it is poisonous
 - It causes Nausea
 - It causes Headaches
 - It causes death in high concentrations
- Small amounts of impurities such as sulphur in fossil fuels
 - This can produce sulphur dioxide during combustion
 - This is detrimental to the environment as it can lead to acid rain which corrodes manmade structures such as limestone (see acidic environment)
 - SO_2 can cause polluted air which decreases the visibility within cities. This causes danger to drivers. These gases also have an effect on asthma patients, making it harder to breathe, causing direct harm to their airways and lungs.

Note: The only ever time you have fractions in equations is on the oxygen in a combustion equation.

Emission control (monitoring and management):

- The engine can be fine-tuned to change the ratio between fuel and oxygen.
- This will give a balance between **obtaining energy** and being **environmentally friendly**.
- When a motor vehicle is re-registered for its pink slip, a mechanic must perform chemical checks.
 - They must put a probe attached to a spectrometer, up the tailpipe of the car, after it is warmed up.
 - It shows peaks for CO_2 and CO .
 - The spectrometer works out the ratio of gasses to check if the motor passes or not.
 - This is known as **emission control**. The government emission control standards must be met.
 - If emission control is not passed, you can fix the engine, replace the engine or buy a new car.

Catalytic converter (monitoring and management):

- Every car has a catalytic converter, it is necessary by law, and to get your car registered.
- The catalytic converter converts CO back into CO_2 . Which is less polluting.
- It also converts NO_x back into N_2 and O_2 .
- There is a separate catalyst in each section of the catalytic converter.
- The catalysts form the catalyst reactant complex. They then break down into the less harmful gases.

Muffler (monitoring and management, non chemical process):

- Muffler silences the noise.
- Reduces noise pollution

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



T1R role of chemists

Note: DO NOT FORGET to study this research task.

*Focus Point 2 - Haber Process

Identify and describe the industrial uses of ammonia

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

Identify the reaction of hydrogen with nitrogen as exothermic

Uses of ammonia:

- **Produce Fertiliser**
 - Nitrogen is essential for life.
 - Plants can not access nitrogen in the air due to the strong triple bond of nitrogen.
 - The fertilisers help break down nitrogen into a usable form.
- **Produce explosives**
 - A process is used to make nitric acid.
 - Nitric acid is then formed into explosive chemical
 - Invented by Alfred Nobel (TNT)
 - Explosives are used in mining, agriculture (stumps), road/rail construction
- **Produce Nitric Acid**
 - The Oswald process is used to produce nitric acid from ammonia

Produce pharmaceutical products

Produce cosmetics

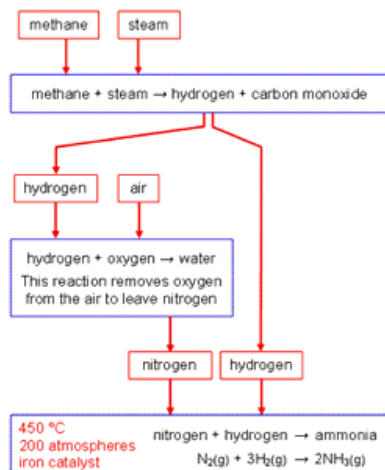
- Household cleaner. (Not industry, possibly industry cleaner)
 - When dissolved in water, ammonium hydroxide is formed, which is found in most cleaning agents.

Synthesis:



- Known as the **Haber process**
- Random picture of him for the lols.
- $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ $\Delta H = -92 \text{ kJ/mole}$. The reaction is **EXOTHERMIC**
- NOTE: DO NOT forget the equilibrium arrow. It is an EQUILIBRIUM reaction**
- The reaction is reversible.

1.
2.
3.
4.
5.
6.
7.



Note: The above flow chart is **NOT** drawn properly. Remember a flow chart should have the products in boxes, the steps on the lines.

Explain why the rate of reaction is increased by higher temperature

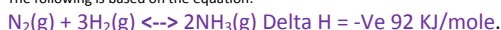
Explain why the yield of product in the Haber process is reduced at higher temperatures using Le Chatelier's principle

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

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

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

The following is based on the equation:



- The reaction is an equilibrium reaction, meaning Le Chatelier's principle will apply.
- In fact, Le Chatelier's principle is used to increase yield and efficiency.

Recall: "In any chemical system in equilibrium is subjected to a change in pressure, volume, concentration or temperature, then the system will react in the direction to minimise that change"

High temperature (collision theory):

- The **rate** of reaction increases as temperature increases
- This is due to collision theory, particles have more kinetic energy and there are more successful collisions.

High temperature (LCP)

- The yield of the product decreases as temperature increases
- The reaction is exothermic, meaning as ammonia is formed (forward reaction), heat is released, raising the temperature of the whole system
- If an increase of temperature was applied, Le Chatelier's principle states that the system will try to cool itself down (minimise the change)
- This is done by favoring the reverse reaction, as it is endothermic, the excess heat is absorbed and stored into chemical energy (the system is cooler now)
- Because now the reverse reaction is favored and the equilibrium lies on the left, there is less concentration of ammonia.
- Thus **higher temperatures reduce the yield**.

Low temperature (collision theory)

- The rate of reaction decreases as temperature decreases
- This is due to collision theory, particles have less kinetic energy and there are less successful collisions.

Low temperature (LCP)

- The yield of the product increases as temperature decreases
- The reaction is exothermic, meaning as ammonia is formed (forward reaction), heat is released, raising the temperature of the whole system
- If an increase of temperature was applied, Le Chatelier's principle states that the system will try to warm itself up (minimise the change)
- This is done by favoring the forward reaction, as it is exothermic, the excess heat is released into the surroundings (the system is warmer now)
- Because now the forward reaction is favored and the equilibrium lies on the right, there is more concentration of ammonia.
- Thus **lower temperatures increase the yield**.

Delicate balancing act:

- Evidently, a balance is required to achieve the most effective reaction rate and most effective, economical, yield.
- This balance is around **350-500 degrees Celsius**

Note: Insure in an exam that all **FOUR** (high temp LCP, high temp collision, low temp LCP, low temp collision) are covered

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

- The catalyst used in the Haber process is **magnetite. Fe₃O₄**
- If you are wondering why the valence in Fe₃O₄ is all the way effed up. It's because magnetite consists of both iron ions meaning it has both Fe²⁺ and Fe³⁺. Thus the empirical formula is Fe₃O₄
- The catalyst will **lower the activation energy** of the reaction.
- Thus the reaction temperature required will be significantly lower.
- This is beneficial as less energy and thus less money is needed to achieve lower temperatures. Thus it is more economically viable.
- The equilibrium **DO NOT CHANGE** when a catalyst is added.
- When a catalyst is added, it **lowers the activation energy** for **both the forward and backward reactions**.
- Therefore the rate of reaction is increased equally, the **equilibrium DOES NOT SHIFT**.
- The **RATE** of reaction changes

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

High pressure poses a risk and thus equipment must be very expensively built.
The ratio is strictly 1:3 (not excess reactants) because the substances are held to obtain.

High Pressure (Safety):

- If the pressure is too high, then the system will explode.
- This is a safety hazard and is very dangerous, thus the pressure can not be too high.

High Pressure (LCP):

NOTE: In an exam, **DO NOT** talk about volume, explain in terms of pressure. (unless asked otherwise)

- Volume is only used here so it is easier to understand, **DO NOT** use volume in an exam.
- When there is **less volume** in a system and thus **more pressure**, the reaction will shift to **compact into** the new volume
- If the volume is increased (pressure decreased), more molecules are required to fill up this space in order to increase the pressure back (minimise change)
- Thus a forward reaction is favored because this forms 2 moles of gas compared to 3 moles in a reverse reaction (**less moles = less space taken**)
- Thus because the equilibrium lies on the right, there will be a higher concentration of ammonia and a higher yield
- However, clearly as stated above, a pressure TOO HIGH, is dangerous.

Low pressure (Collision theory):

Low pressure (LCP):

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

Complete example (past hsc question):

Note: Talk about both too high too low with Le Chatelier, and too high too low with collision. Thus there are 4 "things" to talk about. Do not miss any

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



T2R - Haber
context

***Focus Point 3 - Ion identification**

Deduce the ions present in a sample from the results of tests.

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

Colour test:

- The majority of solutions are colorless, thus judging by color is not a good identification method.
- There are three hydrated cations (in solution) that have distinct colors:
 - Cu²⁺ - Blue
 - Fe³⁺ - Yellow Orange
 - Fe²⁺ - Pale green (however, may not be visible if solution is dilute)

Flame test:

- Flame tests are only effective for some cations, if the emission is within the visible spectrum.
- There are issues with flame tests.
 - Flame tests are concentration dependent
 - Some cations are masking, such as sodium (yellow) and strontium (pinkish)
 - e.g. if sodium is present, the yellow is so strong that it overwhelms any other ion present.
 - Only yellow will be seen (from sodium)(however a blue glass can be used, sodium flame is invisible through blue glass)
 - In HSC, it is possible that there is only one thing present.
 - But in real life this is an issue as there can be a range of ions.

Cation	Solution Colour	Flame Colour
Barium Ba ²⁺	Colourless	Apple-green
Calcium Ca ²⁺	Colourless	Brick-red
Copper Cu ²⁺	Blue or Green	Blue-Green

Flame test methods:

- A platinum wire is cleaned, it is then dipped into HCl.
- It is then dipped into the powdered salt.
 - The purpose of the HCl is to make the salt stick to the film of acid
- The wire is then passed through the COLOURLESS TIP of the flame
- Record any color changes
- Place solution into an atomiser
- Spray into the COLOURLESS TIP of the flame
- Record any color changes

Precipitate test:

- There are two types of ions. Anions (-ve) and cations (+ve)
- Solubility rules are absolutely ESSENTIAL for this topic. Memorise them.
- Soluble salts do not form precipitates.
- Insoluble salts form precipitates

Soluble Compounds	Insoluble Exceptions
Group 1 metals and NH_4^+	
Nitrates (NO_3^-) and acetates (CH_3COO^-)	
Chlorides (Cl^-), bromides (Br^-) and iodides (I^-)	Ag^+ , Pb^{2+} and Hg^+
Sulfates (SO_4^{2-})	Ag^+ , Pb^{2+} , Hg^+ , Ba^{2+} , Sr^{2+} and Ca^{2+}
Insoluble Compounds	Soluble Exceptions
Carbonates (CO_3^{2-}), sulfites (SO_3^{2-}) and phosphates (PO_4^{3-})	Group 1 metals and NH_4^+
Hydroxides (OH^-)	Group 1 metals, NH_4^+ , Ca^{2+} and Ba^{2+}
Sulfides (S^{2-})	Group 1 and 2 metals and NH_4^+
Oxides (O^{2-})	Group 1 metals, NH_4^+ , Ca^{2+} and Ba^{2+}

- When we have a sample of ions, we have a specific sequence to test for which ions are present.
- A flow diagram is the best way of representing and remembering the process.
- The specific tests are in an order to avoid incorrect conclusions this is known as an **elimination sequence**.

Anion identification:

- The order that anions should be tested are:

- Carbonates
- Sulphates
- Chlorides
- Phosphates

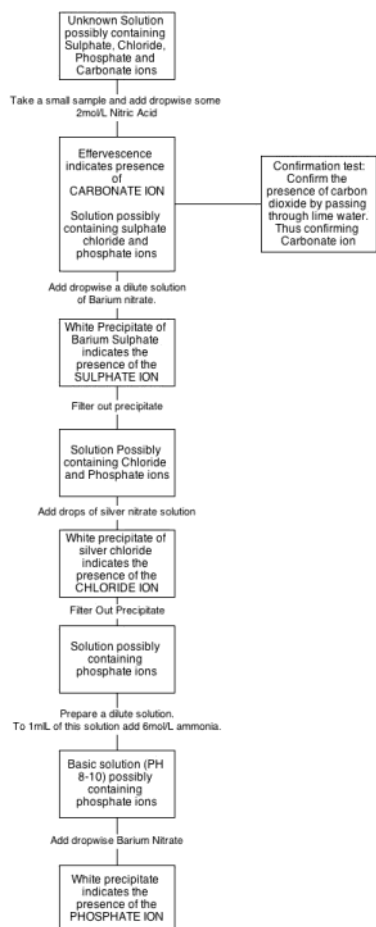
Anion	Individual Identification method	Equation and Observation and conclusion
Carbonate	<ul style="list-style-type: none"> Take a small sample of the unknown solid in a test tube. Add drop wise some 2mol/L nitric acid. Usually Nitric acid is added as we do not wish to produce Cl^- are SO_4^{2-} by adding HCl or H_2SO_4. However, an individual test can be done with any strong acid. Note: This individual test DOES NOT require the original substance to be in solution. 	
Sulphate SO_4^{2-}	<ul style="list-style-type: none"> Dissolve the solid in water (if solid) However, if it is insoluble, dissolve it in nitric acid. Add drop-wise a dilute solution of barium nitrate 	Fine white precipitate BaSO_4
Chloride Cl^-	<ul style="list-style-type: none"> Dissolve the solid in water (if solid) However, if it is insoluble, dissolve in dilute nitric acid Add drops of silver nitrate solution 	
Phosphate PO_4^{3-}	<ul style="list-style-type: none"> Prepare a dilute solution Firstly, we add NH_3, in order to make the solution basic. (see note under) Next, Ba^{2+} ions are added. We add barium nitrate as all nitrates are soluble. The added Ba^{2+} ions produce $\text{Ba}_3(\text{PO}_4)_2$, Barium phosphate. 	

Note: Effervescence is the escape of gas from an aqueous solution and the foaming or fizzing that results from a release of the gas.

Note: The reason we added ammonia first is so that the solution turns basic. If the solution is acidic, (i.e. excess H_3O^+ ions), the H_3O^+ ions will react with the PO_4^{3-} ions to form Phosphoric acid. This is a weak acid, where the equilibrium lies on the left. This means it only slightly ionises. Thus, there will be little amounts of PO_4^{3-} to react in our test.

On the other hand, adding ammonia, making the solution basic, will ensure that the PO_4^{3-} are in ion form, not in molecular form as phosphoric acid.

Anion testing Flow Chart:



Individual cation tests:

Cation	Individual Identification method	Equation and Observation and conclusion
Lead Pb^{2+}	To 1L of the solution add 2 drops of dilute HCl	A white precipitate
Calcium Ca^{2+}	Add F^-	
Barium Ba^{2+}	Add S^{2-}	

Copper (II) $2+$		
Iron (II) Fe^{2+}		
Iron (III) Fe^{3+}		

Primary test:

Add HCL. If white precipitate, lead is present. If no white precipitate, lead is not present

1. Filter out the precipitate
 2. Add H_2SO_4 . If white precipitate forms, Calcium AND OR Barium are present.
 3. Restart. Do lead test Filter out lead. Add NaF to solution. If white precipitate, calcium present. If no precipitate formed, barium present
 4. Restart testing for iron: add a base (NaOH) if a brown precipitate forms, Fe^{3+} , if green / white green Fe^{2+}
- If from step 5 blue one forms, then possible copper. If so, add NH_3 , if blue precipitate dissolves forming a DARK BLUE solution, then copper is present.

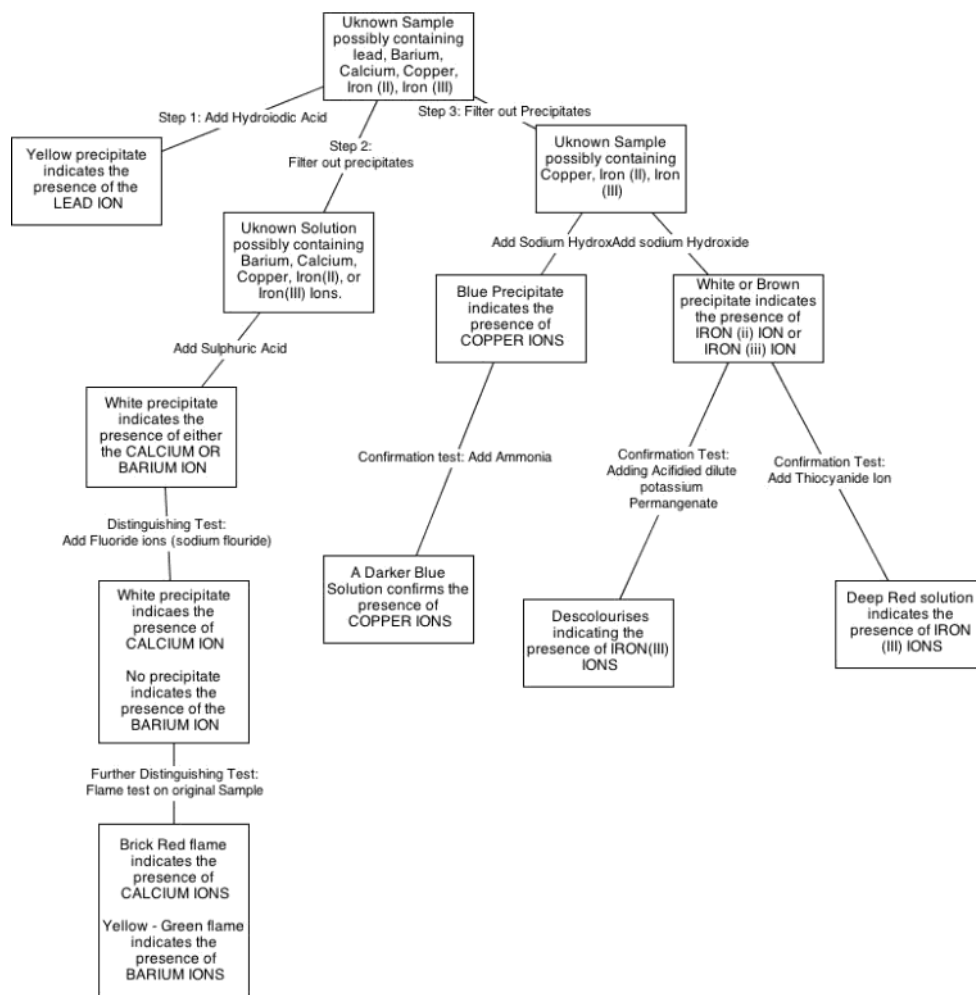
Secondary test:

Flame tests for all 3

Cation test elimination sequence:

- The order that Cations are tested are:

- Lead
- Barium / Calcium
- Copper
- Iron (II) / Iron(III)



Prac work / method:



Identification
of Ions

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

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

Note: AES (Atomic emission spectroscopy) and AAS (atomic absorption spectroscopy) are **NOT** the same thing. Syllabus specifies **AAS. (not AES)**

Note: There is probably too much detail here for a "describe" dot-point.

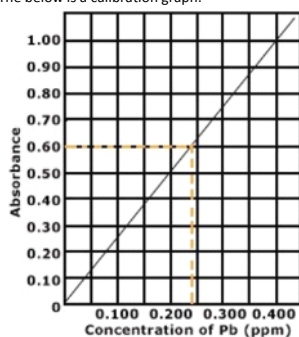
AAS overview and use:

- Atomic-absorption (AA) spectroscopy uses the **absorption of light** to measure the concentration of **gas-phase atoms**.
- This only works when the **concentration is very low**. But can work accurately with very low concentrations.
- AAS can measure a quantity for a certain element, **REGARDLESS** of anything else
- Only effective for metals as non metals require extremely high energy e.g. in AES (which is a whole other animal not on the syllabus)
- This means that AAS can pick up **trace elements** (1 to 100ppm), previous of AAS technology, trace elements could not be detected (see below for impact)
- AAS is widely used in a range of areas including:
 - Analysis rock and mineral samples in the mining industry for purity of metal ions
 - Monitoring of pollution levels in water when water is polluted with metal ions.
 - Monitoring of pollution levels of metal ions in air.
 - Monitoring of essential trace elements in soil by the agricultural industry.
 - Analysis of blood and urine samples for the presence of an excess or deficiency of a metal ion.

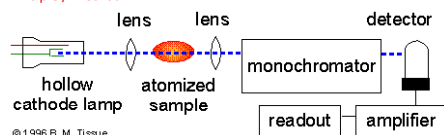
Calibration:

- Before AAS, the spectroscope is calibrated.
- This is done by forming a calibration graph:
 - The calibration graph is formed by passing known concentrations (standards) through AAS.

- E.g. (0.1, 0.2, 0.3, 0.4 ppm)
- If the sample tested is not in the calibration graph then either dilute the standards or dilute your sample
- E.g., if sample is too concentrated, dilute it to fit the scale, then multiply at the end by the dilution factor
- E.g. if sample is not concentrated enough, dilute the standard samples to form a more fitting calibration graph
- The below is a calibration graph:



Principle / Method:



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Main Principle: The EMR emitted by the excited atom (cathode lamp), will be absorbed by the ground state atom. (atomized sample)

- Simply, AAS detects the amount of light (of a specific wavelength) absorbed by an atomized sample and thus calculates the concentration.
- This is a **QUANTITATIVE** analysis. The ions in the sample tested must be **known**.
- This sample is vaporized through a flame.
- The flame converts the metal ions (from the solution) into atoms (element ground-state).
- Light from a cathode lamp (which uses the same element), is shone through the atomized sample.
- The light source emits the light spectrum of the element tested
- This causes atoms of the samples to absorb energy from the light. (due to the principle above)
- This causes the light to be modified.
- The modified light passed through the **monochromator** which concentrates the required wavelength (corresponding to the element)
- The light is then passed to a **photomultiplier** (or amplifier) which amplifies the signal to a computer.
- The **computer** produces a graph which displays absorption value and from there, calculates concentration.



Important: The amount of light absorbed by the sample is **proportional** to the concentration of the metal ion in the solution being tested.

Impact analysis (trace elements and effectiveness in pollution control):

- AAS are able to detect **trace elements** of metals in life forms, which were not previously understood.
- The trace elements are **essential** by living organisms.
- The need or even existence of such trace elements was not recognised until the development of AAS.
- Older analytical methods such as gravimetric analysis were not sensitive enough to detect such small concentrations
- AAS demonstrated how trace elements were essential for the well-being of organisms
- This means that we have been able to monitor essential trace elements, which has **impacted agriculture**
- This has also allowed us to find out which and how certain trace elements affect a living being.
- We have also been able to detect poisonous trace elements (e.g. mercury) and understand their effects.
- As well as this we understand the level (concentration) of poisonous trace elements that will effect a body of water

E.g. Zinc for example, is essential for plants as it regulate plant growth hormones. In animals, zinc is need for amino acid metabolism, energy production, insulin production, development of immune cells and regulations of bone calcification. Deficiency in zinc leads to health problems in both plants and animals. As has lead to diagnosis and deficiencies by testing blood or urine sample sand the analysis of trace elements in soil, determining the conc entration needed to produce maximum crop yield.

From AAS We have also understood that:

- Zinc is needed for energy production
- Iron is required for production of hemoglobin
- Copper is needed for enzyme production
- Iodine is needed for the proper function of the thyroid gland.

Advantages of AAS	Limitations of AAS
Quick, easy accurate and specific means of determine the concentration of over 65 elements	Only a quantitative analysis, the composition must be known first
Enhanced our understanding of trace elements	Expensive equipment
Increased ability to detect pollutants in air, water and soil	Can not be used to test anions, some anions can even interfere
Allowed the analysis of metal content in minerals, to determine economic viability	Standards must be prepared before hand. (meaning a estimate range of concentration of the sample must be known)
Pollution control advantages	Pollution control disadvantages
<ul style="list-style-type: none"> • AAS can absorb very small concentration of pollution. • It can also pinpoint specific type of elements that cause the pollution. • AAS is an expensive setup, but after that it is reused, thus it is relatively cost effective • AAs is also easy to use and readily available, and moderately quick 	<ul style="list-style-type: none"> • Sometimes AAS is still not precise enough.

Assessments / Evaluations:

With minimal limitations, AAS has had a beneficial impact as it has not only lead to a greater understanding of trace element s, but it has also led us to be able to monitor the amounts of trace elements in certain systems when needed.

AAS is extremely effective in pollution control in air, water and soil. This is because it can pinpoint small concentrations of specific elements and is reasonably quick and reliable.

Results and Interpretation of secondary data:

- Absorbance is graphed on the Y-axis, concentration on the X.
- Draw the standard graph first, and then read off the graph to find the concentration.

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.



T4R- Need
to monito...

Lead:

- Lead is a highly toxic heavy metal
 - Lead causes brain damage, behavioral disorders, kidney damage, stunted growths, deafness
 - Lead also replaces calcium and inhibits the formation of hemoglobin, causing anemia.
 - This is especially damaging to children as their bones are still growing
- Lead Bio accumulates
 - Once it enters the bottom of the food chain, it remains in the tissue
 - e.g. little fish eats lead, big fish eats little fish, humans eat big fish, lead goes into humans
- Lead Biomagnifies
 - Lead can not be digested well
 - 5 Little fish has lead inside it, a shark eats all 5 and thus has all the more lead inside it
 - This process continues, lead accumulates as it can not be digested or removed from the body easily

Note: read prac report for detailed evidence and explanations

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

- This experiment is an example of **gravimetric** and **quantitative** analysis.
- Quantitative analysis is the determination of what **amounts** are present in substances

Equipment and definitions:

Equipment	Use
Solid Fertiliser	
Concentrated hydrochloric acid dropper	
Barium concentration solution	
Electronic balance	
Hot plate	
Glass Rod	
Watch glass	
Supernatant	Denoting the liquid lying above a solid residue after crystallization, precipitation, centrifugation, or other process.

Risk Assessment:

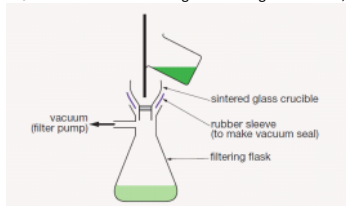
Identify	Assess	Control
Hot Plate	May burn upon contact	Exercise caution Wear gloves
Ionic compounds (barium sulphate, barium chloride, ammonium sulphate...)	Barium chloride solution is toxic	Wear Safety Glasses
Hydrochloric acid	Highly corrosive, causes unwanted burn on skin	Wear safety glasses and gloves

Method (school lab):

1. Wash all equipment thoroughly with DISTILLED water
2. Weigh out 0.5 g of the fertiliser and transfer to a 500mL beaker using 25mL of distilled water
 - This is to dissolve other anions that may precipitate with the barium ion. Eg. Carbonate or phosphate
3. Have the solution gently to boiling with a hotplate
 - The extra heat increases the kinetic energy of the particles so that the reaction occurs faster (collision theory)
4. Set up a burette containing 5% w/v barium chloride solution and add **drop wise** until no further precipitate is formed, while stirring consistently with a glass stirring rod.
 - It is added **drop wise** so that the precipitate comes out in clumps
5. Allow the precipitate to settle and test the supernatant solution with a few more drops of barium chloride
 - This ensures **complete precipitation**
6. Filter the solution using weighed filter paper, using a small amount of DISTILLED water to ensure complete transfer
7. Dry the filter paper in a low temperature oven
 - This ensures no extra moisture remains in the precipitate, which will make the mass heavier
8. Wash the precipitate with distilled water
 - This is to ensure that the crystallised ions like ammonium nitrate are not present
9. Wash first with water, then with ethanol, then dry and weigh to constant mass and record.
10. Calculate

Method (USYD - sintered glass crucible):

1. Steps 1-5 are the same
6. Filter the solution using a sintered glass crucible, turn on vacuum pump and slowly pour in solution against stirring rod (as shown below)



Explanation of chemistry involved:

Net ionic equation: $\text{Ba}^{2+}_{(\text{aq})} + \text{SO}_4^{2-}_{(\text{aq})} \rightarrow \text{BaSO}_4(\text{s})$

Overall equation: $(\text{NH}_4)_2\text{SO}_4(\text{aq}) + \text{BaCl}_2(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NH}_4\text{Cl}(\text{aq})$

Note: The overall equation depends on what is used, it is not always the same!

Note: In exam, no need to write overall unless specified to BE CAREFUL.

Problems encountered:

Problem	Explanation	How does this effect the result?	Solution
Using real lawn fertiliser	Real lawn fertiliser has insoluble components	Precipitate may weigh more or less	<ul style="list-style-type: none"> • The ammonium sulphate must be dissolved and the insolubles must be filtered
Weighing Error	A small sample can lead to a large weighing error percentage	Precipitate may weigh more or less	<ul style="list-style-type: none"> • Use a larger sample - The larger the sample, the less the weight error
Use of Tap Water	Tap water contains impurities and excess ions	Precipitate may weigh more or less	<ul style="list-style-type: none"> • Use distilled water
Incomplete Dissolution	The ammonium sulphate may not completely dissolve	Precipitate weighs less	<ul style="list-style-type: none"> • We grind up the ammonium sulphate sample using a mortar and pestle - This increases the surface area, and thus makes it more soluble • Heat and put in ice for more solubility

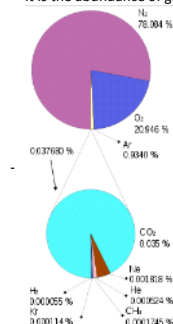
			<ul style="list-style-type: none"> We also add plenty of solvent
Incomplete Precipitation	Not all the sulphate might of precipitated	Precipitate weighs less	<ul style="list-style-type: none"> Add enough Barium chloride to precipitate the sulphate. After filtering, take some of the filtrate and add more barium chloride to see if more precipitation occurs - i.e. test for complete precipitation
Co-precipitation e.g. Barium Carbonate and Barium Phosphate present in precipitate	Another substance besides barium sulphate may precipitate	Precipitate weighs more	<ul style="list-style-type: none"> Ensure distilled water is used Add concentrated HCl to neutralise the carbonate and to also form phosphoric acid, a weak acid in molecular form.
Incomplete drying		Precipitate weighs more - Extra water	<ul style="list-style-type: none"> Leave in oven for enough time to ensure complete drying Dry to constant mass Re dry in the oven, weigh again Repeat until constant mass achieved
Filter paper too coarse	<ul style="list-style-type: none"> The precipitate is extremely fine If filter paper is too coarse, some precipitate goes through the filter. 	Precipitate weighs less	<ul style="list-style-type: none"> Refilter, filter numerous times until no precipitate formed - i.e. ensure complete filtration
Passage of Barium sulphate through sintered glass funnel or filter paper			<ul style="list-style-type: none"> Add the barium chloride slowly from hot solution This maximises the size of the particles
Contamination of the precipitate with substances absorbed from solution			<ul style="list-style-type: none"> Wash with distilled water and dissolve

*Focus Point - Atmosphere

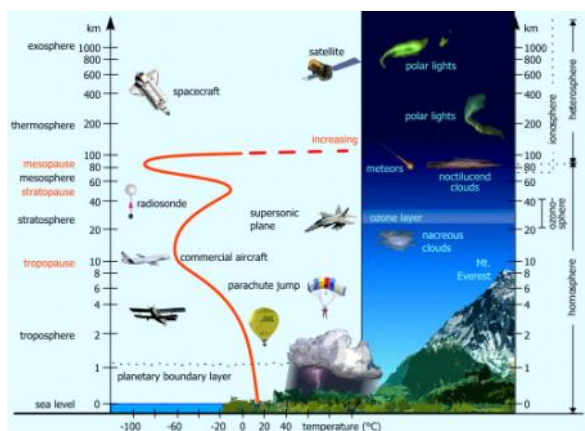
Describe the composition and layered structure of the atmosphere.

Layered Structure:

- The atmosphere can be split into 4 main layers:
 - Troposphere
 - Stratosphere
 - Mesosphere
 - Thermosphere
- The % composition of gases in each layer are about the same
 - This is roughly 79% Nitrogen, 19% oxygen, 1% Argon and <1% other gases
 - It is the abundance of gases that are different



- It is important to note that each layer is defined by **TEMPERATURE** rather than altitude
- However, as there is a relation between altitude and height, each layer has a distinct height range too



Troposphere:

- This layer is the lowest layer of the atmosphere (least altitude)
 - It extends from between sea level to 15 Km above sea level
- The Troposphere has 75%+ of the gases in the atmosphere
- It is composed of Oxygen gas (20%), Nitrogen gas (78%), Carbon dioxide gas and other inert gases
- The Troposphere has high pressure, this is due to the many gases hitting each other
- The Troposphere contains all the weather including clouds, lightning and rain
- Temperature decreases as altitude increases
- This is because _____

Stratosphere:

- The stratosphere is the next layer up (above the troposphere)
 - It extends from between 15km above sea level to 50km above sea level
- The stratosphere has much less gas than that of the troposphere (about 20%)
- The stratosphere has lower pressure than the troposphere as it contains less gases
- The stratosphere contains the ozone layer
 - The ozone layer is important in this focus point (see later)
- Temperature increases as altitude increases
- This is because of the presence of the Ozone layer
- The ozone layer absorbs UVB and UVC radiation

Mesosphere:

- The mesosphere is the next layer up (above the stratosphere)
 - It extends from between 50km above sea level to 80km above sea level
- There are very few gas molecules

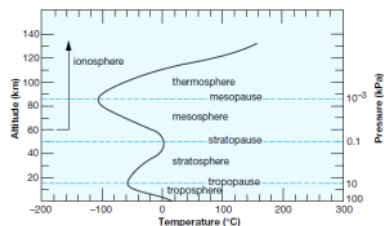
Thermosphere:

- The thermosphere is the next layer up (above the mesosphere)
- It extends between 85Km above sea level to 600Km above sea level

Summary:

Layer	Altitude (Km)	Composition	Pressure	Temperature	Other facts
Troposphere	0-15	79% Nitrogen, 19% oxygen, 1% Argon and <1% other gases (Contains some polluting Ozone)	Highest (most particles)	Temperature decreases as altitude increases	Ozone is a pollutant here
Stratosphere	15-50	79% Nitrogen, 19% oxygen, 1% Argon and <1% other gases (Contains most Ozone)	Lower	Temperature increases as altitude increases	The ozone layer is found here
Mesosphere	50-80	79% Nitrogen, 19% oxygen, 1% Argon and <1% other gases	Even Lower	Temperature decreases as altitude increases	
Thermosphere	85-600	79% Nitrogen, 19% oxygen, 1% Argon and <1% other gases	Lowest	Temperature increases as altitude increases	Atoms are converted to gaseous ions here e.g. O ⁺ O ₂ ⁺ NO ⁺

Note: The following diagram shows the way temperature changes through moving up the atmosphere, you should remember this graph



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

Note: Oxygen gas and Nitrogen gas are **NOT** pollutants

- In this case, the "lower atmosphere" refers to the troposphere

Pollutant	Sources	Effects
Carbon Dioxide (CO ₂)	<ul style="list-style-type: none">• Combustion of fossil fuels- E.g. use of petrol• Volcanic eruptions• Bush fires	<ul style="list-style-type: none">• Infrared radiation from the sun bounces off the ground- This infrared then gets trapped in the Carbon Dioxide• This is not necessarily harmful- However, if there is excess CO₂ then there will be too much heat trapped• This leads to global warming, increasing the temperature of the planet- This causes melts to polar ice-caps and rise in sea levels
Carbon Monoxide (CO)	<ul style="list-style-type: none">• Incomplete combustion• Bush Fires• Cigarettes	<ul style="list-style-type: none">•
Sulphur Dioxide (SO ₂)	<ul style="list-style-type: none">• Combustion of metal sulphides e.g. ZnS + O₂ --> ZnO + SO₂• Coal power station	<ul style="list-style-type: none">• Acts as a pollutant creating breathing and visibility problems• Leads to acid rain (see acidic environment)
Oxides of Nitrogen	<ul style="list-style-type: none">• Car combustion chambers• Natural lightning strikes (see acidic environment)	<ul style="list-style-type: none">• Acts as a pollutant creating breathing and visibility problems• Leads to acid rain (see acidic environment)
Ozone	<ul style="list-style-type: none">• Photochemical smog• Photo oxidation• Natural production of O₃ from UV light (see later)	<ul style="list-style-type: none">• Greenhouse gas, causes global warming• Poisonous
Chlorofluorocarbons	<ul style="list-style-type: none">• Refrigeration, air conditioning	
Volatile Organic Compounds (e.g. Benzene)	<ul style="list-style-type: none">• Produced by field refineries• Petrol Diesel combustions	
Particulates (e.g. asbestos)		

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

Ozone:

- Ozone is a gas and has chemical formula O₃
- It has harmful effects to health, it is therefore a pollutant
- However, Ozone also acts as a UV radiation shield which absorbs UV-B and UV-C radiation
- Ozone exists in both the stratosphere and the troposphere



Ozone in the Stratosphere:

- Most of the Ozone is found in the stratosphere. In the Stratosphere, Ozone acts as a UV radiation shield
- Although Ozone has damaging effects on health, it is not a pollutant in this level as the altitude is too high (can not reach humans or living things)
- The Ozone in this level is naturally produced when high energy UV splits oxygen into free radicals
- The radicals then combine with other oxygen molecules to form Ozone
- O₂(g) --- (High Energy UV Radiation) --> 2O*(g)
- O*(g) + O₂(g) --> O₃ Delta H = -106KJ/mol

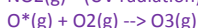
- The Ozone layer in the stratosphere is important as it **absorbs harmful UV Radiation**
- UV radiation causes **sunburn** and the **mutation of cells**, skin cancer and also **causing photochemical smog**
- Therefore, the Ozone is important, UV Radiation shielding is important
- When UV radiation hits the Ozone layer, the UV-B and UV-C are absorbed. The ozone molecule decomposes
- O₃(g) --- (Medium Energy UV Radiation) --> O*(g) + O₂(g)
- Ozone is also depleted by reacting with Oxygen free radicals:
- O₃(g) + O*(g) --> 2O₂(g) Delta H = -390 kJ/mol

Note: Ozone only absorbs UV-B radiation and UV-C radiation it does NOT absorb UV-A radiation. UV-A radiation is needed by plants for photosynthesis. UV-B radiation is harmful and causes cancers

Natural Ozone reformation:

Ozone in the troposphere:

- In the troposphere, Ozone acts as a pollutant
- It is toxic to humans, causing breathing problems
- This leads to problems such as coughing and chronic phlegm
- It readily oxidises living tissue, Ozone is a very strong oxidising agent
- Ozone also disrupts chemical reactions within the body
- Ozone is not formed naturally in the troposphere, it is most commonly formed through sunlight, car exhaust gases and oxygen
- The reaction is as follows (formation of ozone in the troposphere):



This mixture of nitrogen dioxide and ozone from a car exhaust is known as **photochemical smog**.

Note: The Astriek (*) denotes a free radicle. When in an exam, a dot should be used.

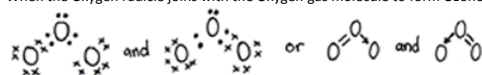
Note: Source of NO₂: (refer to acidic environment topic) High temperature combustion reactions in furnaces and internal combustion engines producing significant amounts of NO, the NO oxidises in air to form NO₂

- $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$
- $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$

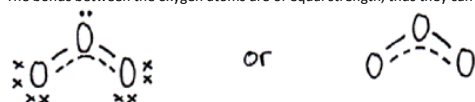
Describe the formation of a coordinate covalent bond

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

- A coordinate covalent bond is a covalent bond in which one atom provides both electrons to form the bond
- Coordinate covalent bonds are formed when one atom does not have a complete outer shell, while another atom does have a complete outer shell and has at least one unshared electron pair.
- When the Oxygen radical joins with the Oxygen gas molecule to form Ozone, a **coordinate covalent bond** is formed.



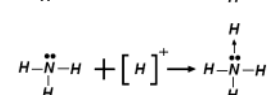
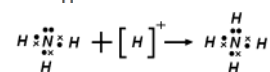
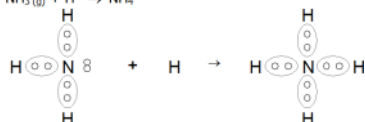
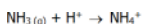
- The bonds between the oxygen atoms are of equal strength, thus they can be written as:



Warning: The coordinate covalent bond and the covalent bond are formed differently, but they have the same characteristics when formed. Meaning they are indistinguishable.

Drawing the formation of the bonds:

- In some cases the (→) Arrow is used to denote the coordinate covalent bond
- The formation of ammonium ion is a common example that involves a formation of a coordinate covalent bond



Note: You should know how to draw these in an exam. Practice and be prepared to draw anything you have not come across before

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

- Oxygen Gas (O₂) and Ozone (O₃) are allotropes.
- Allotropes are different structural modifications of an element, the atoms of the element are bonded together in a different manner. Allotropes must be in the **SAME STATE**

Property	Ozone	Oxygen	Oxygen Free radical
Reactivity	High	Moderate	High
Boiling point (°C)	-111	-183	N/A
Melting Point (°C)	-193	-219	N/A
Density	1.61 g/mL	1.15 g/mL	N/A
Odour	pungent	odourless	N/A
Colour	pale blue gas	colourless gas	N/A
Shape	bent	linear	Single atom
State	Gas	Gas	N/A
Effect on Humans (not really a property)	Causes breathing problems - Leads to coughing and chronic phlegm	Essential for life	Disrupts biochemical reactions in the body
Solubility	More Soluble than oxygen	Slightly	N/A
Structure and bonding	Three Oxygen atoms held together with 1 double covalent bond and 1 single coordinate covalent bond The ozone contains a resonating bond, where the double bond and single bond are evenly distributed between the three Oxygen atoms.	Two Oxygen atoms held together by a double covalent bond	Each radical contains two unpaired valence shell electrons
Lewis Dot Diagram (not really a property)			

Accounting for the properties:

- Reactivity (relates to intramolecular bonds):
- The **resonating bond (1.5 bond)** of Ozone due to its coordinate covalent bonding has a lower bond energy making it more reactive than O₂
- On the other hand O₂ has a double bond, which requires much more energy to break
- The Oxygen free radical contains the presence of unpaired electrons which make it reactive

- Boiling and melting Points (relates to intermolecular bonds):
 - Ozone is polar due to the donation of its electron pair, it forms dipole-dipole forces which require large amounts of heat energy to break
 - Whereas Oxygen is non polar and does not form intermolecular dipole-dipole forces, Oxygen is straight and forms dispersion forces, which are much weaker and require less heat energy to break
- Densities:
 - Ozone has greater mass than Oxygen gas. This is because Ozone has 3 oxygen atoms whereas oxygen gas only has 2
 - Thus Ozone has more mass per molecule and is more dense than Oxygen gas
- Solubility:
 - Ozone is polar, it forms dipole-dipole bonds with water and thus it is more soluble than Oxygen
 - Oxygen is non-polar, it is therefore not as soluble as it can not form these dipole-dipole bonds

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

- Isomers are compounds of the same molecular formula, but different structural formula
- It is very confusing to name isomers without remembering the correct rules:
 - Bromo-, Chloro-, Fluoro- and Iodo- are used as prefixes depending on their presence in the chain
 - The above halogens have their positions denoted by a number. If more than one of each type is present, di-,tri-,tetra-... are used and a location number is given for each such atom.
 - E.g. if there are 2 chlorines and they are attached to the 2nd and 3rd carbon, then you would name it as 2,3, Di-Chloro-....
 - Remember that you want to minimise the sum of all the numbers. So you number from the end that gives you the smallest SUM of numbers
 - If more than one type of halo atom is present, list them alphabetically. Bromo>Chloro>Fluoro>Iodo..
 - This rule is used only if rules 1-4 lead to more than 1 name. The correct name is the one that gives the lowest numbers to the most electronegative halogens
 - The order of electronegativity is Fluorine > Chlorine > Bromine > Iodine, Fluorine being the most electronegative.

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

- Here we go, another modeling dot point T_T
- The dotpoint does state "pictorial representations", so you can just simply draw some isomers of haloalkanes
- Remember that isomers occur when different atoms are in different positions of the molecule
- You could also use the molymod set.
- You built a haloalkane then without removing or adding extra balls you switched the positions of some halogens, this makes an isomer

Student molymod set (the stupid ball and sticks thing)

Benefits:

- Physical representation of the type and quantity of atoms involved
- Demonstrates the difference between various bonds
- Provides a simple representation to help understanding, someone may understand the simplified model better than the theory.
- Hands on, some people are hands on learners

Limitations:

- Relative sizes, and distances between atoms are unrealistic
- The dynamic nature of various molecules and their bonds is not shown
- Over simplifies the model.
- Not complete, not full picture due to time restraints.

Risks (wtf? I know right...):

- Swallowing small items can be hazardous and can cause choking which may be life threatening. Exhaust caution, do not put near mouth.
- Falling or tripping on model balls can lead to serious injuries. Do not leave models on floor.
- Damage to eyes from the models. Exhaust caution when handling the models, do not approach face.

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

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

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.

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.

Chlorofluorocarbons (CFCs):

- CFCs only have Chlorine, Fluorine and Carbons in their structure
 - They do NOT contain hydrogen
- In the past, ammonia gas was used in refrigerators
 - However, because this was toxic, the use of refrigeration was not practical in households
 - Thus CFCs were developed to act as a non-toxic, non reactive replacement for the ammonia gas in refrigerators
 - CFCs thus originated in fridges
- CFCs are also used in spray cans, propellants e.g. computer cleaners
- Eventually in the 1970s and 1980s, it was discovered that CFCs have high ozone depleting potential (see later)
 - By 1996, an agreement was formed to phase out CFCs

Halons:

- Halons are a compound containing bromine, fluorine and carbon and possibly chlorine
 - Halons were developed to extinguish fires due to its inability to combust
 - This was used in applications such as fire extinguishers
- It was also discovered that Halons had high ozone depleting potential (see later)
- The most common halon is bromochlorodifluoromethane CBRCIF₂

Problems associated with CFCs:

- CFCs are a problem as they can deplete the ozone layer
 - They have high ozone depleting potential
- Essentially what happens in a nutshell is that UV light causes CFCs to break down, forming chlorine free radicals. These chlorine free radicals act to breakdown the Ozone, which is needed for its UV Shielding abilities
- If Ozone is destroyed then more UV-A and UV-B will penetrate through the atmosphere increasing cancer rates, sunburn and mutation of cells

Note: In the following equations the CFC used will be CCl₂F₂, the most simplest of CFCs. Use this in your exam when writing an equation, don't bother with a hard one.

- CFCs are inert, this is a big problem, this allows them to reach the stratosphere
- Once in the stratosphere, the CFCs break down from UV radiation, forming Chlorine free radicals:

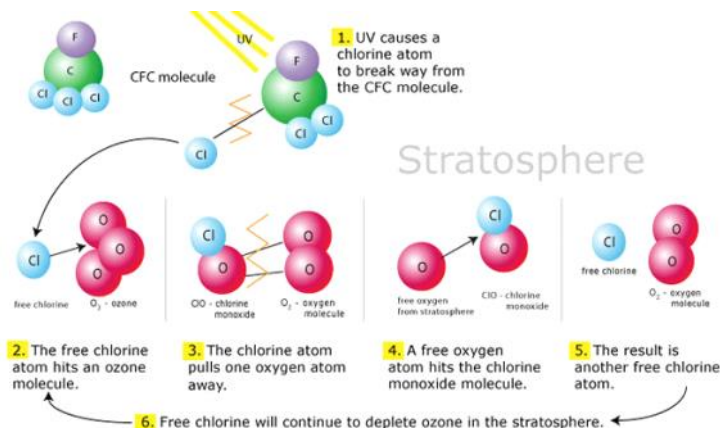
$$\text{CCl}_2\text{F}_2(\text{g}) \xrightarrow{\text{(UV Radiation)}} \text{CClF}_2^*(\text{g}) + \text{Cl}^*(\text{g})$$
- Next, the Chlorine free radicals react with ozone

$$\text{Cl}^*(\text{g}) + \text{O}_3(\text{g}) \rightarrow \text{ClO}^*(\text{g}) + \text{O}_2(\text{g})$$
- This forms Chlorine monoxide which then reacts with the oxygen free radical to regenerate the chlorine free radical

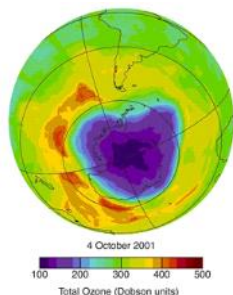
$$\text{ClO}^*(\text{g}) + \text{O}^*(\text{g}) \rightarrow \text{Cl}^*(\text{g}) + \text{O}_2(\text{g})$$
- The above is summarised in the below picture, note that one chlorine radical can destroy billions of ozone molecules
- There are only really 2 ways that this chain reaction can stop
 - The chlorine free radical reacts with methane

$$\text{Cl}^* + \text{CH}_4 \rightarrow \text{HCl} + \text{CH}_3^* \text{ (CH}_3^* \text{ is harmless)}$$
 - The chlorine monoxide reacts with NO₂

$$\text{ClO}^* + \text{NO}_2(\text{g}) \rightarrow \text{ClONO}_2(\text{g}) \text{ (also harmless)}$$

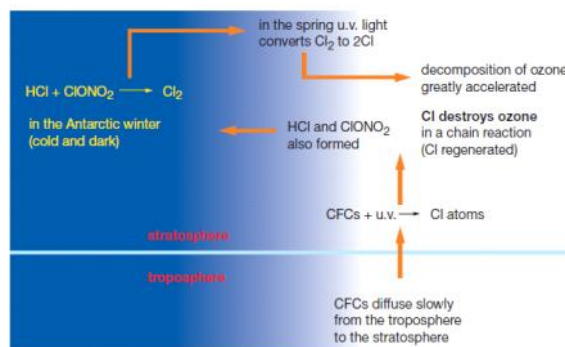


- As evident, the CFCs break down the ozone.
- An important point to note from the equation is that the Cl^* free radical that starts the first step is regenerated in the second step. This means that a single chlorine radical can act as a catalyst to destroy many thousands of O_3 molecules.
- This makes CFCs extremely harmful, giving them the high ODP.
- It was measured that 56% of ozone was depleted from 1987-2000 due to CFCs and halons.
- Each spring (in the southern hemisphere) since 1979, researchers have observed a thinning of the ozone layer over Antarctica.
- This is known as the ozone hole.
- Satellite images have shown a "hole" in the ozone layer over the south pole.
- During August and September 1986, NASA research team flew a plane equipped with analytical instruments into the ozone hole 25 times.
- Their measurements demonstrated that the decrease in ozone concentration had a relation to the increase in Chlorine Oxide radicals.
- Clearly, CFCs were the major problem.



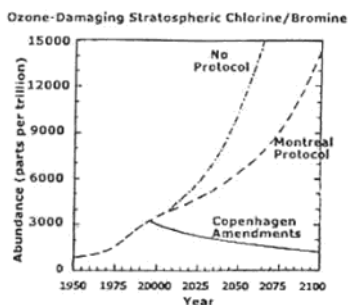
Why Antarctica?

- Geography students would know that due to the polar vortex Antarctica has extremely cold conditions.
- In these cold conditions the natural HCl and $ClONO_2$ would become solid and thus react in the following reaction: $HCl + ClONO_2 \rightarrow Cl_2 + HNO_3$.
- This happens harmlessly during winter. There will be a huge buildup of Cl_2 gas. Winter in Antarctica has literally 0 UV sunlight thus 0 UV radiation.
- However, as soon as spring comes the UV light splits the chlorine molecules up into separate chlorine atoms: $Cl_2 \xrightarrow{UV \text{ Light}} 2Cl^*$.
- This then leads to ozone depletion in the same way that Cl^* from CFCs do.
- This leads to the Antarctic ozone hole which is greatest in late October and early November.
- Generally the Ozone hole eventually disappears during Christmas time or early January.



Steps taken to alleviate problems:

- After the realisation of the ODP of CFCs, in 1987, 27 countries signed the Montreal protocol, which aimed to reduce CFCs and Halon production.
- The protocol basically banned the production of numerous substances that lead to ozone depletion, such as CFCs.
- This was evidently very successful and effective, by 2002 186 countries had signed the protocol.
- An Australian study in 2002 has shown that the levels of ozone destroying chemicals were falling, and the ozone hole would begin to start closing in 5 years, with the process completed in 2050.
- Hence it can be assessed that the Montreal protocol was effective in alleviating the problem of Ozone depletion.
- The Montreal Protocol was amended in London in 1990 and again in Copenhagen in 1992 following evaluation of ozone levels.
- The amendments included suggestions for alternative chemicals including the replacement of HCFCs with hydrocarbons.



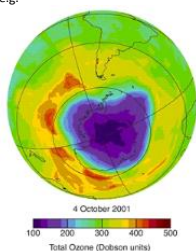
Replacement (Also a step taken to alleviate problems):

- Thus, due to these amendments, Another step taken is the use of new compounds to replace CFCs. This includes HFCs and HCFCs.
- These are more reactive due to the presence of the **H-C bond**
- And because they are more reactive, they react before they reach the stratosphere
- Thus they do not have a chance to deplete the ozone layer
- As well as this, HFCs do not contain the Chlorine atom or the bromine atom so they can not deplete the ozone
- The use of HFCs have been greatly effective as the 2002 Australian study shows that levels of Ozone destroying chemicals were falling and that the ozone hole will begin closing within 5 years.
- The below diagram shows the effectiveness of the steps taken in reducing the abundance of Ozone depleting substances

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

Information available:

- Pictorial diagrams (From Dobson Ozone Spectrophotometers)
e.g.



- Statistical information
- It has been measured that 56% of Ozone has been depleted from 1987 to 2000 due to CFCs and halons
- The reduction of Ozone in the Antarctic per year is about 60% whilst anywhere else in the world is only 3-8%
- It has been showed that Ozone holes form with lower than 220 D.U

Note: D.U is a Dobson unit and is the unit of measurement of Ozone = 0.01 mm of thickness

- In the stratosphere, Ozone concentrations can be measured by:
 - Ground - based instruments
 - Instruments in satellites
 - Instruments in aircraft
 - Instruments in balloons

Dobson ozone spectrophotometer:

- The Dobson Spectrometer measures the total ozone by measuring the **relative intensity** of the dangerous UVB radiation that reaches the Earth and comparing it to that of UVA radiation at ground level.
- If all of the ozone were removed from the atmosphere, the amount of **UVB radiation** would equal the amount of **UVA radiation** on the ground.
- As ozone does exist in the atmosphere, the Dobson Spectrometer can use **the ratio between UVA and UVB radiation on the ground** to determine how much ozone is present in the upper atmosphere to absorb the UVC radiation.

Note: Remember that Ozone only absorbs UVB and UVC radiation, not UVA. Thus in this method we compared the amount of UVA(not absorbed) to UVB(absorbed)

Total Ozone mapping Spectrometer (TOMS) / Ozone monitoring instrument (OMI):

- TOMS can measure "total column ozone" - the total amount of ozone in a "column" of air from the Earth's surface to the top of the atmosphere under all daytime observing and geophysical conditions.
- This is done by measuring the incoming solar energy and backscattered UV radiation above the ozone layer at six different wavelengths
- The two are then compared to determine the amount of radiation that was absorbed and hence the amount of ozone

Warning: Remember that the Dobson Ozone instrument is a spectro-**PHOTO**-meter whilst TOMS is a **spectrometer**

Balloons:

- Spectrophotometers are also used in balloons which are sent up into the atmosphere
- The balloons can measure directly the concentration of Ozone in the stratosphere

*Focus Point - Water

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

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

Water:

- Our bodies are almost 70% thus water is very important to us
- Potable water refers to water that is drinkable
- For this, the water must be of high quality
- In this dotpoint we explore the 6 factors that can have an effect on water quality, and qualitative / quantitative tests we can perform to analyse the quality of water samples.
- This is a long dotpoint, there are so many factors that can effect water quality, so keep calm and read on!

Concentration of common ions:

- This refers to the concentration of common Cations (Na⁺, Mg²⁺, Ca²⁺, K⁺, Sr²⁺, Fe³⁺) and Anions (Cl⁻, F⁻, SO₄²⁻, HCO₃⁻)
- Some Cations such as Al³⁺ and heavy metal ions are mobilised in the soil due to acidity (e.g. acid rain)
- Potable water must have low ion concentrations otherwise:
 - The water will taste salty
 - Some ions can be toxic to the human body (e.g. heavy metals)
- Cations are tested by Atomic absorption spectroscopy (see earlier)

- This method is easy and practical
- Anions however, are not metallic and thus can not be tested with AAS
- Anions are tested by gravimetric analysis, volumetric analysis or by an ion-selective electrode

Total Dissolved solids:

- Total dissolved solids are the solids dissolved in a water sample
- TDS is measured in ppm, a TDS above 1000ppm indicates a degraded waterway
- When the TDS is too high, the water is uninhabitable by many species
- TDS can be tested by gravimetric analysis or a conductivity probe
- In the school laboratory, a known volume of water can be evaporated to dryness and the remaining solid's mass determined using an electronic balance. A calculation of concentration can then be determined. (see later)
- **The TDS of fresh water is around 0-500 ppm. Sydney water supply has TDS <100ppm. The TDS of seawater is 35,000 ppm.**

Note: Using a conductivity probe when testing total dissolved solids assumes that most solids dissolved are ionic

Hardness:

- Water can be classified as either hard or soft
- Hard water contains significant amounts of Ca^{2+} and Mg^{2+}
- Soft water does not contain significant amounts of Ca^{2+} and Mg^{2+}
- Hard water does not lather with soap
- Instead, black insoluble scum forms
- Hard water has a very strange taste, very deep in flavor
- Water can be naturally hard, in fact many rivers contain naturally hard water
- This is because water washes up minerals at the bottom of rivers or on the rocks it washes past
- There are two types of hard water; temporary and permanent
- Temporary hard water is caused by the presence of calcium hydrogen carbonate and magnesium hydrogen carbonate
- Temporary hard water can be softened upon boiling
- Permanent hard water caused by the presence of heat stable calcium and magnesium
- Permanent hard water can not be softened upon boiling and must be softened via softeners (aka adding sodium phosphate)

Note: A sample of hard water can be instantly and easily softened by simply diluting it. (Because you are reducing the ppm of the Mg^{2+} and Ca^{2+} to a point where it is classified as "soft")

- The hardness of water can be tested qualitatively via the soap test or quantitatively via titrating against EDTA (see later) or AAS

Turbidity:

- A measure of suspended solids in water
- When high amounts of solids are suspended, the water becomes milky or cloudy
- Water with high turbidity is milky / cloudy
- Turbidity therefore is the opposite of clarity. The clearer the water, the lower its turbidity
- i.e. clear water has 0 turbidity
- High turbidity can be due to:
 - Soil erosion
 - Industrial and sewage wastes
 - Presence of excess nutrients leading to growth of algal blooms
- Turbidity (too much suspended solids) is an issue because:
 - It reduces light penetration, this light is essential for the photosynthesis of plants, this then impacts the rest of the food chain
 - Suspended sediment / solids can act as charged surfaces, attracting nutrients, pesticides and microbes into waterways
 - Turbidity can mask the presence of dangerous submerged objects in recreational water
- Turbidity is measured using a secchi disk or a turbidity tube
 - The disk is lowered into a body of water, it has a cross or mark on it
 - The disk is lowered until the point when the cross can not be seen
 - There is then a reading on the disk to show the depth it is at, which is proportional to the turbidity of the water
 - Turbidity is measured in the unit of NTU (a relative unit)
 - Turbidity can also be measured using a nephelometer, this measures the light scatter at 90 degrees to the original path.
 - The more turbid, the more scatter there is
 - Turbidity can also be measured with a spectrometric procedure. It measures the extent suspended solids block light from transmitting through water
 - Standard solutions are used to compare the sample with
- Potable water has <3 NTU. Water able to support aerobic organisms have <25 NTU

Note: The higher the NTU the more cloudy, the higher the turbidity, the higher the amount suspended solid and the less the clarity

Acidity:

- You should already know that acidity is a measure of the pH of water
- Potable water has pH range 6.5-8.5
- pH depends on many factors:
 - The source of the water
 - The geology of the catchment (e.g. basic rocks? Limestone? (basic))
 - The biological activity within the system
 - The pollution in the area (e.g. is the area exposed to acid rain a lot?)
- Most aquatic organisms cannot survive in water which has either a very low or a very high pH.
- If water is too acidic, metal pipes are corroded and the water is toxic to aquatic organisms
- If water is too basic, ammonium ions are converted to ammonia, which is toxic to aquatic organisms
- Same as usual, the pH is measured using universal indicator or a pH meter or a pH glass electrode

Dissolved oxygen content (DO)

- As the name suggests, Dissolved oxygen content is the amount of oxygen dissolved in the water
- Aquatic life forms need dissolved oxygen to survive.
- Waters with consistently high levels of dissolved oxygen (between 80 and 100% saturation) are able to support a large variety of aquatic organisms.
- This is effected by several factors:
 - Water temperature (oxygen is soluble at lower temperatures)
 - Pressure of atmospheric oxygen (more oxygen above surface means more dissolved oxygen under surface)
 - The tumbling / moving of water (Waves, and the tumbling of water increase the contact between water and the air, thus increasing the dissolved oxygen content)
 - Presence of other solutes (Some salts which may be present can reduce the DO)
 - Presence of pollutants (organic wastes are broken down by bacteria which use up oxygen, this reduces the DO)
- DO is measured using an oxygen sensitive electrode and a data logger or by the Winkler titration method
- Healthy water has > 6mg/l DO

Biochemical oxygen demand (BOD):

- Living things require oxygen.
- Biochemical oxygen demand is the measure of how much oxygen is used up
 - This can tell us about how much biological substances (that require oxygen) is in the water
- When there is organic waste, the bacteria breaks down the waste, but the bacteria itself requires high amounts of oxygen
- This increases the biological oxygen demand
- Thus human activities such as sewage or industrial waste can greatly increase the BOD of water (bacteria require oxygen to breakdown the waste)
- The BOD is often measured for 5 days. This is called the BOD₅
- The BOD₅ can be measured using the 5 day BOD test:
 - The DO is measured at the time of collection using an oxygen probe or two samples (collected from the same source)
 - The 2nd sample is stored in the dark at 20 degrees Celsius, the DO is measured again after 5 days
 - The two DOs are then compared, the difference will show the BOD

BOD = DO Initially - DO After 5 days

Note: The 2nd sample is left in the dark so that photosynthesis does not occur. Photosynthesis produces oxygen thus can make the results invalid

Note: Also note how the DO is used to measure the BOD in the BOD₅ test. BOD and DO are linked.

Summary:

- I realise this dotpoint is very long. Here is a summary of all the criteria for quality water and the tests you should know

Property	Qualitative Test	Quantitative Test
Concentration of common ions	<ul style="list-style-type: none"> Precipitation tests or flame tests can be used (those learnt in the ions topic) Anions can not be tested with AAS and are tested qualitatively with precipitation 	<ul style="list-style-type: none"> Cations can be tested quantitatively with AAS
Total dissolved solids (TDS)	<ul style="list-style-type: none"> Conductivity Meter: Most DS are ionic in nature, which act as charge carriers and contribute to the electrical conductivity of the water sample. As such, a conductive meter (once calibrated with known standard solutions at a certain temperature), can be used to determine concentration of TDS when compared to the calibration curve. 	<ul style="list-style-type: none"> Gravimetric Analysis: A known volume of water can be evaporated to dryness and the remaining solid's mass determined using an electronic balance. A calculation of concentration can then be determined.
Hardness	<p>Qualitative tests: Soap flakes (e.g. sodium stearate) are added to a test tube sample of the water. In 'soft' water, significant lather is produced (mixture of soap, air and water), whereas in 'hard' water a precipitate (e.g. calcium stearate) is formed instead (soap scum).</p> <p>Quantitative tests: AAS can be used to determine $[Ca^{2+}]$ and $[Mg^{2+}]$ with their specific lamps.</p>	
Turbidity	<p>Qualitative tests: Using a glass tube, water from one sample is added until a black cross marked underneath the glass tube is rendered invisible when viewed from the top. The procedure is repeated for another sample of water, and the depth of solution required is used to compare turbidity (less depth = more turbid)</p> <p>Quantitative tests: A turbidity tube calibrated to nephelometric units from a series of standards can be used; adding the water sample until a black cross is invisible.</p>	
Acidity	<p>Quantitative tests: Indicator papers or solutions (narrowing down the range with a series of tests), calibrated pH meter, pH probe attached to a data logger during titration</p>	
Dissolved Oxygen (DO)	<p>Quantitative tests:</p> <p>Winkler titration method: manganese ions are added to an alkaline solution of sample water (reacting with DO), then acidified iodide is added to form iodine. The solution is then titrated to determine iodine concentration and hence DO.</p> <p>- An oxygen sensor (an electrochemical cell) can be used; the voltage applied between the Pt and Ag electrodes does not cause electrolysis until oxygen reaches the electrolyte solution (the water sample is separated from the electrolyte by a membrane which allows oxygen to pass through). The amount of electrolysis is proportional to the amount of oxygen, and the level of DO is determined by comparing the value to a calibration curve formed by a series of standards.</p>	
Biochemical Oxygen Demand (BOD)	<p>Quantitative tests:</p> <p>Determined by the <u>5-day BOD test</u>. DO of a 1L water sample is measured using an oxygen probe during time of collection. Another sample is then stored for 5 days at 20°C in the dark then DO measured again. The BOD is calculated by subtracting the DO value after 5 days from the initial DO value.</p>	

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

- The concentration of such ions can be affected by:
 - The flow rate of the stream (Faster the rate, the more sediment is picked up)
 - The terrain the water moves in (e.g. if touching limestone then some calcium will dissolve)
 - pH of local rain water (acidic conditions allows certain ions which are normally insoluble to dissolve, increasing concentrations e.g. Al^{3+})
 - Heavy rain / flooding - (Large amounts of rain will decrease concentrations of all ions)
 - High evaporation rates - (less amounts of water, = more concentration)
 - Temperature of the water (more solids dissolve at high temperatures)
 - Proximity to farms - Rivers pick up **phosphates and nitrate** from fertilisers near farms as well as **pesticides and fertiliser**
 - Proximity to factories / industry - Factories / industries release heavy metal ions into the water (industrial effluent)
 - Land clearing - Land slides / erosion allows soil ions to enter water
 - Aquatic organisms - Some shelled invertebrates use calcium / carbonate ions from the water to construct their exoskeletons. This lowers the concentration of these ions.

Note: For an exam write "fertiliser run-off due to rain" not just fertilisers / farms

Note: For an exam write "industrial discharge / effluent discharge" not just industry / factories

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

Tests for common ions:

- The presence of anions are tested by either gravimetric analysis or volumetric analysis or an ion-selective electrode
 - Gravimetric analysis is:
 - Titration is:
 - An ion selective electrode

Anion	Information	Test
Fluoride	<ul style="list-style-type: none"> F^- ions are added to water is to improve dental health The Fluoride prevents tooth decay Since the government added F^- ions into water, there has been a general increase in tooth health This reduces the nation's health budget 	<ul style="list-style-type: none"> Use of an ion-selective electrode

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

Overview:

- We must purify and sanitise water in mass supplies for cities and towns
- This ensures quality water for consumption and is part of monitoring and management
- Purification refers to removing dissolved solids, suspended particles and so on, whilst sanitisation refers to removing bacteria and viruses
- Firstly water is purified, purification involves five steps:
 - Screening
 - Aeration
 - Flocculation (aka coagulation)
 - Sedimentation*
 - Filtration*
- Next, the water is sanitised, which involves 1 step:
 - Chlorination*
- The last step is fluoridation, it is not part of sanitation or purification
 - In fact, fluoridation has nothing to do with water quality (see later). But it is important
- Fluoridation

***Note:** It is important to remember that water is tested three times in the whole process, after these three steps.

Purification Step 1 - Screening:

- The water is passed through a net
- Large debris is removed by the net (screen)
- These are objects such as bags and bottles
- This process only removes large objects, therefore there are still ions and microbes after this step

Purification Step 2 - Aeration:

- This is done to increase the concentration of dissolved oxygen
- Water is sprayed into the air
- Any H₂S gas is oxidised to sulphate ions, iron salts are oxidised to insoluble iron oxides
- This is done to ensure the desirable DO levels in water, oxygenated water tastes better

Note: The word "Oxidised" should not be used when describing the addition of oxygen to water, rather the word "oxygenated" is used. Oxidised is a different term in chemistry.

Purification Step 3 - Flocculation (aka coagulation):

- Flocculation is the precipitating of suspended solids, this is also called coagulation
- A coagulant is added to a chamber of water. In this case the coagulant is Iron(III) Chloride
- Suspended solids such as clay colloids are unable to settle due to the repulsion between their negative surfaces
- Their charge prevents them from settling
- Iron(III) Chlorides neutralises charges on dissolved solids
- Once charges have been lost, the dissolved solids become insoluble
- Next, Iron(III) Chloride reacts with water to form Iron(III) Hydroxide
$$\text{Fe}^{3+}(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) \rightarrow \text{Fe}(\text{OH})_3(\text{s}) + 3\text{H}^+(\text{aq})$$
- The iron(III) Hydroxide forms floc, this starts to accumulate
- Suspended particles and insoluble particles start accumulating on the floc
- Eventually this floc appears at the bottom of the water, this needs to be removed by the next step (sedimentation)
- This process is highly effective as 95% of suspended impurities are removed, after sedimentation.

Purification Step 4 - Sedimentation

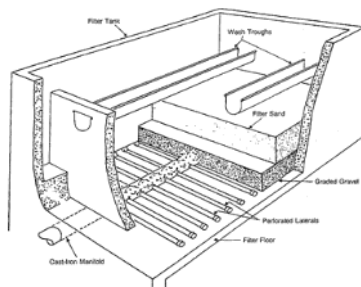
- The flocs from the above step are allowed to settle to the bottom
- These solids are then removed
- This process is highly effective as 95% of suspended impurities are removed

Purification Step 5 - Filtration

- This process removes the rest of the suspended particles, minerals, bacteria and coloured matter
- In most cases, a sand bed filter is used (like in Sydney)
- This sand bed contains sand and gravel
- The sand bed filter is much finer than the first filter (screening)
- Water is passed through this filter
- This catches most solids, suspended particles, minerals, bacteria and coloured matter
- This step decreases the turbidity of the water
- The water produced should be clear
- If the color of the water is still not removed after this step then the following is done:
- The water is passed over charcoal
- The charcoal absorbs coloured matter into its surface

- This process is effective as virtually all particles larger than the specified pore size are removed

Note: Some advanced purification industries will use devices such as membrane filters. (see the next dotpoint for this)



Sanitisation - Chlorination

- This is the next step. However, note how it is not part of purification. Instead it is sanitation.
- Chlorination is the addition of chlorine to kill bacteria, viruses and pathogens
- The addition of chlorine gas forms hypochlorite ions which kill the microbes, bacteria, viruses and pathogens
$$\text{Cl}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{OCl}^-(\text{aq})$$
- This is quite effective in killing bacteria in microbes
- However, some microbes are chlorine immune and thus this process will not kill them
- The chlorine level needs to be monitored carefully as if it is too high it can cause the production of carcinogenic chlorinated alkanes, as well as being a skin irritant
- Too much chlorine also makes water smell and taste weird. Some people hate it.

Fluoridation:

- This is not part of improving water quality
- The water quality is already ensured after it has been purified and sanitised
- Rather this step is to improve dental health
- The government attempts to reduce the national health budget by adding fluoride into our water
- This way, since everyone drinks water, everyone's teeth will be healthier
- This is very smart and has been effective
- Fluoride is added to around 1ppm
- It strengthens tooth enamel and prevents tooth decay

Post-Treatment

- Some other steps then follow such as the adjusting of pH
- This is done by adding lime, sodium carbonate or hydrochloric acid
- Another step is the addition of disinfecting chlorine and ammonia to form monochloramine, a long-acting disinfectant

Assessment of effectiveness:

- I have written some points on effectiveness above already
- Sydney water treatment is largely effective, this is evident in:
 - Clean tap water
 - Continuous water testing reveals encouraging results that adhere to the standard healthy guidelines (this includes DO, BOD, Turbidity, pH, TDS, Hardness, concentration of ions)
 - Not many recorded doctor visits have shown illnesses directly linked to or caused by Sydney drinking water
 - Statistics show 99% of pathogens are removed, 99% of suspended particles are removed
- However, on the other side of the debate, there have been some concerns in the past
 - In 1998, Giardia and cryptosporidium were reported to be found in Sydney water
 - Sydney residents were advised to boil all water for human consumption
 - However, this is the only bigger scale outbreak

Assessment/Judgement: It is evident that overall, the processes of purification and sanitation of water have been largely effective

Need for collaboration:

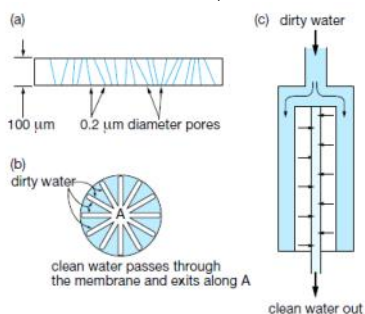
- This is not specified in the dotpoint, but the HSC can definitely ask the need for collaboration in preparing quality water
- Clearly, there are so many steps and one person can not do so much
- There must be experts in each field
- A diverse range of skills is required:
 - Microbiologists to monitor micro-organisms
 - Analytical chemists to perform analysis (e.g. volumetric analysis, gravimetric analysis)

- Production chemists to maintain and operate instruments and to supervise processes
- Environmental chemists to collect field samples (e.g. collecting water samples to give to analytical chemists to test)
- Chemical engineers to monitor and operate water and sewage plants
- These chemists must work together (collaborate) to ensure efficiency and to ensure effective treatment of water
- Working together / sharing resources also reduces costs

Note: If you have forgotten, this collaboration stuff refers to the very first dotpoint of chemical monitoring and management. (refer to previous)

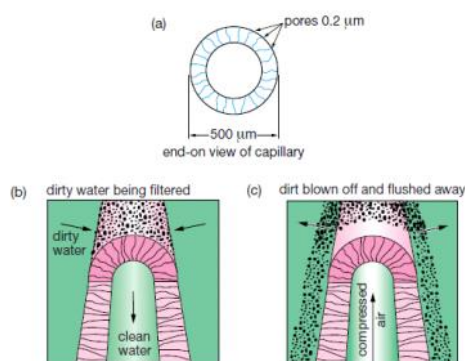
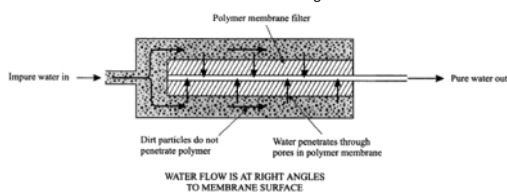
Describe the design and composition of microscopic membrane filters and explain how they purify contaminated water.

- These microscopic membrane filters can possibly be used in the filtration step (see above)
- This is an alternate to sand bed filters
- A membrane filter is an extremely fine filtering system where water is passed through a semi-permeable membrane
- The membrane is made of synthetic polymers such as cellulose acetate
- They have a pore size of below 500nm
- These filters can remove organic and biological particles including suspended solids, algae, faecal bacteria and protozoans such as cryptosporidium and giardia.
- The membrane filter can filter and disinfect the water in one step
- There are three main types (filters), based on the size of the pores:
 - Micro filtration (Can remove particles of 200-500nm)
 - Ultra filtration (Can remove particles of 2-100nm)
 - Nano Filtration (Can remove particles of <1nm)
- The membrane filter is structured as a sheet of porous polymer folded around a central rigid porous core and held in place by surrounding mesh
- It can also be structured as hollow capillaries that are housed inside a filtering unit



How it works:

- Pressure developed through either a pump, gravity or even a vacuum is used in order to force the water through the filter
- In the following structure of the membrane, water is pushed from the outside of the filter
- This results in clean water collected in the inside
- Dissolved substances can not be filtered using a membrane



Note: Water is made to flow across the membrane not through it. This reduces the blockage of the pores and contaminants are carried away as waste.

Note: Microscopic membranes are NOT used in Sydney as they are too expensive. And the sand bed filtration method is already proven very effective / much cheaper

Reverse osmosis

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 Metal tests:

Eutrophication:

- Organisms required **Phosphorus and nitrogen compounds**, however if there is too much this can be harmful
- Too much phosphorous or nitrogen compounds leads to **algal boom and eutrophication**
- Wikipedia has the following definition: **Eutrophication** or more precisely hypertrophication, is the ecosystem response to the addition of artificial or natural substances, such as nitrates and phosphates, through fertilizers or sewage, to an aquatic system.
- The excess nitrogen and phosphorous compounds enter water ways by:
 - **Fertilisers** being washed by rain and irrigation from **agricultural land** into rivers and lakes

- **Sewage discharge**
- **Laundry detergents** may also contain phosphorous and nitrogen nutrients (see saponification in Elective: industrial chemistry)

- **Algal bloom** is the problem, it is caused by eutrophication
- Initially, too much phosphate and Nitrogen levels leads to the rapid increase in algae (this is called algal bloom)
- The algal bloom results in a whole layer of **algae covering the surface of the water**
- This **prevents sunlight** from reaching deeper aquatic plants
- This also **prevents atmospheric oxygen from dissolving into the water**
- Thus this causes low oxygen levels as aquatic plants can not photosynthesise (create oxygen), nor can oxygen dissolve into the water
- When the blooms die, oxygen levels are used up (This is because bacteria use up the oxygen in breaking down the blooms)
- Now there is even less oxygen, the oxygen level is near depleted
- This causes **anaerobic decomposition** to occur (since there's no oxygen). Anaerobic decomposition releases smelly gases
- e.g. Hydrogen sulfide / methane
- In these conditions, **Cyanobacteria** and **anaerobic bacteria** also **release toxins** which kill aquatic life

Note: Cyanobacteria is known as blue-green algae. But it is not algae, it is bacteria. Cyno = Cyan = blue-green

Note: Eutrophication is a natural process, but it has been accelerated by humans. In this case eutrophication caused by humans is called cultural eutrophication

Measuring and monitoring Eutrophication:

- Eutrophication is measured by measuring the level of nitrogen and phosphorus
- Nitrogen levels are measured by the Kjeldahl method
- Nitrogen content of a water sample is measured by colourimetry.

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

- **catchment area**
- **possible sources of contamination in this catchment**
- **chemical tests available to determine levels and types of contaminants**
- **physical and chemical processes used to purify water**
- **chemical additives in the water and the reasons for the presence of these additives**

Note: Most of this dotpoint was covered in the above notes

- A catchment area is all the area supplied to by the river

Features of a particular catchment area:

- The Warragamba catchment area expands from the west at Lithgow all the way to the north at ____ and south at Goulburn
- Located about 65 kilometres west of Sydney in a narrow gorge on the Warragamba River, Warragamba Dam is one of the largest domestic water supply dams in the world.
- Water is collected from the catchments of the Wollondilly and Cox's River systems covering an area of 9,050 square kilometres to form Lake Burragorang and Warragamba Dam.

Introduction

Remember: These notes are NOT complete. There are still a few bits missing and have not been edited.

I have managed to compile up notes from a huge range of different sources (at least 20 different places), I have made my notes as detailed yet concise as possible. Unfortunately I can not disclose the sources where my information is from but please trust me in that they are valid and reliable. However, I did not just copy and paste from different sources. I rewrote almost everything based on a variety of sources to give the best possible answer to each dotpoint in the syllabus. I did copy and paste images, I am not an artist.

-Scott Zhou

*Focus Point 1 - Shrinking world resources

Discuss the issues associated with shrinking world resources with regard to one identified natural product that is not a fossil fuel, identifying the replacement materials used and/or current research in place to find a replacement for the named material
identify data, gather and process information to identify and discuss the issues associated with the increased need for a natural resource that is not a fossil fuel and evaluate the progress currently being made to solve the problems identified

Natural Sources of Rubber and the lack of supply:

- Natural rubber is obtained and produced from the sap of many plants, principally the rubber tree.
- Rubber trees are native to South America, but in the late 19th century, it spread to the tropical regions of Asia
 - These were non developed areas where supply was hard to obtain
- Rubber was being used for gloves, adhesives, convey belts, erasers, rubber bands and many other products
- However, the main use of Rubber is mainly in **car Tyres**.
- As the demand of rubber increased during the **1980s** due to the expansion of the **motor industry**
 - The production could not keep up with the demand
- During WWII, world supplies of natural rubber decreased
 - Japan was controlling the rubber-producing areas (Asia)
- As a result, **demand increased, supply decreased**
 - The price of natural rubber went up, and it became a **shrinking world resource**

Note: The term "shrinking world resource" in this case means that demand can not keep up with supply, it does not mean that the world is running out of rubber trees.

Issues associated with increasing need for natural rubber:

- Primitive harvesting methods could not keep in pace with demand
- Reliability of supply was poor
 - Caused by shortage of labour as well as dependence on imports and weather problems
- Price increased
 - As demand increased, companies that supplied it had increased price controls
- During WWII, Japan cut off supply of natural rubber
- The development of synthetic rubber has solved the above problems

Synthetic replacement of rubber:

- Evidently, due to the high demand and low supply, a new replacement material was needed
- Scientists in Germany and the US developed synthetic rubber from **fossil fuels**
- The first and most common was **Styrene butadiene (SBR)** it is:
 - An addition polymer made from styrene and butadiene
 - It is arranged as: $[BBBS]_n$

SBR (replacement)	Rubber
80% of today's rubber	Small percentage of today's rubber
More chemically resistant	Less chemically resistant
Physically more durable	Physically less durable
Cheaper to produce	More expensive to produce
NON renewable (see below)	Renewable
-Produced from fossil fuels	- produced from plants

Synthetic rubber - a non renewable resource:

- Even though synthetic rubber solves the problems of previous rubber, it is a non renewable resource itself
 - This is because it is produced from fossil fuels (non renewable)
- Thus, this non-renewable resource may become a "shrinking world resource" in itself, eventually running out of supply
- It is evident that further new methods are to be developed in the future

Potential biomass replacement:

- In **June 2012**, **Bridgestone** corporation announced that had produced synthetic rubber from **biomass**
 - This could **potentially be a cost-effective replacement** as Biomass is renewable, easy to produce and biodegradable (see POM for biomass)

Evaluation / Assessment:

There has been **significant progress** in solving the issues of rubber. Synthetic rubber has solved the issue of the higher demand and low supply of natural rubber. Synthetic rubber such as SBR is also superior to natural rubber as it is more chemically resistant, physically durable and cheaper to produce. Significant research has also been done into the use of Biomass which is renewable and will solve the non-renewable issue of synthetic rubber. Hence it is evident that there has been **great progress** and research into solving the problems associated with rubber.

*Focus Point 2 - Qualitative equilibrium

Explain the effect of changing the following factors on identified equilibrium reactions
pressure, volume, concentration, temperature

- This dot-point should be simple revision (boring Le Chatelier we meet again)
- The following is **copied and pasted** from my Le Chatelier principle notes for the acidic environment:

Le Chatelier's principle:

- In 1885, the French chemist, Le Chatelier, put forward a principle for predicting the effect of change on reversible reactions:
- In any chemical system in equilibrium is subjected to a change in pressure, volume, concentration or temperature, then the system will react in the direction to minimise that change
- i.e. A system will be kept at equilibrium even if there is a **disturbance**
- Disturbances include a **change in temperature, pressure, volume and concentration**
- The system will go back to dynamic equilibrium (it does not reach equilibrium but minimises the disturbance)

Concentration:

- When a substance is more concentrated in the reaction, the reaction will shift to reduce this concentration
- If the **reactants** are more concentrated, then the rate of **forward reaction** will increase
- If the **products** are more concentrated, then the rate of the **reverse reaction** will increase

Pressure / Volume:

NOTE: In an exam, **DO NOT** talk about volume, explain in terms of pressure. (unless asked otherwise)

- Volume is only used here so it is easier to understand, **DO NOT** use volume in an exam.

- When there is **more volume** in a system and thus **less pressure**, the reaction will shift to **spread out** into the new volume
- When there is **less volume** in a system and thus **more pressure**, the reaction will shift to **compact into** the new volume
- Consider $A+B \rightleftharpoons 2C + D$ (assume all are gases)
 - If the volume is increased (pressure decreased), more molecules are required to fill up this space
 - Thus a forward reaction is favored because this forms 3 moles of gas compared to 2 moles in a reverse reaction (**more moles = more space taken**)
- Similarly, if the volume is decreased (pressure increased), molecules need to fill up a smaller space and thus there should be less molecules
- Thus a reverse reaction is favored because this forms 2 moles of gas compared to 3 moles in a forward reaction (**less moles = less space taken**)

Temperature:

- Consider the reaction $A+B \rightleftharpoons C + D + \text{Heat}$
- The reaction is exothermic, meaning as A and B convert into C and D, heat is released, raising the temperature of the whole system
- If an **increase** of temperature was applied, Le Chatelier's principle states that the system will try to **cool itself down**
- This is done by favoring the reverse reaction, as it is endothermic (the reverse of an exothermic reaction is endothermic, vice versa), the excess heat is absorbed and stored into chemical energy (the system is cooler now)
- If a **decrease** of temperature was applied, Le Chatelier's principle states that the system will try to **warm itself up**
- This is done by favoring the forward reaction, as it is exothermic (the reverse of an exothermic reaction is endothermic, vice versa), the heat required is released from chemical energy as a reactant, in order to heat the system (the system is warmer now)

Remember: the ionisation of acids are exothermic, any dissolution of gas in water is exothermic
 e.g. $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$ ΔH is negative

In an exam:

- Write down the **equation**
- State what the **disturbance** is (i.e. adding more temperature or more concentration of reactant)
- Refer to **Le Chatelier's principle** and equilibrium disturbed
- State that the system will oppose or **minimise the disturbance** / change
- State the **system reaction** (i.e. attempt to decrease temp, make more moles of gas)
- State the direction the system will thus react in, **where the equilibrium lies**. Refer to **equation**.
- If temperature question, mention **exothermic and endothermic** (forwards / backwards reaction).
- If pressure question, mention the **number of moles** on each side.
- State the **Results**. (thus more of ____ is produced, and less of ____)
- Refer to **rates of reaction** or **yield of products** if necessary.

Interpret the equilibrium constant expression (no units required) from the chemical equation of equilibrium reactions
Identify that temperature is the only factor that changes the value of the equilibrium constant (K) for a given equation
Process and present information from secondary sources to calculate K from equilibrium conditions

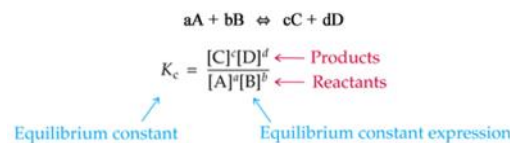
Equilibrium constant expression:

NOTE: The reaction has to be an **EQUILIBRIUM REACTION**. (double arrow)

- Consider $aA + bB \rightleftharpoons cC + dD$
- By convention, the left hand side is the reactants, the right hand side is the products
- Regardless of the direction, this is true. Thus,
- Equilibrium expression: A **qualitative** / Descriptive way of talking about the equilibrium system
- $K = \frac{[\text{Products}]}{[\text{Reactants}]}$
- $= \frac{[C]^c [D]^d}{[A]^a [B]^b}$

Note: THIS EXPRESSION MUST BE WRITTEN FIRST BEFORE CALCULATION

Note: DO NOT INCLUDE SOLIDS when writing the expression or calculating the constant.



Equilibrium Constant:

- Equilibrium constant: a **quantitative** value
- Substitute the concentrations into the expressions to obtain a value
- The equilibrium constant is **ONLY** affected by the temperature
- A reaction has different constants at different temperatures
- However, the expression is the same.
- Note:** DO NOT INCLUDE SOLIDS when writing the expression or calculating the constant. This is because solids DO NOT participate in an equilibrium reaction. (Gases and aqueous only)

Calculation of Equilibrium constant (ice box):

- The ice box method is easy to use when calculating equilibrium constants
- The following is an example:



This equilibrium is within a 2L container. At equilibrium, 0.2 mol of I_2 were present. Calculate the value of k (the equilibrium constant)

We can use the Ice table to calculate K, making a table like this one, and filling in everything that is known. Clearly, 1 mol of HI in 2L has a concentration of 0.5 mol/L. By using stoichiometric ratios and the fact that $I + C = E$, we work out the concentrations of all the substances:

	HI(g)	H ₂ (g)	I ₂ (g)
Initial (I) conc.(mol/L)	0.5	0	0
Change (C) in conc. (mol/L)	-0.2	+0.1	+0.1
Equilibrium (E) conc. (mol/L)	0.3	0.1	0.1

Note: It is the Change in Concentration (C) (middle row) in which -the stoichiometric ratios will apply. NOT THE OTHER ROWS!

Note: Always start with 0 products, the change in reactant should always be -ve and the change in products always positive

- If the reaction in play is a reverse reaction, then write the equation reversely and use the "products" as the reactants

Thus we can first write the equilibrium expression as: $k = \frac{[H_2][I_2]}{[HI]^2}$

Then, we can sub in the values from the ice box and calculate: $k = \frac{0.1 \times 0.1}{0.3^2} = 0.1$

Note: ALWAYS write the equilibrium expression first. WITHOUT substituted values.

Note: ALWAYS show the substitution line second WITHOUT calculation

Interpreting K (Equilibrium constant):

- $K > 1$ There are more products than reactants. Equilibrium favours products (RHS)
- $K \approx 1$ There are approx equal concentration of products and reactant. Equilibrium is centred
- $K < 1$ There are less products than reactants. Equilibrium favours reactants (LHS)
- Note:** Be careful, the above is **NOT true**. (Even though teachers say it is)
- A lower concentration can be raised to a higher power, creating a higher number, thus the K constant can be misleading if thought of in the above way.
- Note:** Different K values can not be compared with each other as the **UNITS may not be the same**
- K Values do actually have units, they are just omitted for simplicity.

- Must have LEGENDS (key) if drawing a concentration graph

Identify data, plan and perform a first-hand investigation to model an equilibrium reaction

Thought experiment:

- Tennis analogy - Coan
- One player has all the tennis balls at the start
- The person on the other side has no balls

- Once the balls are thrown, the other player tries to throw the balls back
- Eventually a state of equilibrium is reached where no player can have all the balls on one side.

Modelling practical

<<insert prac report>>

Part A:

1. Construct a table to record your results
2. Make the measuring cylinder A and B. Fill measuring cylinder A with water to the 100mL mark.
3. Place the large pipette upside-down (tip upwards) into A so that it rests vertically on the bottom. Seal the tip tightly with your finger and transfer its contents to measuring cylinder B without spillage.
4. Place the smaller pipette upside-down into B. Seal and then transfer its contents back to A. This completes one 'transfer cycle'
5. Measure the volume of water now present in each cylinder to the nearest mL. Record this in your results table.
6. Repeat steps 3-5 for 30 cycles, recording the volumes for each cycle.

Advantages	Disadvantages
Forwards and backwards reaction rates are equal	A real chemical reaction is not occurring, products / reactants stay the same - Model only has water, does not show chemical reaction
Reacts to changes in equilibrium (volume) - Application of Le Chatelier's principle	Does not react to changes in temperature
Gives a visual representation helping students - Some people are visual learners	Oversimplified, does not represent the constant microscopic forward and reverse reactions
Gives a hands-on experience - Some students have had hands on learners	

Questions to consider:

Observations: Describe the shape of the 2 lines on your graph

Conclusions:

1. In the last few cycles, when the volumes of A and B were not changing, what can be concluded about the amounts being transferred from A → B, B → A?
2. Would you describe this as "dynamic equilibrium"?
 - There are still transfers from A to B and from B to A, but no change in the volumes in each tube.
 - Thus it is dynamic
3. What happened when the equilibrium was disturbed?
 - Both cylinders eventually reached the same volume
 - One volume increased, one decreased
 - It acted to reverse the change.
4. Calculate the ratio of the 2 equilibrium states: Water (B) / Water (A) (2 sig figs)
 - This ratio corresponds to the equilibrium constant.
5. Describe ways in which this is analogous to a chemical system reaching and achieving equilibrium
 - Both reach dynamic equilibrium
 - Both can only reach equilibrium if the system is closed
 - When both systems were disturbed, it responded in a way to reverse the change (LCP)
 - Even though the volumes were different for the two cylinders at equilibrium, the ratio was constant. Same as chemical equilibrium. (IF TEMP IS SA2ge hunters ME)
 - In both systems, rates depended on the concentrations of the products / reactants.
6. How does this differ to a real equilibrium?
 - Not affected by pressure (only applies to gases)
 - Chemical reactions are microscopic, but you can see this experiment
 - No chemical reaction, no new products formed
 - Can't show if exothermic or endothermic, can't see effect of temperature
 - Forward and reverse reactions do not happen in the same time

Validity of this model: (2011 hsc question):

Choose equipment and perform a first-hand investigation to gather information and qualitatively analyse an equilibrium reaction

Risk assessment:

Identify	Assess	Control
Iron (III) chloride and ammonium thiocyanate solutions	These solutions are moderately poisonous	Wear safety goggles and glasses Wash hands if solution spills
Hot water	Hot water can harm skin	Have cold water running nearby Handle with care Wear safety gloves

Method:

1. Make a solution by mixing 2mL of 0.1M Iron (III) Chloride solution with 2mL of 0.1M ammonium thiocyanate solution
2. Make the total volume 20mL with deionised water



Note: This is the same equation/ reaction as the confirmatory test for Fe³⁺ ion testing in chemical monitoring and management

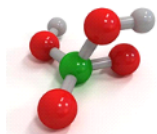
3. Divide the 20mL solution evenly between six test tubes
4. Impose the following changes to a test tube each. Leave one test tube.
 - Add 5 drops of 0.5 M Iron (III) chloride solution
 - Add 5 drops of 0.5M Ammonium Thiocyanate solution
 - Add 5 drops of 0.5 M Sodium Hydrogen Phosphate solution
 - Warm a mixture in a water bath
 - Cool the mixture in an ice bath
5. The last test tube acts as a control, which colour changes can be compared to:

Results:

Action	Observation	Explanation
Add 5 drops of 0.5 M Iron (III) chloride solution	Solution turns from red to deeper red • Test tube warmer	Equilibrium shifts forward producing more FeSCN ²⁺ ions which are red in solution. The forward reaction is exothermic, so the test tube warms up.
Add 5 drops of 0.5M Ammonium Thiocyanate solution	Solution turns from red to deeper red • Test tube feels warmer	Equilibrium shifts forward producing more FeSCN ²⁺ ions which are red in solution. The forward reaction is exothermic, so the test tube feels warmer
Add 5 drops of 0.5 M Sodium Hydrogen Phosphate solution	Solution turns from red to lighter red • Test tube feels colder	The PO ₄ ³⁻ ions react with the Fe ³⁺ ions - This causes the equilibrium to shift in the reverse direction - Less FeSCN ²⁺ ions which are red in solution Note: The Fe(PO ₄) ₂ ion that forms is colorless in solution The reverse reaction is endothermic, so the test tube feels colder
Warm a mixture in a water bath	Solution turns from red to lighter red	Equilibrium shifts in the reverse direction to absorb all the excess heat - Less concentration of FeSCN ²⁺ ions which are red in solution

Cool the mixture in an ice bath	Solution turns from red to deeper red	Equilibrium shifts forward to release heat - More concentration of FeSCN^{2+} ions which are red in solution
---------------------------------	---------------------------------------	--

*Focus Point 3 - Sulphuric acid / Frash Process / Contact process



Outline three uses of sulfuric acid in industry

Uses:

Use	Outline
Clean Metals	Sulphuric acid is used to clean pieces of metal - This is necessary before the piece of metal can be galvanised or coated in general
Making fertiliser	In a coke oven, sulphuric acid can extract ammonia from a mixture of gases by reacting with the gas. - This is later used to produce ammonium sulphate fertiliser - $2\text{NH}_3(\text{g}) + \text{H}_2\text{SO}_4(\text{l}) \rightarrow (\text{NH}_4)_2\text{SO}_4(\text{s})$ Sulphuric acid also converts insoluble phosphate into soluble mixture which can be used in phosphate fertilisers
Dehydrating agent	<ul style="list-style-type: none"> Concentrated sulphuric acid is a powerful dehydrating agent It is used to increase yield and act as a catalyst during esterification (see Acidic environment) It also dehydrates ethanol into ethylene and water (see Production of materials)

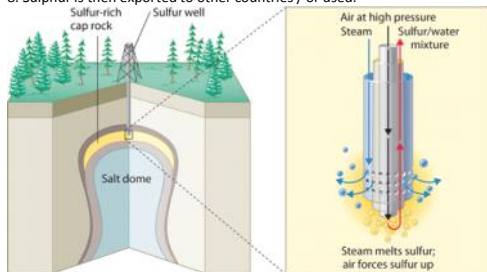
Describe the processes used to extract sulfur from mineral deposits, identifying the properties of sulfur which allow its extraction and analysing potential environmental issues that may be associated with its extraction

Note: The Frasch process is **NOT USED IN AUSTRALIA**. Since SO_2 can be mined in Australian mines, rather than produced from extracting sulphur and reacting it with oxygen. (see later)

The Frasch Process:

- The process of extracting sulphur from **mineral deposits**
- Elemental sulphur deposits are found in **volcanic or sedimentary areas** of Italy, USA, Russia and the Ukraine.

- Holes are drilled down through the overlying rock to the sulphur deposit.
- A series of circular pipes (3 concentric pipes) are inserted into the hole.
- Superheated steam / water is pumped down the outer most pipe
 - This melts the sulphur (see properties), combining with it to make an emulsion (see properties)
- Compressed air is sent down the innermost pipe
 - This pressurises the sulphur emulsion, forcing it up the innermost pipe
- The Sulphur-water emulsion, moves up the middle pipe (see properties)
 - This forms a foam / airted slurry
- This is then connected to a cooling tank, which cools the emulsion, forming solid sulphur. (98% pure) (see properties)
- Sulphur is emitted and crystallised into "flowers of sulphur"
- Sulphur is then exported to other countries / or used.



Properties of sulphur allowing the Frasch Process:

Property	Use
Sulphur is unreactive with water Sulphur is insoluble	Sulphur-Water emulsion Separates quickly when cooled, 98% pure sulphur is obtained
Sulphur has low density	Emulsion can be easily lifted to the surface by the compressed air
Sulphur has low melting point of 113 degrees C	Allows the superheated steam to melt the sulphur

Note: In an exam, mention these properties and how they allow the extraction of sulphur.

Difficulties / environmental issues:

Issue	Explanation	Way to overcome
Sulphur may oxidise to form SO_2 or reduce to form H_2S	Both SO_2 and H_2S are chemical pollutants SO_2 can form acid rain which causes many problems (refer to acidic environment)	Make sure not exposed to air Care must be taken to ensure no oxidation or reduction of sulphur
Water may contain dissolved impurities	The superheated steam which is used in the Frasch process may have remains of other elements / sulphur in it	Water should be reused, not discharged into environment
Heat	The heat from the superheated steam and the water may lead to thermal pollution of the surrounding environment	
Caverns	The Frasch process leads to caverns in the ground These "holes" are very hard to backfill This makes the land unusable and unbuildable.	

- In USA, many sulphur deposits are on quick sand, making it hard to set up equipment, or transport.

The extraction of sulphur from mineral deposits (non Frasch process):

- As well as the Frasch Process, sulphur can also be extracted from minerals.

- In Australia, there are no deposits of element sulphur, so to make sulphuric acid, sulphur dioxide is obtained
- This is done by the roasting of mineral sulphides such as iron sulphide or lead sulfide:
 - $2\text{FeS} + 2\text{O}_2 \rightarrow 2\text{FeO} + \text{SO}_2$
- Thus sulphur dioxide is obtained without oxidising sulphur obtained from the Frasch process.
- This **avoids the difficulties and environmental issues stated above**

Note: This is **important to know** as the 2003 HSC marking criteria for a certain question was looking for this information

- Of course, everyone got owned.

Outline the steps and conditions necessary for the industrial production of H_2SO_4 from its raw materials

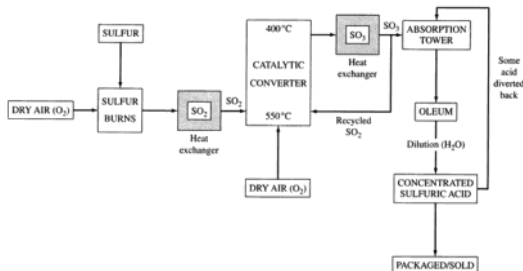
Describe the reaction conditions necessary for the production of SO_2 and SO_3

Apply the relationship between rates of reaction and equilibrium conditions to the production of SO_2 and SO_3

Gather, process and present information from secondary sources to describe the steps and chemistry involved in the industrial production of H_2SO_4 and use available evidence to analyse the process to predict ways in which the output of sulfuric acid can be maximised

Overview:

- After Sulphur is obtained from the Frasch process, there are still 4 more steps to go until sulphuric acid is produced
- The steps are illustrated below in the flow chart:



Equations:

- Step 1: $\text{S}_{(\text{s})} + \text{O}_{2(\text{g})} \rightarrow \text{SO}_{2(\text{g})}$
- Step 2: $2\text{SO}_{2(\text{g})} + \text{O}_{2(\text{g})} \xrightarrow{\text{vanadium pentoxide catalyst}} 2\text{SO}_{3(\text{g})}$ (Rate determining step) $\Delta H = -99\text{kJ/mol}$
- Step 3: $\text{SO}_{3(\text{g})} + \text{H}_2\text{SO}_{4(\text{l})} \rightarrow \text{H}_2\text{S}_2\text{O}_7(\text{l}) \leftarrow \text{Oleum}$
- Step 4: $\text{H}_2\text{S}_2\text{O}_7(\text{l}) + \text{H}_2\text{O}_{(\text{l})} \rightarrow 2\text{H}_2\text{SO}_{4(\text{l})}$

- The **rate determining step** is the second step.
- This is the important step where we must consider how to compromise between rate and yield
- It is this step that is known as the **contact process**

Step 1: Combustion of sulphur into sulphur dioxide:

- $\text{S}_{(\text{s})} + \text{O}_{2(\text{g})} \rightarrow \text{SO}_{2(\text{aq})}$
- This step is a combustion reaction
- Sulphur is melted and sprayed into a combustion chamber
- There is an excess of dry air
- Dry air **ensures acid mist is not created** which can corrode pipes
- When produced, the SO_2 is at a temperature of 1000°C which must be cooled down to 400-450°C

Note: This step happens in a **furnace**

Step 2: Catalytic oxidation of sulphur dioxide into sulphur trioxide (Contact process)

- This is the most important step for us to learn, it is the rate determining step
- This is because it is an equilibrium reaction. Yyyyy Lachattier again!



- The catalyst used is Vanadium Pentoxide (V_2O_5)
- The SO_2 is mixed with air with Vanadium Pentoxide forming sulphur trioxide
- The catalyst beds increase the surface area and thus promote a **faster reaction rate, but NOT A HIGHER YIELD.**
- Of course the reaction conditions must be manipulated to **increase yield.**
- **Low temperatures** (450): The reaction is exothermic, according to LCP, by lowering the temperature the system will favour the forward reaction in order to increase its temperature. This promotes a higher yield of product. (However a temperature too high would require too much energy / money, a delicate balance is reached)
- **Slightly high pressure:** A higher pressure, according to LCP will favour the forward reaction as there are 3 moles of gas on the products side and 2 moles on the reactants side. The equilibrium will lie to the left to attempt to reduce the pressure and thus there will be more yield of SO_3 (However, this effect is minimal, and a pressure too high will cause safety risks (see Haber process))
- **Excess Oxygen:** A small excess of oxygen is used to promote a higher yield of SO_3 . According to LCP, by increasing the concentration of the reactants (oxygen), then the system will favour the forward reaction in order to achieve a new equilibrium. Thus more yield of SO_3 . (The air to SO_2 ratio is 5:1, meaning the Oxygen to SO_2 ratio is 1:1)

Note: This step happens in a **converter**

Step 3: Absorption of Sulphur trioxide to form Oleum



- Sulphur Trioxide is dissolved in pure sulphuric acid to form Oleum
- Oleum is $\text{H}_2\text{S}_2\text{O}_7$, it is a liquid state. It is also known as fuming sulphuric acid or Nordhausen acid
- This step is done in an absorption tower (shown below)



- From the acidic environment topic we learnt that $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$
- Whilst this is true, we do not use this method, instead we use a round about method (producing oleum first)
- This is because the reaction of adding SO_3 to water is highly exothermic, which is a dangerous procedure
- It also creates sulphuric acid mist which is dangerous and **hard to collect**

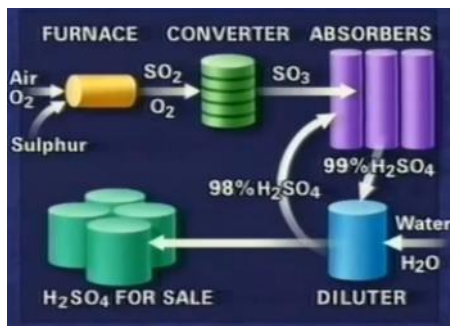
Note: This step happens in an **absorber**

Step 4: Conversion of Oleum to sulphuric acid:



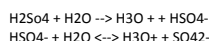
- The oleum is mixed with water to form Sulphuric acid
- The yield of acid at the completion of the process is about 98% v/v and the final concentration is usually about 18 mol L⁻¹.

Note: This step happens in a **diluter**.



Describe and explain the exothermic nature of sulfuric acid ionisation

- When water is added to sulphuric acid, it becomes ionised
- The reaction is highly exothermic:



Overall equation: $\text{H}_2\text{SO}_4 + 2\text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{SO}_4^{2-}$ $\Delta H = -90 \text{ kJ/mol}$

- The reaction is highly exothermic because _____

Identify and describe safety precautions that must be taken when using and diluting concentrated sulfuric acid
Use available evidence to relate the properties of sulfuric acid to safety precautions necessary for its transport and storage

Storing:

- Stored on a ceramic dish - ensuring drops do not contact other surfaces
- Stored in airtight container since it will absorb water from atmosphere
- Stored and transported in containers which are physically strong
 - to avoid breakage
- Storing in containers which withstand corrosion
 - if acid comes in contact with water, a dangerous reaction will result (exothermic)
- Kept away from organic material, e.g. wood
 - will dehydrate and cause wood to combust
- Have Sodium bicarbonate nearby to neutralise spills

Precaution	Property
Airtight Container	Absorbs water from air
Ceramic Dish	Highly corrosive, ensuring drips do not contact the bench itself
Stored in Glass containers	Highly Corrosive, Oxidising agent
Away from organic material e.g. wood	Dehydrating agent: Acts to dehydrate wood Causes combustions

Diluting:

- Wear safety glasses and a lab coat because sulphuric acid causes serious damage to skin and eyes
- The number one safety rule is to **add acid to water**, not water to acid.
 - Remember: Acid to water, in that order (rhymes.. Sort of.. Lol)
- Make sure you add SMALL volumes of acid to a LARGE amount of water
- This is because the reaction of concentrated sulphuric acid and water is highly exothermic
- This causes boiling or spluttering which may cause serious harm.
- Have Sodium bicarbonate nearby to neutralise spills

Precaution	Property
Safety Glasses	Sulphuric acid is Highly Corrosive
Apron	- Harms Skin
Lab coat	Dehydrating agent: can destroy living tissue
Add little acid to large amounts of water	Highly exothermic reaction with water - Boiling, spluttering, may cause harm

Transporting:

- Transported in concentrated form
 - Concentrated form is mostly molecular, meaning there are **very few ions to attack other material**
- Stored in steel drums
 - Sulphuric acid does not react with the steel drums due to the formation of a passivating layer of iron(III) Sulphate
 - Steel is also stronger than glass
- Kept away from water
 - Water and sulphuric acid form a highly exothermic reaction which can melt the containers
 - The water might dilute the sulphuric acid, which can cause a vigorous exothermic reaction with the steel (as opposed to the passivating layer formed by concentrated sulphuric acid)

Precaution	Property
Concentrated form	- Concentrated form is mostly molecular, few ions to attack containers
Steel Drums	- Sulphuric acid does not react with the steel drums due to the formation of a passivating layer of iron(III) Sulphate
Stored away from water	Dilute sulphuric acid (ionised) will react with the steel Water and Sulphuric acid form a highly exothermic reaction

Perform first-hand investigations to observe the reactions of sulfuric acid acting as:

- **an oxidising agent**
- **a dehydrating agent**

Note: These experiments are dangerous, (Sulphuric acid and SO₂), **teacher demonstration only**

Oxidising agent: Copper + Sulphuric Acid

1. Add a few drops of Conc. Sulphuric acid to a granule of copper in a test tube in a fume cupboard
2. Add 5ml of dilute sulphuric acid to a granule of copper in a test tube

3. Observe and compare the two test tubes, record observations

- Both Aqueous and Concentrated Sulphuric acid was added to Copper

Aqueous: $\text{Cu(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{CuSO}_4(\text{aq})$

Observation: A blue solution forms

The gas released can be tested by the hydrogen pop test.

Concentrated: $\text{Cu(s)} + 2\text{H}_2\text{SO}_4(\text{l}) \rightarrow 2\text{H}_2\text{O(l)} + \text{SO}_2(\text{g}) + \text{CuSO}_4(\text{aq})$

Observation: A blue solution forms

The gas released can be tested by using a litmus paper. SO_2 is acidic and turns blue litmus red.

Dehydrating Agent - Dehydrating of Copper Sulphate PentaHydrate and BBC Prac

- Add enough Conc sulphuric acid to cover 3g of copper sulphate pent-hydrate in a test tube
- Observe reaction
- Repeat for Sucrose

- $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + 5\text{H}_2\text{O}$

Observation:

- Turned from Blue (copper sulphate penta hydrate), to white (copper sulphate)

- Stop having a dirty mind, BBC stands for big black carbon.
- The BBC prac involved the dehydration of Sucrose
- $\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s}) \rightarrow (\text{conc H}_2\text{SO}_4) \text{12C(s)} + 11\text{H}_2\text{O(g)}$
- The initially white sugar turned black and started growing out of the test tube

Risk assessment:

Identify	Assess	Control



*Focus point 4 - Sodium Hydroxide

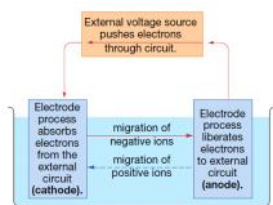
Explain the difference between galvanic cells and electrolytic cells in terms of energy requirements

Comparison: Electrolytic vs Galvanic

- Electrolysis is required in the production of sodium hydroxide.
- Electrolytic cell is just a fancy way of saying that electrolysis is occurring.
- Electrolysis is the process in which an electric current is used to bring about a chemical reaction which does not occur spontaneously
- I.e. a chemical reaction is driven by a supplied voltage
- The suffix -lysis comes from the Greek stem meaning to loosen or split up.
- Electrolysis literally uses an electric current to split a compound into its elements.
- If any two half equations are written down, the voltages are added:
- If the cell voltage is positive, it operates as a Galvanic Cell (Spontaneous)
- If the cell voltage is negative, it operates as an Electrolytic Cell

Galvanic Cell (can refer to topic 1)	Electrolytic Cell
Energy Requirements (syllabus Point): Requires chemical energy	Energy Requirements (Syllabus Point): Requires electric energy
Produces electricity	Uses electricity
2 Electron transfer (redox) reactions occurring	2 Electron transfer (redox) reactions occurring
Energy Change: Chemical - Electrical	Energy Change: Electrical-Chemical
Anode Oxidises, Cathode Reduces	Anode Oxidises, Cathode Reduces
Anode (-), Cathode (+)	Anode (+), Cathode (-)
Reaction occurs spontaneously	Reaction does not occur spontaneously
Electrons flow through external circuit Cathode → Anode	Electrons flow through internal circuit Cathode → Anode
$E^0 > 0$	$E^0 < 0$
Salt Bridge Present	No Salt bridge necessary

An electrolytic cell:



Analogy of the battery (Mr Kay):

- Imagine a battery:

Balancing redox reactions:

Identify data, plan and perform a first-hand investigation to identify the products of the electrolysis of sodium chloride

<<Insert prac report>>

Risk Assessment:

Identify	Assess	Control
NaOH	It is caustic and causes skin and eye damage	Wear Safety glasses
Chlorine gas	Poisonous when inhaled	Perform experiment in a fume cupboard or a well-ventilated area
Hydrogen gas	Explosive in the presence of a spark or flame	Keep flames and sparks away, and ensure good ventilation

Method:

- A U-Glass tube (youtube) was filled with a dilute (0.1M) solution of NaCl
- A few drops of phenolphthalein was added
- Two graphite electrodes were dipped into the solution, at each end connected to a power source
- Litmus paper was dipped at each end of the U tube next to each electrode
- The power source was turned on and observations were recorded
- The experiment was repeated for concentrated NaCl (2M)
- The experiments (both dilute and concentrated) were then repeated three times to assess reliability

Results / Observations:

	Dilute	Concentrated
Anode	<ul style="list-style-type: none"> Bubbles produced - indicating gas produced Litmus paper was red Phenolphthalein was colorless - These two indicate an acidic condition which indicates the presence of H⁺ ions. - $2\text{H}_2\text{O(l)} \rightarrow \text{O}_{2(\text{g})} + 4\text{H}^+_{(\text{aq})} + 4\text{e}^-$ 	<ul style="list-style-type: none"> Bubbles produced - indicating gas produced Litmus paper was red Phenolphthalein was colorless - These two indicate an acidic condition which indicates the presence of H⁺ - $2\text{H}_2\text{O(l)} \rightarrow \text{O}_{2(\text{g})} + 4\text{H}^+_{(\text{aq})} + 4\text{e}^-$ However, litmus paper was also bleached, indicated Chlorine gas A strong smell is released $\text{Cl}^- \rightarrow 1/2\text{Cl}_{2(\text{g})} + \text{e}^-$
Cathode	<ul style="list-style-type: none"> Bubbles produced - indicating gas produced Litmus paper was blue Phenolphthalein was pink - These indicate a basic condition which indicates the presence of OH⁻ ions - $2\text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-_{(\text{aq})}$ 	<ul style="list-style-type: none"> Bubbles produced - indicating gas produced Litmus paper was blue Phenolphthalein was pink - These indicate a basic condition which indicates the presence of OH⁻ ions - $2\text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-_{(\text{aq})}$

Analyse information from secondary sources to predict and explain the different products of the electrolysis of aqueous and molten sodium chloride

- Products obtained from the electrolysis of sodium chloride **vary**, depending on the **reaction conditions**

Concentrated Aqueous Solution (used in production of NaOH):

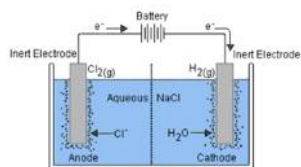
- When concentrated solution of NaCl (> 2M) the following reactions occur:

Oxidation Equation: $\text{Cl}^- \rightarrow 1/2\text{Cl}_{2(\text{g})} + \text{e}^-$

Reduction Equation: $2\text{H}_2\text{O(l)} \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-$

Overall Equation: $2\text{H}_2\text{O(l)} + 2\text{Cl}^- \rightarrow \text{Cl}_2 + \text{H}_2 + 2\text{OH}^-$

Overall Equation with Spectator Ion: $2\text{NaCl(aq)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Cl}_{2(\text{g})} + \text{H}_{2(\text{g})} + 2\text{NaOH(aq)}$ <--- used in production of Sodium Hydroxide



Dilute Aqueous Solution:

- When a dilute solution of NaCl (0.1M) is electrolysed the following reactions occur:
- Water is oxidised instead of chloride

Oxidation Equation: $2\text{H}_2\text{O(l)} \rightarrow \text{O}_{2(\text{g})} + 4\text{H}^+_{(\text{aq})} + 4\text{e}^-$

Reduction Equation: $2\text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-_{(\text{aq})}$

Overall Equation: $6\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 2\text{H}_{2(\text{g})} + 4\text{OH}^-_{(\text{aq})}$

$2\text{H}_2\text{O(l)} \rightarrow 2\text{H}_{2(\text{g})} + \text{O}_{2(\text{g})}$

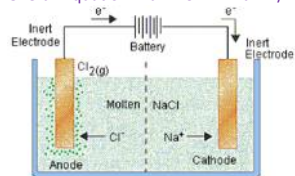
Molten NaCl

- Solid NaCl, like all salts, does not conduct electricity
- Thus we use the molten state to conduct electricity on **PURE** NaCl
- To obtain molten state, the salt is **heated until it melts (above 801 degrees Celsius)**
- The Cl⁻ ions approach the anode and are oxidised to form Cl₂(g)
- The Na⁺ ions approach the cathode and are reduced to form Na
- Thus the net effect and purpose of this electrolysis reaction is to **decompose NaCl into Na metal and Cl₂ Gas**.
- Clearly this can not be performed in a school laboratory

Reduction Equation: $\text{Na}^+ + \text{e}^- \rightarrow \text{Na(l)}$

Oxidation Equation: $\text{Cl}^- \rightarrow 1/2\text{Cl}_{2(\text{g})} + \text{e}^-$

Overall Equation: $\text{Na}^+ + \text{Cl}^- \rightarrow \text{Na} + \frac{1}{2}\text{Cl}_2$



Note: This is **MOLTEN PURE NaCl**, thus water is not present and thus there will be no oxygen or hydrogen gas formed

Explanations:

- The Reduction reactions are either Sodium ions or water
- In molten there is no water - thus the reduction of sodium ions
- In aqueous solutions water is reduced instead (This is because water is a lot easier to reduce than sodium ions)
- The Oxidation reactions are either Chlorine ions or water
- In molten there is no water - Thus the oxidation of chlorine ions
- Chloride and water are both easy to oxidise, Thus the **concentration** determines the oxidation reaction
- In concentrated, there is more concentration Cl ions and thus Cl is oxidised
- In dilute, there is less concentration Cl ions, thus H₂O is oxidised

Outline the steps in the industrial production of sodium hydroxide from sodium chloride solution and describe the reaction in terms of net ionic and full formulae equations

Overview:

- **Caustic soda** is a common name for Sodium hydroxide
- The main process of production is called the chloralkali Process (don't need to know this name)
- There are **three** main industrial processes used to produce sodium hydroxide:
 - The Diaphragm Cell
 - The Mercury Cell
 - The Membrane Cell
- Caustic Soda (NaOH) is important as it has many uses in **industry**
- It acts as a **strong chemical base** in the production of:
 - Pulp and paper
 - Textiles
 - Drinking Water
 - Detergent

Brine:

- Brine is a name for Sodium Chloride solution
- This is the initial starting material for all three processes of NaOH production
- Brine is a readily available source in seawater
- Thus most industrial NaOH plants are next to the sea / ocean
- Brine is pure NaCl solution, so the sea water must be processed and purified to remove impurities
- In a landlocked country, Brine has to be made by solid NaCl
- Brine can also be obtained from flushing underground salt deposits

Steps and equations:

- Essentially, **Concentrated** brine is electrolysed to produce hydroxide ions, creating a sodium hydroxide solution.
- The product when using dilute brine is different, it does not produce NaOH. (refer later)
- Industrially, Concentrated brine is used.

Anode Equation (Oxidation): $2\text{Cl}^-_{(\text{aq})} \rightarrow \text{Cl}_{2(\text{g})} + 2\text{e}^-$

Cathode equation (Reduction): $2\text{H}_2\text{O}_{(\text{l})} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-_{(\text{aq})}$

Net ionic equation (add the two above): $2\text{H}_2\text{O}_{(\text{l})} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-_{(\text{aq})}$

Full formulae equation (includes Na): $2\text{H}_2\text{O}_{(\text{l})} + 2\text{NaCl}_{(\text{aq})} \rightarrow \text{Cl}_{2(\text{g})} + \text{H}_{2(\text{g})} + 2\text{NaOH}_{(\text{aq})}$

Note: Na⁺ is a spectator ion, thus it is not included in the net ionic equation

Note: The anode and cathode equation are on the standard potential list. Thus there is no need to memorise them.

Distinguish between the three electrolysis methods used to extract sodium hydroxide:

- **mercury process**
- **diaphragm process**
- **membrane process**

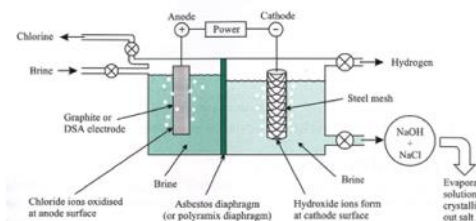
By describing each process and analysing the technical and environmental difficulties involved in each process

Brief Overview:

Process	Overview
Mercury Process	• Sodium metal forms as an amalgam at a mercury cathode; this sodium is then reacted with water to produce NaOH.
Diaphragm Process	• Uses a steel cathode, and reaction of NaOH with Cl ₂ is prevented using a porous diaphragm.
Membrane Process	• Similar to the diaphragm cell process, with a modified Teflon membrane to separate the cathode and anode reactions. - It is less expensive than the diaphragm cell process, and it produces a higher quality of NaOH.

Diaphragm Process:

- This is the oldest process
 - The solution formed in the cathode compartment contains both NaOH and NaCl.
 - This is further purified by the crystallisation of sodium chloride.
 - The final solution is about 50% w/v NaOH with a salt contamination of about 2%.
1. The brine is electrolysed and the redox reaction occurs
 2. The sodium ions migrate from the anode compartment through the diaphragm to the cathode compartment
 - This occurs to maintain neutrality (since negative OH⁻ ions have been created)
 3. The diaphragm is porous to all ions, some chloride ions also migrate through
 4. The mixture resulting is piped out.
 - The mixture contains NaOH and NaCl, which is then purified by crystallising NaCl



Note: The brine level is higher on the anode side than the cathode side to minimise impurities of the product.

- I.e. it minimises the Cl⁻ flowing through to diaphragm and the OH⁻ flowing through the diaphragm

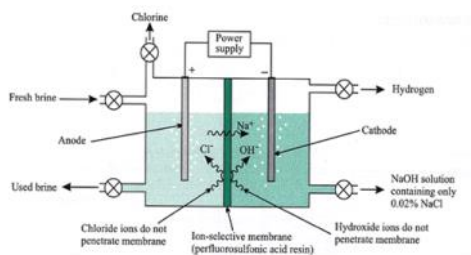
Anode	Titanium / Graphite
Cathode	Steel / Iron mesh
Anode equation	$2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^{-}$ Note: Water can also react in the anode, but this is prevented by using concentrated brine
Cathode equation	$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{aq})$
Partition	Porous diaphragm - Formerly made of asbestos - Now made of polyaramix
Purity of Product	Contaminated with NaCl
Electrolyte	NaCl (brine)

Technical Difficulties	Environmental Issues
<ul style="list-style-type: none"> The product is least pure (relative to other processes) - This is because the pores of the diaphragm are large enough to allow both Na^{+} and Cl^{-} through - As a result both NaOH and NaCl are piped out as products - This mixture then needs to be purified by crystallisation - This difficulty makes the process less efficient as more labour and energy is needed to purify the product Sodium Hydroxide reacts with Chlorine gas forming an unwanted product - $\text{NaOH} + \text{Cl}_2 \rightarrow \text{NaOCl} + \text{H}_2\text{O}$ - This reduces the yield of NaOH, making the process less efficient 	<ul style="list-style-type: none"> The diaphragm war contains asbestos which is harmful - Asbestos can penetrate the inner linings of lungs as dust - This triggers cancers, mesothelioma and asbestosis - Even a short exposure can kill some people - This poses a safety risk to chemists who work at NaOH production plants

Membrane Process:

- Essentially, the Membrane process is **very similar to the diaphragm process**
- The difference is, instead of a diaphragm, a membrane is used.
- The membrane is an anionic coated surface, which repels anions
- Thus anions such as Cl^{-} and OH^{-} can not pass through it (see technical difficulty of diaphragm process)
- Making the resultant product more pure (compared to diaphragm process)
- The "water levels" in this cell are **level** unlike in the diaphragm cell
- This is because the membrane is enough to keep the purity of the product

Note: The membrane process is the most superior process, and is widely used today as it has none of the technical or environmental difficulties the other two cells have.



- First the brine is electrolysed and the redox reaction occurs
- The sodium ions migrate from the anode compartment through the diaphragm to the cathode compartment
- This occurs to maintain neutrality (since negative OH^{-} ions have been created)
- Chloride and hydroxide ions CAN NOT pass through the membrane**, as the membrane is coated with an anionic surface
- The negative membrane repels the negative ions
- As a result, the solution formed in the cathode compartment is **VERY PURE (NaOH)** (More pure than diaphragm, less pure than mercury)

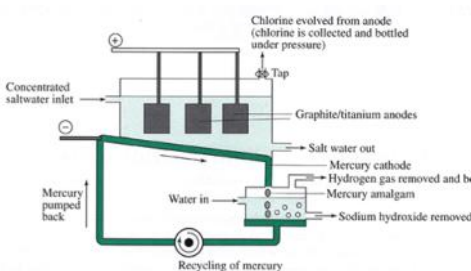
Anode	Titanium / Graphite (Note: Same as diaphragm)
Cathode	Steel / Iron mesh (Note: Same as diaphragm)
Anode equation	$2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^{-}$ (Note: Same as diaphragm)
Cathode equation	$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{aq})$ (Note: Same as diaphragm)
Partition	Membrane - Surface covered in anionic groups - Anions can not penetrate through, and are repelled
Purity of Product	Very pure - Purer than diaphragm, less pure than mercury
Electrolyte	NaCl (brine)

Technical Difficulties	Environmental Issues
<ul style="list-style-type: none"> No real technical difficulties - Uses the least energy, offers a highly pure product, does not have the issues with the other cells 	<ul style="list-style-type: none"> No environmental difficulties
<ul style="list-style-type: none"> Cost of polymer to make membrane - The only real technical difficulty, could be the cost of the polymer used to make the membrane 	

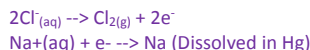
Note: The membrane process is the most superior process, and is widely used today as it has none of the technical or environmental difficulties the other two cells have.

Mercury Process:

- The main difference is that there are **two reaction chambers** in the mercury process
- This is why mercury process produces the most pure product (compared to the other processes)
- The two chambers ensure that no Cl^{-} ions can reach the second vessel, and no OH^{-} ions can reach the first vessel
- Note how in this process, Mercury is the cathode, rather than a steel / iron mesh
- Sodium is reduced, not Mercury as it is inactive



- The brine is electrolysed to form chlorine gas and sodium metal, reactions are as follows:



- Sodium metal then forms an amalgam with mercury
- The amalgam flows to the next chamber where it reacts with pure water to form sodium hydroxide, the reaction is as follows:



Note: in this equation, Na and Hg are not chemically joined, it is simply an amalgam

- The mercury is reused, while the chlorine and hydrogen gas are stored for other uses

Anode	Titanium / Graphite
Cathode	Mercury
Anode equation	$2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_{2(\text{g})} + 2\text{e}^{-}$ Note: Water can also react in the anode, but this is prevented by using concentrated brine
Cathode equation	$\text{Na}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Na} \text{ (dissolved in Hg)}$
Equation of Second Vessel	$2\text{Na}(\text{dissolved in Hg}) (\text{l}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{aq}) + \text{H}_2(\text{g})$
Partition	The two reactions happen in different chambers
Purity of Product	Highest purity of all processes
Electrolyte	NaCl (brine)

Technical Difficulties	Environmental Issues
<ul style="list-style-type: none"> Operates at highest voltage <ul style="list-style-type: none"> This means it is more costly as it requires more energy To try and minimise the cost, high purity salt can be used, (impurities reduce efficiency) Mercury is an expensive metal. 	<ul style="list-style-type: none"> Loss of mercury through the environment The mercury enters the food chains where it bio accumulates, biomagnifies and causes harm to humans (expand on this in an exam, talk about all the effects of mercury)

Comparison:

Process	Overview	Oxidation equation (Anode)	Reduction equation (cathode)	Environmental Issues	Technical Issues	Advantages	Disadvantages
Diaphragm	<ul style="list-style-type: none"> Sodium metal forms as an amalgam at a mercury cathode; this sodium is then reacted with water to produce NaOH. 	$2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_{2(\text{g})} + 2\text{e}^{-}$	$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{aq})$	<ul style="list-style-type: none"> Contains asbestos diaphragm, which is harmful 	<ul style="list-style-type: none"> Sodium Hydroxide reacts with Chlorine gas forming an unwanted product Least purity 	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> Inferior in every way
Membrane	<ul style="list-style-type: none"> Uses a steel cathode, and reaction of NaOH with Cl_2 is prevented using a porous diaphragm. 	$2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_{2(\text{g})} + 2\text{e}^{-}$	$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{aq})$	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> Superior in everyway (although mercury process produces purer NaOH) 	<ul style="list-style-type: none"> None
Mercury	<ul style="list-style-type: none"> Similar to the diaphragm cell process, with a modified Teflon membrane to separate the cathode and anode reactions. 	$2\text{Cl}^{-}(\text{aq}) \rightarrow \text{Cl}_{2(\text{g})} + 2\text{e}^{-}$ Note: The anode equation is the same for all three cells	$\text{Na}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Na} \text{ (dissolved in Hg)}$ Note: The cathode equations are the same for the diaphragm and membrane cells	<ul style="list-style-type: none"> Mercury is dangerous 	<ul style="list-style-type: none"> Requires a high voltage 	<ul style="list-style-type: none"> Purest product 	<ul style="list-style-type: none"> High costs (energy) Danger to environment

Deriving equations

- It will be **very silly** to try and remember all the equations
- ALL** the redox equations in the production of sodium hydroxide can be **COPIED from the list of standard potentials** (given in an exam)
 - With the exception of $2\text{Na}(\text{dissolved in Hg}) (\text{l}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{aq}) + \text{H}_2(\text{g})$ (which is just metal + water general equation)
- When deriving an equation, firstly consider, what do I start off with?
- For example, if I wanted to find out the cathode equation for the diaphragm process:
 - I know it is on the list of potentials, and it is the one with only water on one side
 - Thus I only have 1 to choose from
 - Now I know that I start off with water, I do not start off with hydroxide ions, hence I must write the water on the LHS and copy the equation down that way

*Focus point 5 - Saponification



Describe saponification as the conversion in basic solution of fats and oils to glycerol and salts of fatty acids

- Saponification** is the reaction between triglycerides (Fatty esters) and an alkali (usually sodium hydroxide) to form glycerol and soap (as salt of a fatty acid)
- Generally: Triglycerides + Sodium Hydroxide \rightarrow Glycerol + Soap
 - In this topic we talk about the product "Soap"
 - Glycerol, the other product, in industry is purified and used for other purposes (it is not important to us)
 - However, it has been asked the uses and impacts of glycerol in ap at hsc (2007 question 28d), thus I will address glycerol below
- Saponification is an example of a **hydrolysis reaction**
- This is a chemical reaction / process in which a molecule is split into two parts by reacting it with a molecule of water (see POM)

Note: It may be common sense to think that saponification is spelt "soap"fonication. However it is not, be careful.

- A triglyceride is the general name for a compound containing 3 "fatty acid" molecules joined to one "glycerol" molecule. Triglycerides are esters.
- Fatty acids are long-chain hydrocarbons with a carboxylic (-COOH) group at one end, which is either saturated or unsaturated.
- Glycerol is a 'triple alcohol' i.e. it contains 3 OH- functional groups. Systematically, it is named 'propantriol'

- Fats and oils are both types of triglycerides. The difference is that fats are solid at room temperature due to all single C-C bonds, therefore they are said to be saturated.
- Oils are liquid at room temperature due to the presence of many C=C bonds i.e. it is 'unsaturated'.

An example of Saponification:

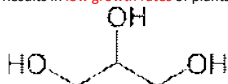
Tristearin + Sodium Hydroxide → Glycerol + Sodium Stearate

Soap:

-

Glycerol:

- Glycerol can be used to make many:
 - Pharmaceuticals
 - Toiletries
 - Cosmetics
 - Paints
 - Varnishes
 - Explosives
 - Confectionary
- Glycerol is taken by mouth for weight loss, improving exercise performance, helping the body replace water lost during diarrhea and vomiting, and reducing pressure inside the eye in people with glaucoma.
- Athletes also use glycerol to keep from becoming dehydrated.
- This has positively impacted the society as it allows an extensive range of products to be produced and has an extensive range of uses.
- Glycerol is **toxic**, in the case of a glycerol spill into water ways:
 - Could result in **death of animals**, fish, birds
 - Results in **low growth rates** of plants in water ways



IMPORTANT Note: "Saponification products" refers to soap and glycerol ONLY. NOT synthetic detergents (see later). In a question, such as 2007 hsc 28 d) make sure you talk about soap AND glycerol ONLY.

Gather, process and present information from secondary sources to identify a range of fats and oils used for soap-making

- Simple identify syllabus point
- A range of fats and oils that are used for soap making include:
 - Lard (pig fat)
 - Tallow (cow fat)
 - Olive oil
 - Coconut oil

Perform a first-hand investigation to carry out saponification and test the product

Describe the conditions under which saponification can be performed in the school laboratory and compare these with industrial preparation of soap

Laboratory saponification:

- In the lab, soap can be made by heating a mixture of oil with NaOH or KOH.
- The soap produced can be precipitated by using a saturated sodium chloride solution and washed to remove excess glycerol and base.
- Dilute acid can be used to neutralise any excess base.
- Yes this practical does involve making soap in school. Wonderful.

Procedure:

Note: It is better to use a reflux process as the substances are volatile. The following method does not give a reflux process

1. Place 20g of coconut oil and 100mL of 6M NaOH in a 500mL beaker.
 2. Gently boil the solution for 10 minutes with a Bunsen burner while stirring.
 - Occasionally add distilled water to maintain the volume
 3. Add 100 mL of cold 6M NaCl solution to "salt out" the solution
 4. Decant the liquid from the mixture
 5. Rinse the soap twice with water
 6. To test, place soap in water and shake, and see if a lather is produced
- Note: DO NOT TEST BY USING THE SOAP.** The Soap created in the lab does not use the industrial process, thus it is quite impure. Even if you wash it with dilute acid, it can still contain traces of NaOH. NaOH is highly caustic, if you try to wash your hands with the soap, you will get owned.

Risk Assessment:

Identify	Assess	Control
6M NaOH	Highly caustic, will harm skin and eyes if come in contact	<ul style="list-style-type: none"> • Wear safety glasses, and gloves • Exert Caution • DO NOT TOUCH THE SOAP PRODUCED • -NaOH can still remain
Bunsen burner / Open Flame	May cause burns upon contact	<ul style="list-style-type: none"> • Exercise caution • Wear Safety glasses

Industrial saponification:

- Industrially, soap can be prepared in one stage (Kettle Boiled Batch process) or two stages (fatty acid neutralisation process).
- You only need to know one, I have done the **"Kettle boiled batch process"** as it is MUCH easier
- Generally, vegetable oils and fats are heated to high temperatures in a sodium hydroxide solution.
- This process takes place in large, open steel tanks called 'kettles'. The reaction mixture is kept constantly via injection of high pressures, which also helps keep the reaction mixing.
- The product has all surface fat skimmed upon cooling and the remaining mixed with brine.
 - The soap is thus "salted out".
- Colouring and perfumes are then added (for marketing).
- The product is then packaged and cut, pressed into a mold (soap shape).
- The brine solution is combined with acid to neutralise any excess sodium hydroxide, and then distilled to produce the glycerol. Glycerol is then used in other areas.

Comparison between Laboratory and Industrial Saponification:

Factor	School Laboratory	Industrial
Basic Reaction:	Same	Same
Fats and oils are mixed with concentrated alkali and heated	Remember: The basic, fundamental saponification reaction for making soap is the same for both school and industrial.	Remember: The basic, fundamental saponification reaction for making soap is the same for both school and industrial.
Concentrated brine is used to salt out the soap	Same	Same
The crude soap is washed	Same	Same But washed more thoroughly
Quantity of fat/oil	• Few grams	• Over 100 Tones
Number of different fat/oils	• Usually one	<ul style="list-style-type: none"> • Many, a mixture is used including: <ul style="list-style-type: none"> - Lard (pig fat) - Tallow (cow fat) - Olive Oil - Coconut oil
Heating	<ul style="list-style-type: none"> • Heated by a (relatively) low temperature bunsen burner • Relatively low temperature 	<ul style="list-style-type: none"> • Heated by high pressure steam • Much higher temperatures

Pressure	• Normal Atmospheric Pressure	• High pressure (5MPa)
Stirring	• Stirred with a stirring rod	• "Stirred" by high pressure steam
Glycerol Use	• Not used, discarded - Note: This is organic waste, it goes into the organic waste container, NOT the bin or the sink.	• First, Glycerol is purified • It is then used for other purposes
Emulsification	• Usually none - We can use methylated spirits - This makes the sodium hydroxide and triglycerides mix better	• Emulsified with salt and soap from previous batch - This makes the sodium hydroxide and triglycerides mix better
Additives	• None, we don't bother - We only do it in the school lab to learn the chemistry, we are not selling or using the soap	• Additives - Colouring - Fragrances • This is for marketing. Everyone wants their hands to smell like flowers.
Time	• Production process takes between 15 minutes to a period (1 hour)	• Production process takes a few days
Purity of product	• Not very pure	• Very pure

Historical "Production" methods:

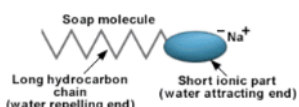
- The following history stuff is just for fun, it is **not on the syllabus**
- However I believe knowing this stuff will give u a better general understanding
- You may think that soap is a more recent invention
- Surprisingly, soap dates back as far as 6000 years.
- Clearly, they did not have the kettle boiled batch process or the fatty acid neutralisation process back then

Account for the cleaning action of soap by describing its structure

Explain that soap, water and oil together form an emulsion with the soap acting as an emulsifier

The structure of Soap:

- All soap / detergents have basically the same structure
- A hydrophobic tail, attached to a hydrophilic head (as shown below)
- $\text{CH}_3\text{-(CH}_2\text{)}_{15}\text{-CH}_2\text{-COO}^-$



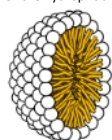
Note: note the COO^- head

Surfactant / Formation of micelles and Emulsifier:

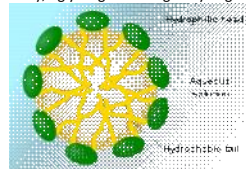
- It is this structure that allows for the "cleaning action of soap"
- The soap is known as a **surfactant**
- This means it reduces the surface tension of water
- This increases the ability of water to "wet" a surface
- Note: You do not have to know how surfactant works in detail
- The hydrophobic tail of the anion starts to dissolve into the stain / dirt
- The hydrophilic end of the anion interacts with the water
- 40 - 100 anions cluster together and surround droplets of grease
- This forms a stable structure known as a **micelle**
- A micelle forms as this minimises contact between the hydrophobic parts of the detergent and water

IMPORTANT NOTE: In the exam, if accounting for the formation of the micelle, you must state that the micelle minimises contact between the hydrophobic parts of the detergent and water

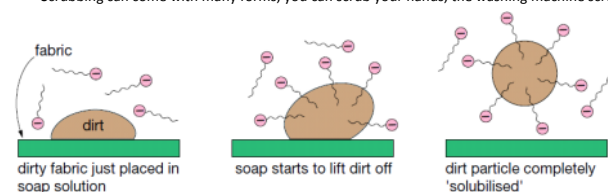
- Or the hydrophobic parts of the detergent are attracted to each other



Sorry, ugly diagram that gives you goosebumps, I know.



- An **Emulsion** is a mixture of two or more liquids that are normally immiscible
- The soap, water and oil (grease, dirt) **form an emulsion**, with soap acting as an **emulsifier**
- The micelles (see above) formed, have the hydrophilic negative end on the outside
- Thus, the micelles repel each other (negative repels negative)
- This way the micelles suspend in the water
- Hence the fats and oils and dirt are suspended in the water, forming an **emulsion**
- After some vigorous agitation, the micelles come off, bringing the dirt with them off
- Scrubbing can come with many forms, you can scrub your hands, the washing machine scrubs by spinning, the dish washer scrubs by spraying water



Distinguish between anionic, cationic and non-ionic synthetic detergents in terms of:

- **chemical composition**
- **uses**

Distinguish between soaps and synthetic detergents in terms of:

- **the structure of the molecule**
- **chemical composition**
- **effect in hard water**

Hard water:

- Hard water is water that has high mineral content
- In other words, it contains cation impurities
- The cation impurities are mainly Mg^{2+} and Ca^{2+}
- Hard water is not harmful for drinking, but can cause problems when detergents are used
- Sydney does not have the issue of hard water, however some places like Melbourne do
- Detergents are ionic (excluding non-ionic detergents), meaning they can react with the hard water
- This causes many problems, depending on the detergent type (see below)

Soap:

- Although soap is classified as an anionic detergent, it should be specifically mentioned here
- When soap comes into contact with hard water, black "scum" is created
- This precipitate is formed by the anionic **soap** reacting with the cations (Mg^{2+} , Ca^{2+}) in hard water
- Synthetic detergents do not have the problem of producing "scum"

Synthetic detergents:

- A detergent is any cleaning product
- Soap is a natural detergent, it fits into the anionic detergent category
- Other detergents are all synthetic, and this fits into three main categories:

Anionic Detergents:

- Anionic detergents are those with a **negatively charged head group**
- Soap, (everything mentioned above), is an example of an anionic detergent
- **Instead of the COO^- head in soap, synthetic anionic detergents usually have a SO_3^- head**
- Synthetic detergents do not form precipitates (scum) in hard water
- However, anionic synthetic detergents might form **soluble complexes** with Ca^{2+} Mg^{2+} in hard water
- Although this is not a precipitate like scum, it can neutralise the anionic head
- This **limits the cleaning potential** of the detergent as the anionic head is important to act as a surfactant
- Some examples / uses of anionic detergents include:
 - Dishwashing liquid
 - Toothpaste
 - Laundry Detergent
 - Oven cleaner

Cationic detergents:

- Cationic detergents are those with a positively charged head group
- This positive head group is usually the **alkyl ammonium group**
- Cationic synthetic detergents do not form precipitate (scum) in hard water
- Neither does it form any complexes as the Positive head does not react with the positive cations in the hard water (Mg^{2+} Ca^{2+})
- Thus hard water has no effect on cationic detergents
- Cationic detergents are usually used to **neutralise static charges** from residue anionic detergents
- In hair conditioner, cationic detergents can **attract to the negative ends** of hair
- This ensures the conditioner remains in the hair, **improving the texture** of the hair
- Cationic detergents also act as **biocides**
- This means they react with bacteria to kill them
- This allows cationic detergents to be used in household bacteria killers
- Cationic detergents are not used to clean glass
- Glass is negatively charged, the cations will attract to the glass
- This makes them difficult to wash off, making the glass feel greasy
- Thus a few examples / uses of cationic detergents include:
 - Hair Conditioner
 - Fabric softeners
 - Antiseptics
 - Lozenges (cough / throat lollie)
 - Mouth washes
 - Disinfectants

Non-Ionic Detergents:

- Non-ionic detergents are those that are not ionic
- The head is not charged, but instead is polar
- This can be achieved with many hydrogen / oxygen atoms at the head (alcohol group)
- The non-ionic detergent contains many polar oxygen atoms scattered along the chain
- This improves the ability of the polar and non-polar groups to adhere to each other
- Non-ionic detergents do not form precipitate (scum) in hard water
- Neither does it form any complexes as the non-ionic heads do not react with the positive cations in the hard water (Mg^{2+} Ca^{2+})
- Thus hard water has no effect on cationic detergents
- Because it has a non-ionic head, the non-ionic detergent is usually not as strong as other detergents
- Non-ionic detergents form much **less foam** than other detergents
- Thus it is combined with other detergents (anionic and cationic) to improve stability and **reduce the amount of foam** formed
- Thus a few examples / uses of non-ionic detergents include:
 - Dish washers (not foam as much)
 - Car shampoo
 - Paints
 - Cosmetics
 - Adhesives

Summary / Comparison:

	Soap	Anionic	Cationic	Non-Ionic
Structure / head	• Negative head	• Negative head	• Cationic head	• Non-ionic, polar head
Effect on hard water	• Forms black Scum	• Forms soluble complexes - Reduces cleaning potential	• No effect	• No effect
Uses	- Hand Soap	- Dish washing liquid - Toothpaste - Laundry detergent - Oven cleaner	- Hair conditioner - Fabric softener - Antiseptics - Lozenges - Mouth washes - Disinfectants	- Paints - Cosmetics

*Focus point 6 - Sodium Carbonate , Solvay process

Describe the uses of sodium carbonate

- This dot point is meant to make you think that sodium carbonate is useful so that you don't feel angry when learning the tedious production method :D
- Sodium carbonate is an extremely useful chemical, it can be used in:

Washing Soda:

- Washing soda (sodium carbonate) can soften hard water
- The Na_2CO_3 precipitates the calcium and magnesium ions
 - $\text{Na}_2\text{CO}_3(\text{aq}) + \text{Mg}^{2+}(\text{aq}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{MgCO}_3(\text{s})$
 - $\text{Na}_2\text{CO}_3(\text{aq}) + \text{Ca}^{2+}(\text{aq}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{CaCO}_3(\text{s})$

Titration:

- Commonly, especially in school labs, standard solutions are made with Na_2CO_3
- Na_2CO_3 is used as primary standard because:
 - Obtainable in pure form, have a known formula/ formula mass (e.g. a compound)
 - It has a stable mass.
 - If deliquescent like NaOH , then the mass is not stable.
 - Must not decompose on heating
 - Does not react with air
 - Carbon dioxide does not dissolve in substance
 - Not volatile
- Relatively high formula mass
 - Weighing errors are minimised
 - Reduces error, increases accuracy
- Solid
 - Easy to transport, easier to handle

Note: The above points were copied from my titration notes in the acidic environment section

Glass Manufacture:

- Glass manufacturers use Na_2CO_3
- Na_2CO_3 lowers the melting point of SiO_2 and CaCO_3 mixture in the manufacture of glass

Soap and detergent manufacture:

- As seen in the saponification topic, a base is needed for saponification
- Sodium Carbonate is a base and can be used for saponification rather than the NaOH
- Although NaOH is a better base to use (stronger)

Identify the raw materials used in the Solvay process and name the products

Identify, given a flow chart, the sequence of steps used in the Solvay process and describe the chemistry involved in:

- brine purification
- hydrogen carbonate formation
- formation of sodium carbonate
- ammonia recovery

Raw materials:

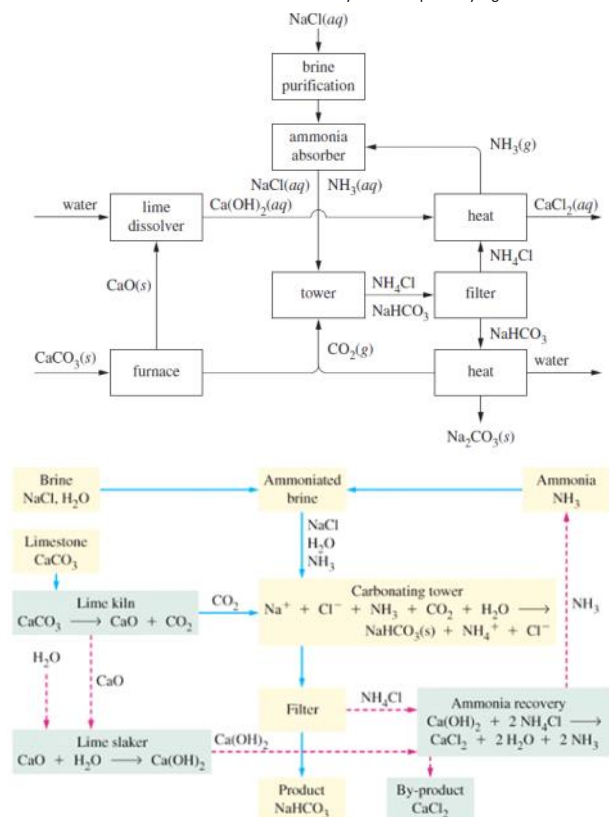
- The raw materials in the Solvay process are CaCO_3 and NaCl (brine)

Products:

- The Solvay process produces Na_2CO_3 , the main product
- CaCl_2 is a waste product, so is water

General outline:

Note: You do not ever have to draw a flowchart. The syllabus dot-point says "given a flow chart". However, do memorise the steps so you can fill in a flowchart if asked to.



- A brine solution is saturated with ammonia
- CaCO_3 is burnt to form CO_2
- The Brine, Ammonia and CO_2 react together in the tower forming NH_4Cl and NaHCO_3
- The NH_4Cl and NaHCO_3 are filtered out from each other
- NaHCO_3 is heated to produce Na_2CO_3 (the final produced wanted)
- The NH_4Cl is heated up with Ca(OH)_2 to recycle the NH_3

7. Water and CaCl₂ are formed as waste products

Overall equation: $2\text{NaCl}_{(\text{aq})} + \text{CaCO}_{3(\text{g})} \rightarrow \text{CaCl}_{2(\text{aq})} + \text{Na}_2\text{CO}_{3(\text{s})}$

Note: The above reaction is **not actually happening**. It is through a series of steps in which the actual reaction happens. However, the overall equation can be used to simplify mathematical calculations (see later)

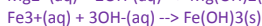
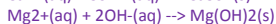
- The Solvay Process can be broken down into the following crucial steps

Warning: The steps are very hard to explain by text, and thus when you read the following steps you should try and follow the flow chart to help your understanding of the process.

Step 1: Brine and Brine purification:

- Brine is a name for Sodium Chloride solution
- Brine much like in the industrial production of NaOH, is obtained from seawater
- Brine is a readily available source in seawater
- Thus most industrial Sodium Carbonate plants are located near the sea (see later)
- Brine is pure NaCl solution, so the sea water must be processed and purified to remove impurities
- In a landlocked country, Brine has to be made by solid NaCl
- Brine can also be obtained from flushing underground salt deposits

- Brine can contain impurities of Ca²⁺ and Mg²⁺ and some Fe³⁺, these two can be purified by the following equations:



- These equations are similar to those learnt in the chemical monitoring and management topic
- Precipitates are formed, and then filtered out, thus effectively removing the ions

Step 2: Ammonium Saturator:

- The brine is saturated with ammonia in the ammonium saturator
- This is then all sent to the tower (carbonator)

Step 3: Carbon Dioxide Production:

- CO₂ is needed for the production of Na₂CO₃
- The CO₂ is obtained from the raw material Limestone (CaCO₃)
- CaCO₃ is crushed and heated in a furnace (lime kiln)
- This forms CO₂ and CaO
- $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- The CO₂ is an important material, it is sent to the tower (carbonator)

Step 4: Main reaction - The tower (carbonator) - Hydrogen carbonate formation:

- This is where the main reactions occur
- $\text{CO}_2(\text{g}) + \text{NaCl}(\text{aq}) + \text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{NH}_4\text{Cl}(\text{aq}) + \text{NaHCO}_3(\text{aq})$
- The products from the tower (NH₄Cl and NaHCO₃) are then sent to the filter
- The filter uses manipulated solubility rates to filter out the NH₄Cl from the NaHCO₃

Step 5: Ammonium Recovery:

- Firstly, the CaO from the furnace (lime kiln) is dissolved in H₂O to form Ca(OH)₂
- $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2$
- The NH₄Cl is then filtered from the NaHCO₃.
- IMPORTANT:** The NH₄Cl and NaHCO₃ are filtered by lowering the temperature of the vessel. NaHCO₃ is much less soluble than NH₄Cl at low temperatures and will precipitate out, whilst NH₄Cl remains in solution. The NaHCO₃ can then be filtered out from the NH₄Cl solution.
- The NH₄Cl from the filter is then heated with this Ca(OH)₂
- This produces NH₃, H₂O and CaCl₂ (waste product)
- $\text{Ca}(\text{OH})_2(\text{aq}) + 2\text{NH}_4\text{Cl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + 2\text{NH}_3(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- The NH₃ produced is recycled, going back into the ammonia absorber
- By doing molar ratios it can be seen that the moles put in = moles out of NH₃
- This means NH₃ is continuously recycled with minimal loss

Step 6: Formation of Na₂CO₃ (final product):

- NaHCO₃ from the filter is then used to produce Na₂CO₃
- This is done by drying the NaHCO₃ and then heating up to 300 degrees Celsius in the converter
- The NaHCO₃ decomposes to form Na₂CO₃, H₂O and CO₂
- $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$
- The CO₂ produced from this equation is then recycled and sent back to be used in the tower

Note: Unlike the NH₃, The CO₂ recycled is less than the CO₂ input and thus limestone (CaCO₃) must be continually crushed and heated to produce more CO₂

Step 7: Waste:

- H₂O is a waste product after the decomposition of NaHCO₃ to Na₂CO₃, CO₂ and H₂O
- The H₂O is very hot (see later for environmental issues)
- It is discharged into the ocean
- CaCl₂ is the main waste product and is formed during the ammonium recovery process
- The CaCl₂ is also discharged into the ocean (see later for environmental issues)

Equations:

- Here are all the equations listed out in case they are needed in a quantitative calculation

- $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- $\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{CO}_{3(\text{aq})}$
- $\text{NH}_3(\text{aq}) + \text{H}_2\text{CO}_{3(\text{aq})} \rightarrow \text{NH}_4(\text{aq}) + \text{HCO}_3(\text{aq})$
- $\text{Na}^+(\text{aq}) + \text{HCO}_3(\text{aq}) \rightarrow \text{NaHCO}_3(\text{s})$
- $2\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
- $\text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{OH})_2(\text{aq})$
- $\text{Ca}(\text{OH})_2(\text{aq}) + 2\text{NH}_4\text{Cl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{NH}_3(\text{g})$

Discuss environmental issues associated with the Solvay process and explain how these issues are addressed

- There are five main environmental issues relating to the Solvay process
- Overall, the environmental issues have each been well addressed and thus the Solvay process is fairly environmentally friendly

Environmental Issue (Identify)	Explanation (Assess)	Addressing the issue (Control)
Waste Products (CaCl ₂)	<ul style="list-style-type: none">CaCl₂ is a problem if discharged into waterwaysThe Ca²⁺ ion increases the hardness of waterThe Cl⁻ ion increases the salinity of the water, making it saltierThis can kill or harm fresh water animalsAnother problem is that there might be Ca(OH)₂ impurities in the disposed waste, Ca(OH)₂ is basic	<ul style="list-style-type: none">To address this problem, we discharge the CaCl₂ into the ocean rather than in lakes / rivers (freshwater)This is because the ocean is so large and the Cl⁻ ions will thus have negligible net effectAdding Ca²⁺ ions into the ocean also has negligible effectThe sea water has a buffering action which thus negates the effect of pH change caused by Ca(OH)₂ impuritiesSome countries which are land-locked (no ocean), need to contain their wastes in settling pondsOverseas, calcium chloride is actually used to remove ice from roads and streetsThis is not done in Australia as Australian roads do not get icy
Mining of CaCO ₃	<ul style="list-style-type: none">The mining of CaCO₃ can cause many environmental problemsThe soil in the mining area is destroyed making it uninhabitable and infertileThe trucks used and machineries used for mining create much CO₂ which contributes to greenhouse gases and thus global warming	<ul style="list-style-type: none">To address this problem, the area after a mining operation is rehabilitatede.g. planting trees, making parksIn Australia, there is a law that forces an area to be rehabilitated after a mining operation

Possible loss of gases	<ul style="list-style-type: none"> It is a potential problem that gases (NH₄ and CO₂) are lost into the environment NH₄ is highly toxic and can lead to direct toxic effects on vegetation CO₂ is a pollutant it can cause visibility issues as well as contributing to global warming and greenhouse gases 	<ul style="list-style-type: none"> To address this problem, we ensure that our managing and controlling and design of the plant is up to standards and so no leakage occurs
Thermal Pollution	<ul style="list-style-type: none"> The heated water is a source of thermal pollution If the water is dumped into a body of water, the slight temperature change can cause a change in the oxygen level dissolved in the water and thus killing fish and other organisms 	<ul style="list-style-type: none"> To address this problem, the hot water is discharged into the sea where it will have negligible effect In land-locked countries (no ocean), then a cooling pond or cooling tower is required
Dust Control	<ul style="list-style-type: none"> CaCO₃ is crushed before it is burnt in a furnace This crushing produces dust that is a pollutant The dust particles if escaped into the environment can lead to visibility issues as well as causing problems for asthma sufferers 	<ul style="list-style-type: none"> To address this problem, a dust scrubbing system is used

Note: When you answer these questions in the hsc, make sure you talk about the **CHEMISTRY** too, even if it is not in the question. Too many hsc criteris have wanted a description of the chemistry involved in the process.

Perform a first-hand investigation to assess risk factors and then carry out a chemical step involved in the Solvay process, identifying any difficulties associated with the laboratory modelling of the step

Process information to solve problems and quantitatively analyse the relative quantities of reactants and products in each step of the process

- This dotpoint is simply molarity calculations
 - These calculations should be easier as you have definitely come across them before
- E.g. Calculate the maximum mass of sodium carbonate that can be produced by thermal decomposition of 20.0kg sodium hydrogen carbonate*

$$2\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$$

$$n(\text{NaHCO}_3) = \frac{m}{\text{FM}} = \frac{20000}{22.99 + 1.008 + 12.01 + 3 \times 16.00} = 238.07$$

$$n(\text{Na}_2\text{CO}_3) = 2n(\text{NaHCO}_3)$$

$$n(\text{Na}_2\text{CO}_3) = 119.04$$

$$m(\text{Na}_2\text{CO}_3) = n \times \text{FM}$$

$$m(\text{Na}_2\text{CO}_3) = 119.04 \times (2 \times 22.99 + 12.01 + 3 \times 16.00) = 12.6 \text{ Kg}$$

Use available evidence to determine the criteria used to locate a chemical industry using the Solvay process as an example

Note: The syllabus point states how to locate "a chemical industry" with Solvay process as an "example". This means you can be asked to locate any chemical industry

Note: When you answer these questions in the hsc, make sure you talk about the **CHEMISTRY** too, even if it is not in the question. Too many hsc criteris have wanted a description of the chemistry involved in the process.

- The suitability of locations for most chemical plants can be assessed with the following criteria
- I am using Solvay Plants as an example

Criteria	Explanation
Availability of raw materials	<ul style="list-style-type: none"> Both Brine (seawater) and Limestone CaCO₃ are important raw materials However, because CaCO₃ is much more easily transported (solid), the proximity to the sea takes precedence I.e. it is more important to be close to the sea than to be closer to limestone deposits
Proximity to suitable waste disposal sites	<ul style="list-style-type: none"> The plant should be close to the sea This is for ease of waste disposal, in this case CaCl₂ and heated water This is a major consideration as cooling ponds or burial sites are expensive
Availability of labour force	<ul style="list-style-type: none"> Workers need to be hired and thus the factories should not be located too far from any large population e.g. cities and small towns This means the availability of housing transport schools and shops for workers and their respective families
Proximity to markets	<ul style="list-style-type: none"> Sodium carbonate is a commercial product which must be sold However since sodium carbonate is easily transported, this is not much of a problem
Availability of transport	<ul style="list-style-type: none"> Raw materials and / or products need to be transported easily A reasonable mode of transport would be by train Thus it is desirable to locate a plant near railroad networks
Availability of energy	<ul style="list-style-type: none"> Energy is required for the plant to operate This is unimportant however as low energy is required Energy is also transmitted long distances over power lines and thus there is no need to be too close to a power station



Key Terms

2013年1月3日 17:48

Account

Account for: state reasons for, report on. Give an account of: narrate a series of events or transactions

Analyse

Identify components and the relationship between them; draw out and relate implications

Apply

Use, utilise, employ in a particular situation

Appreciate

Make a judgement about the value of

Assess

Make a judgement of value, quality, outcomes, results or size

Calculate

Ascertain/determine from given facts, figures or information

Clarify

Make clear or plain

Classify

Arrange or include in classes/categories

Compare

Show how things are similar or different

Construct

Make; build; put together items or arguments

Contrast

Show how things are different or opposite

Critically (analyse/evaluate)

Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/evaluate)

Deduce

Draw conclusions

Define

State meaning and identify essential qualities

Demonstrate

Show by example

Describe

Provide characteristics and features

Discuss

Identify issues and provide points for and/or against

Distinguish

Recognise or note/indicate as being distinct or different from; to note differences between

Evaluate

Make a judgement based on criteria; determine the value of

Examine

Inquire into

Explain

Relate cause and effect; make the relationships between things evident; provide why and/or how

Extract

Choose relevant and/or appropriate details

Extrapolate

Infer from what is known

Identify

Recognise and name
Interpret
Draw meaning from
Investigate
Plan, inquire into and draw conclusions about
Justify
Support an argument or conclusion
Outline
Sketch in general terms; indicate the main features of
Predict
Suggest what may happen based on available information
Propose
Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
Recall
Present remembered ideas, facts or experiences
Recommend
Provide reasons in favour
Recount
Retell a series of events
Summarise
Express, concisely, the relevant details
Synthesise
Putting together various elements to make a whole

Solubility Rules

2013年2月3日 10:10

Soluble Compounds	Insoluble Exceptions
Group 1 metals and NH_4^+	
Nitrates (NO_3^-) and acetates (CH_3COO^-)	
Chlorides (Cl^-), bromides (Br^-) and iodides (I^-)	Ag^+ , Pb^{2+} and Hg^+
Sulfates (SO_4^{2-})	Ag^+ , Pb^{2+} , Hg^+ , Ba^{2+} , Sr^{2+} and Ca^{2+}
Insoluble Compounds	Soluble Exceptions
Carbonates (CO_3^{2-}), sulfites (SO_3^{2-}) and phosphates (PO_4^{3-})	Group 1 metals and NH_4^+
Hydroxides (OH^-)	Group 1 metals, NH_4^+ , Ca^{2+} and Ba^{2+}
Sulfides (S^{2-})	Group 1 and 2 metals and NH_4^+
Oxides (O^{2-})	Group 1 metals, NH_4^+ , Ca^{2+} and Ba^{2+}

Matrix

2013年2月3日 10:14

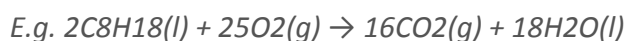
Chemical Reactions Year 12 Chemistry Students Must Know

Posted on September 3, 2012 by [DJ Kim](#) • [0 Comments](#)

CHEMICAL REACTIONS IN YEAR 12

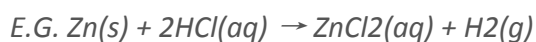
COMBUSTION OF A CARBON COMPOUND

Hydrocarbon + Oxygen → Carbon Dioxide Gas + Liquid Water



METALS WITH ACIDS

Metal + Acid → Salt + Hydrogen gas



CARBONATES WITH ACIDS

Carbonate + Acid → Salt + Carbon Dioxide Gas + Liquid Water



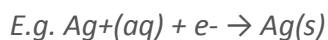
OXIDATION

Metal → Metal Ion + Electron/s



REDUCTION

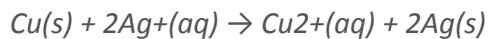
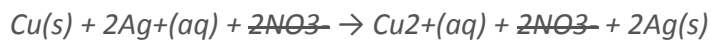
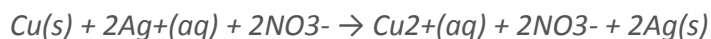
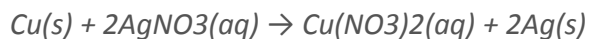
Metal Ion + Electron/s → Metal



REDOX (REDUCTION-OXIDATION REACTIONS)

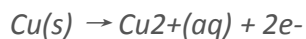
This reaction involves the transfer of electron/s from one reactant to another. This thus results in both a reduction and oxidation reaction occurring. To obtain the redox reaction, you can either write the net ionic equation for a displacement reaction (option 1) or add reduction and oxidation reactions together (option 2).

E.g. OPTION 1:

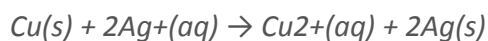
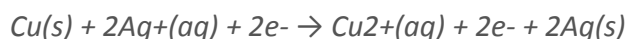
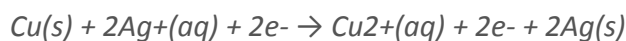


E.g. OPTION 2

NOTE: BOTH THE CONSERVATION OF MASS AND CHARGE MUST BE SHOWN IN YOUR EQUATION!

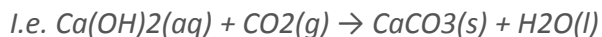


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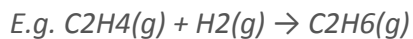
LIME WATER TEST (LIME WATER AND CARBON DIOXIDE)

Calcium hydroxide + Gaseous carbon dioxide → Solid calcium carbonate + liquid water



HYDROGENATION

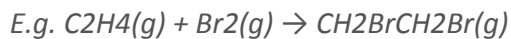
Alkene + Hydrogen → Alkane



Catalyst is Pt(s)

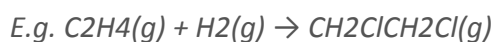
BROMINATION

Alkene + Bromine → Vicinal dibromide



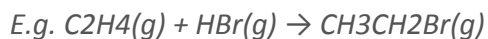
CHLORINATION

Alkene + Chlorine → Vicinal dichloride



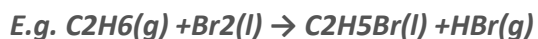
HYDROHALOGENATION

Alkene + HX → Alkyl halide



SUBSTITUTION WITH BROMINE

Alkene + Bromine → Organobromine compound + Hydrogen bromide



NOTE: This reaction requires the presence of UV light.

HYDRATION

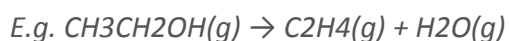
Alkene + Water → Alkanol



Catalyst is dilute H₂SO₄

DEHYDRATION

Alkanol → Alkene + Water



Catalyst is concentrate H₂SO₄

FERMENTATION OF GLUCOSE

Aqueous Glucose → Ethanol + Carbon Dioxide Gas



Catalyst is zymase (found in yeast)

ALPHA DECAY



BETA DECAY



NEUTRALISATION

Acid + Base → Salt + Liquid Water



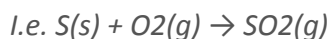
CARBON DIOXIDE AND WATER

Aqueous carbon dioxide + Liquid water \leftrightarrow Carbonic Acid



FORMATION OF SULFUR DIOXIDE

Sulfur + Gaseous oxygen \rightarrow Sulfur Dioxide



FORMATION OF SULFUROUS ACID

Gaseous sulfur dioxide + Liquid water \rightarrow Sulfurous acid



FORMATION OF SULFUR TRIOXIDE

Gaseous sulfur dioxide + Gaseous oxygen \rightarrow Sulfur trioxide



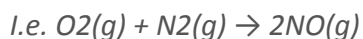
FORMATION OF SULFURIC ACID

Gaseous sulfuric acid + Liquid Water \rightarrow Sulfuric acid



FORMATION OF NITROGEN MONOXIDE

Gaseous oxygen + Gaseous nitrogen \rightarrow Gaseous nitrogen monoxide



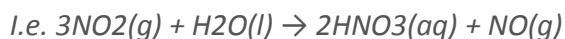
FORMATION OF NITROGEN DIOXIDE

Gaseous nitrogen monoxide + Gaseous oxygen \rightarrow Gaseous nitrogen dioxide



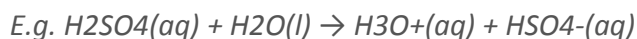
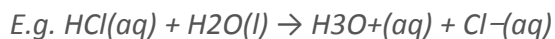
FORMATION OF NITRIC ACID

Gaseous nitrogen dioxide + Liquid water \rightarrow Nitric acid + Gaseous nitrogen monoxide



IONISATION OF AN ACID IN WATER

Acid + Liquid Water \rightarrow Hydronium Ion + Anion



ESTERIFICATION

Ethanoic acid reacts with ethanol in the presence of concentrated sulphuric acid as a catalyst to produce the ester, ethyl ethanoate. The reaction is slow and reversible. To reduce the chances of the reverse reaction happening, the ester is distilled off as soon as it is formed.

Alkanoic acid + Alcohol \rightleftharpoons Alkyl alkanoate + Water (Catalyst: Concentrated sulfuric acid)



FORMATION OF OZONE

1. Gaseous oxygen + High energy UV \rightarrow Oxygen free radical



2. Gaseous oxygen + Oxygen free radical \rightarrow Gaseous ozone

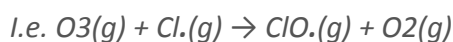


DESTRUCTION OF OZONE

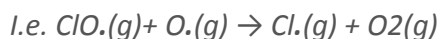
1. Photodissociation of CFC



2. Destruction of Ozone

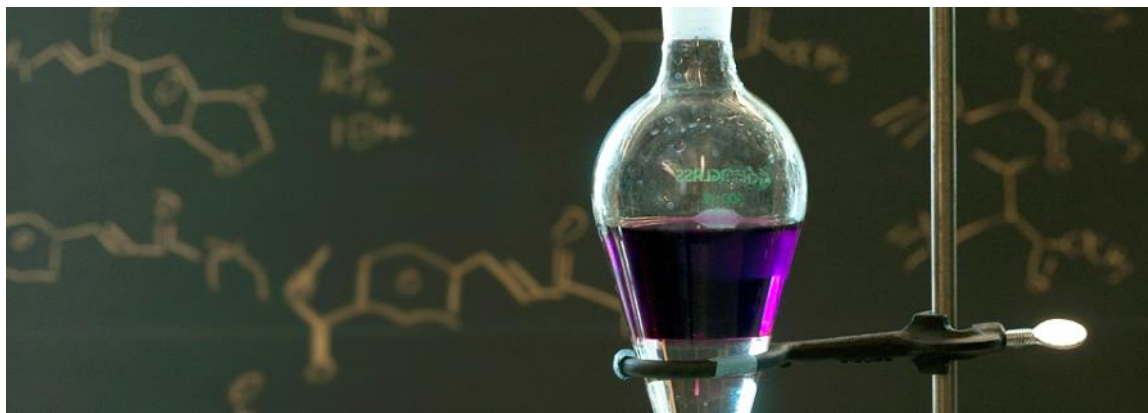


3. Regeneration of Chlorine



源文档 <<http://www.matrix.edu.au/chemical-reactions-year-12-chemistry-students-must-know/>>

HSC Chemistry Exam Tips



Here are eight HSC Chemistry Exam Tips written by Matrix Chemistry Teacher Louise Donnelly.

1. Know what you're being assessed on.

It is important to recognise the HSC Chemistry examination will assess a multitude of skills – it is not just about 'what you know.'

The HSC exam tests your ability to:

- relate chemical concepts;
- interpret questions & analyse data;
- successfully manage your time; and
- communicate effectively.

Developing your examination technique – answering the question, eliminating careless errors, using correct terminology – is essential for success in the HSC.

2. Know your exam structure.

Knowing the structure of any examination enables you to practice similar questions, pre-allocate your time and have all necessary equipment.

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write in blue or black pen
- Draw diagrams using a pencil
- Board approved calculators may be used
- A data sheet and a Periodic Table are provided at the back of this paper.

Total marks – 100

SECTION I Pages 2-23

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks

- Attempt Questions 1-15
- Allow about 30 minutes for this part Part B – 60 marks
- Attempt Questions 16-27

- Allow about 1 hour and 45 minutes for this part

SECTION II Pages 25-35 25 marks

- Attempt ONE question from Question 28-32
- Allow about 45 minutes for this section

You have 3 hours for 100 marks. This equates to 1.8 minutes per mark. This means you should spend around 10 minutes on a 5 mark question. The use of this time is essential – especially for written response questions. Since you will be required to answer around 20 written response questions (ranging from 1-7 marks), losing 1 or 2 marks per question equates to losing 20 – 40%. However, if you can gain that extra 1 or 2 marks, your improvement is substantial.

3. Know how to approach questions.

The key to gaining the maximum mark for a question is to THINK before you respond. Use your allocated time to analyse the question, plan your response carefully, and then work within that framework to produce a clear, logical and concise response. Look at the question. The answer space provided and the marks allocated are guides to the maximum length of response required. Similarly, the key word used in the question gives an indication of the depth of the required response. You may plan to use dot points, diagrams and/or tables; this will help avoid internal contradictions. For example, a question on the use of plastics could include a table that relates structure to a property and to a use. If the question requires a judgement (eg. justify, evaluate,) consider the use of sub-headings such as ‘advantages’, ‘disadvantages’ and ‘assessment’. It is essential to address the question being asked. Many students identify the key verb but neglect to follow through with further analysis. What specifically are you asked to explain or evaluate? What terms should be defined? Are there any specific requirements such as a labelled diagram or balanced equation? Underlining all keywords will focus your attention on the exact task required.

EXAMPLE: 2007 HSC CHEMISTRY

Question 19 (7 marks)

There are many benefits and problems associated with the use of radioisotopes in industry and medicine.

Evaluate the impact on society of the use of radioisotopes in both industry and medicine. In your answer, give examples of specific radioisotopes, making reference to their chemical properties.

Highlighting these “keywords” will help ensure all requirements are met. In the above example you must make a judgement (based on criteria) on the impact on society. You should also recognise the term radioisotope needs to be defined and you must discuss their use in both industry AND medicine. You must also provide more than one example and provide chemical information on each.

[See Also: Glossary of Key Words](#)

4. Know how to answer questions.

Whatever the type of question you are answering it is essential to pay attention to detail. Communicating with Words Your aim is to provide a concise and relevant answer and display good chemistry.

The key is to be SPECIFIC

- do not repeat the question as part of the response.
- identify a specific impact rather than offer a general statement, such as the chemicals “harm” the environment or the substance is “dangerous”
- use specific terminology associated with the course this includes the terminology associated with equipment e.g. dissolved in a volumetric flask and then filled up to the calibration line.
- correct chemical equations should also be included to illustrate the chemical processes described. – ensure all formulas are correct and equations balanced. – remember to check all charges are balanced when writing ionic equations.

RE-READ the question and your response to ensure you have met all requirements and that it “reads well.” The following sample demonstrates a coherent and logical response.

EXAMPLE: 2006 Chemistry HSC

Question 24 (4 marks)

Early in the twentieth century, Fritz Haber developed a method for preparing ammonia. (b) Evaluate the significance of Haber's discovery at that time in world history.

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

5. Know how to communicate with numbers.

When answering questions involving calculations in the HSC you need to set out your work clearly, showing all steps in your working, and expressing your answers with the correct number of significant figures.

If you are required to substitute values into a formula, for example calculating pH, you must state the formula clearly. You should then substitute the values in WITHOUT calculation, and then calculate.

The data you use should be accurately transcribed from The periodic table and data sheet for calculations. Atomic mass of carbon? 12.01 It is advisable to use all 4 figures in your calculation, even if you have to round down for your final answer

Use the correct number of significant figures for your final answer. Remember rounding-off needs to be done at the end of the calculation.

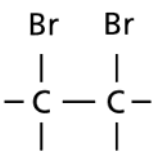
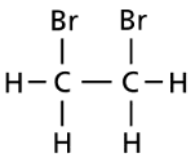
When setting out your working for numerical questions think carefully about the units to be used and the quantities to be substituted into formulae. That is, you need to be "unit-conscious". You must be consistently alert to the possibility that you may have to convert mL to L, or kg to g.

Familiarise yourself with prefixes commonly used. Converting micrograms (μg) to milligrams (mg) is not achievable without such knowledge.

Similarly concentration can be expressed in different ways – mol/L, ppm, %w/v. Identifying that 1ppm is equivalent to 1 mg/L is essential in many analytical/environmental questions.

6. Know how to communicate visually.

Drawing Structural Formula Clearly draw structural formula that shows all covalent bonds between atoms.

			
Do not draw		When you mean	

The covalent bond between O and H in the hydroxyl group of alkanols should be shown.

When drawing a polymer, show two or more monomer units joined together (rather than the simple abbreviated structure) and the bonds at each end of the chain open (without the use of 'n' molecules).

Use appropriate equipment, for example, pencils and a ruler to draw diagrams and graphs.

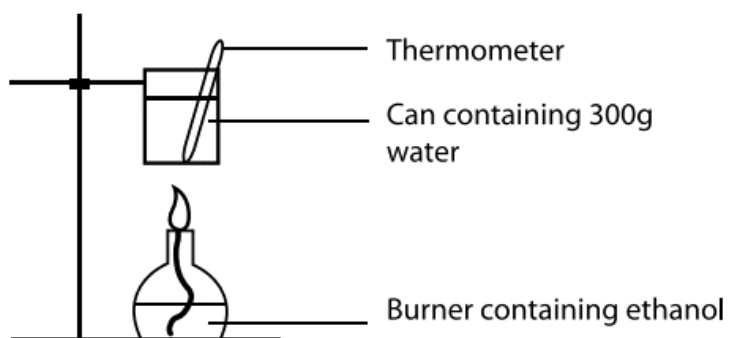
7. Know how to draw equipment correctly.

Drawing scientifically is a fundamental skill that requires attention to detail. It is not appropriate to "sketch" the equipment. Your diagram should be to scale, ruled and clearly labelled. As specifically stated in the HSC Chemistry General Instructions:

- Draw diagrams using pencil

Example:

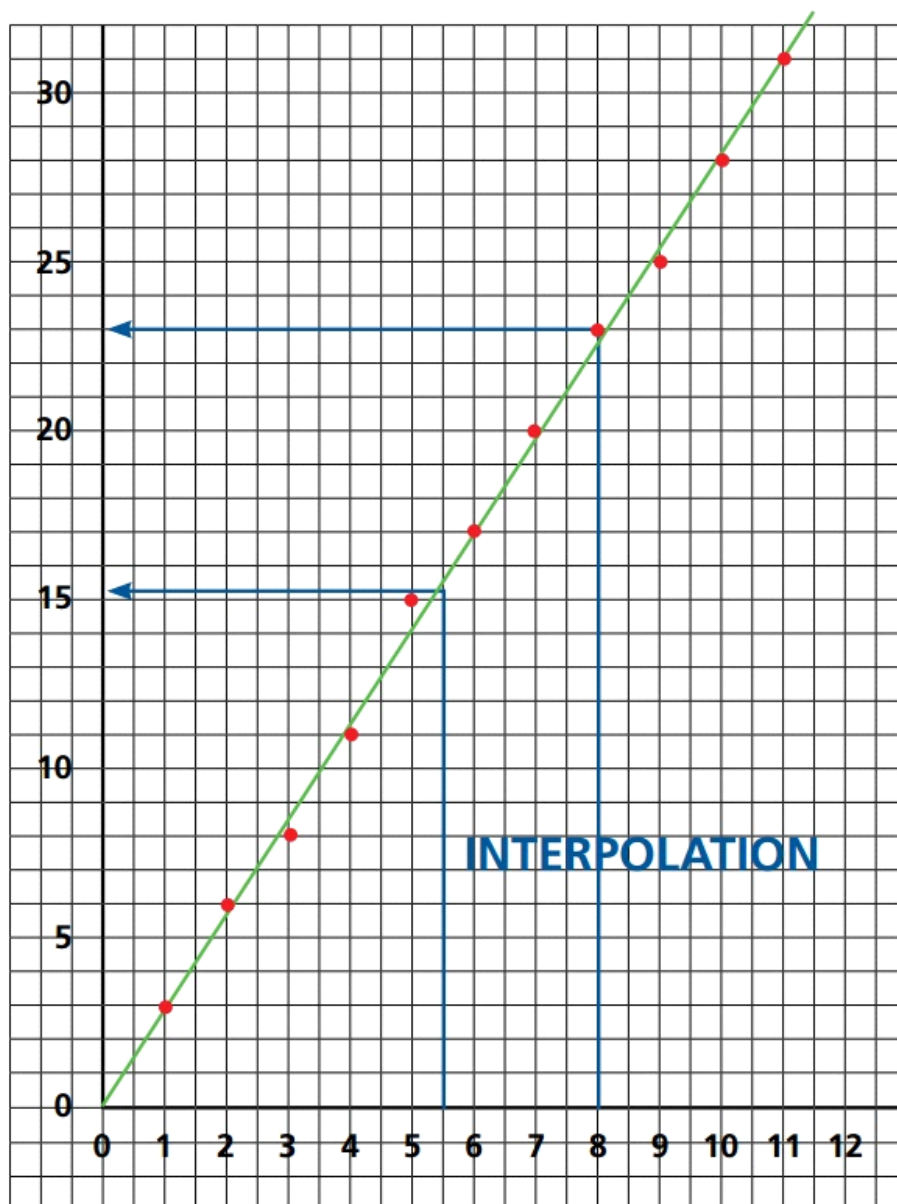
Example:



8. Know how to draw graphs correctly.

It is quite certain that you will have to deal with a graph in one way or another in the HSC examination. A few hints to remember:

- Plot the points accurately by marking the point with a cross or circle and use a pencil and ruler to draw the line of best fit.
- Include scales that are linear and clearly label both axes (with units if applicable).
- Ensure you use the majority of the grid provided.
- Extrapolation should be avoided since predictions are often invalid.



If a value is obtained by an interpolated estimate, clearly show on the graph how the value was obtained. A clear plastic ruler helps to plot points that are further from the axes and rule straight lines of best fit.

源文档 <<http://www.matrix.edu.au/hsc-chemistry-exam-tips/>>

Create: Possible questions for HSC

Friday, 8 February 2013 11:19 AM

Advantages and disadvantages of doing pracs (possible surprise question)

Why do we write equations such as $\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$, if we know they are wrong? Why do we not write addition to water, forming hydroxide ions? (from the past)

Answer: The way it is written is easier and is adequate enough for a simple description, sometimes adding water and hydronium ions is too complex to write.

HSC 2010 7. According to Le Chatelier's principle

Advantages and disadvantages of modeling

Why is the ΔH for strong acid + strong base the same?

Answer: it's the same reaction. $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ (net ionic)

Equilibrium, look out if acidic or neutral salts are added.

Epic titration question :

Suppose you wanted to determine the percentage purity of a sample of washing soda. Sodium carbonate decahydrate, that you had just purchased. Your lab has a solution of HCl labelled 0.25 mol/l it also has the usual range of pure chemicals and indicator solutions, an accurate mass balance, and a full range of volumetric glassware/ Explain fully how you could accurately determine the percentage purity of the washing soda. Include at least one diagram and give all experimental details. Name the indicator you would use and why.

Equations

2013年2月10日 18:37

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

- ***BASIC reactions to remember:***
 - **Acid** reactions:
 - acid + base salt + water
 - acid + metal salt + hydrogen gas
 - acid + carbonate carbon dioxide gas + salt + water
 - Complete **combustion**:
 - hydrocarbon + oxygen water + carbon dioxide
 - **Displacement** reactions:
 - $Y + X \text{ (anion)} \rightarrow X + Y \text{ (anion)}$; where $Y > X$ on *activity series*

Production of Materials:

- *BASIC reactions to remember:*
 - **Acid** reactions:
 - acid + base salt + water
 - acid + metal salt + hydrogen gas
 - acid + carbonate carbon dioxide gas + salt + water
 - Complete **combustion**:
 - hydrocarbon + oxygen water + carbon dioxide
 - **Displacement** reactions:
 - $Y + X \text{ (anion)} \rightarrow X + Y \text{ (anion)}$; where $Y > X$ on *activity series*.
- *Alkene/alkane reactions:*
 - **Cracking** of pentane:

- pentane ethylene + propane
 - $\text{C}_5\text{H}_{12}(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{C}_3\text{H}_8(\text{g})$
- **Hydrogenation** of ethylene:
 - ethylene + hydrogen ethane
 - $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$
- **Hydration** of ethylene:
 - ethylene + water ethanol
 - $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_2\text{H}_5\text{OH}(\text{l})$
- **Halogenation** (more specifically, **Chlorination**) of ethylene:
 - ethylene + chlorine 1,2-dichloroethane
 - $\text{C}_2\text{H}_4(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{C}_2\text{H}_4\text{Cl}_2(\text{l})$
- **Hydrohalogenation** (more specifically, **Hydrofluorination**) of ethylene:
 - ethylene + hydrogen fluoride fluoroethane
 - $\text{C}_2\text{H}_4(\text{g}) + \text{HFl}(\text{g}) \rightarrow \text{C}_2\text{H}_5\text{Fl}(\text{g})$
- Reaction of **cyclohexene** with **bromine water**:
 - cyclohexene + bromine + water 2-bromo-1-cyclohexanol + hydrogen bromide
 - $\text{C}_6\text{H}_{10}(\text{l}) + \text{Br}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_6\text{H}_{10}\text{BrOH}(\text{l}) + \text{HBr}(\text{aq})$
- *Fermentation and other ethanol-based reactions:*
 - **Dehydration** of ethanol:
 - ethanol ethylene + water
 - $\text{C}_2\text{H}_5\text{OH}(\text{l}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{l})$
 - **Combustion** of ethanol:
 - ethanol + oxygen carbon dioxide + water
 - $\text{C}_2\text{H}_5\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{g})$
 - **Fermentation** of glucose:
 - glucose ethanol + carbon dioxide
 - $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g})$
- *Electrochemistry:*
 - **Displacement** of copper from solution due to zinc:
 - zinc + copper sulfate zinc sulfate + copper
 - $\text{Zn}(\text{s}) + \text{CuSO}_4(\text{aq}) \rightarrow \text{ZnSO}_4(\text{aq}) + \text{Cu}(\text{s})$
 - **Ionic equation** of this reaction:
 - zinc + copper(II) ion + sulfate ion zinc(II) ion + sulfate ion + copper
 - $\text{Zn} + \text{Cu}^{2+} + \text{SO}_4^{2-} \rightarrow \text{Zn}^{2+} + \text{SO}_4^{2-} + \text{Cu}$
 - **Net ionic equation** of this reaction:
 - zinc + copper(II) ion zinc(II) ion + copper
 - $\text{Zn}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu}(\text{s})$
 - **Half-equations** of this equation:
 - $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$
 - $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$

Create: examples of band 6 / well answered full mark questions

2013年2月13日 20:04

Create: Remembering sheet

2013年2月13日 20:09

Always right a lot, ask for more paper, like an english exam. They never give u enough lines to get full marks.

Use the exact value for molecular mass on the period table. For example use 12.01 for carbon, NOT 12.

Use \rightarrow for ionisation of strong acids in water

Use \leftrightarrow for ionisation of weak acids in water

If you do not know how to do a question, write as much as u can (calculation) to get marks!

Always talk about lechatilier where question has a \leftrightarrow

Prac Tasks

Sunday, 17 February 2013 2:13 PM

Practical Skills Exams

Aim:

- When asked to write an aim, read all given data and recall the syllabus in order to formulate a correct aim. Reading the method, if provided, will help.
- The aim should start with a verb.

Method:

- Methods for all experiments should be completely memorised
- This includes all equipment, controlled variables, and steps to ensure validity
- When using a control, all aspects of the control must be kept the same e.g. for the fermentation prac, the control had to also be connected to a test-tube of limewater.
- Always include repetitions in your method to assess reliability
- Always include actual measurement data. E.g. write "measure 50ml of water with measuring cylinder and pour into beaker" rather than "pour water into beaker"
- Always include actual time intervals. E.g. do not say "record mass on a regular interval" rather say "record mass every 15 minutes"
- Always include a diagram.

Diagram:

- Must be drawn in 2-dimensions
- Must be drawn in pencil
- Arrow tips must touch equipment when labelling, arrow tips do not cross each other
- USE A RULER
- Markers seem to be faint on diagrams

Risk assessment:

- If asked to assess risks, the best way is to draw a table. Identify, assess, control

Graph:

- Must have a title, dependent y vs independent x
- Label axis with correct units, you may use scientific notation in the axis
- Use X to graph points, this shows there is a degree of uncertainty
- Always circle outliers, do this immediately to avoid forgetting, which would affect calculations
- Draw a LOBF, or curve of best fit. Do not force through origin
- MOST graphs for chemistry are straight lines, NOT CURVES.

Gradient

-Gradient $m = \frac{y_2 - y_1}{x_2 - x_1}$. Show this equation line and then the substitution line. GRADIENTS HAVE UNITS.

- If asked to justify the use of gradient: the y-intercept of the gradient determine the extent of the systematic error.

-Thus using te gradient gives a more accurate answer

Assessing Accuracy and improving accuracy

-Percentage error = $\frac{|x_{\text{accept}} - x_{\text{avg}}|}{x_{\text{accept}}}$

-Degree of accuracy = 100% - percentage error. Make sure you DO NOT USE 1-percentage error, 0.1 – percentage error, 100-percentage error, or anything else that is ridiculously stupid.

MUST GIVE A JUDGEMENT

-State whether degree of accuracy is in an accepted range.

-Give a JUDGEMENT in words for the degree of accuracy. High accuracy, low accuracy

- E.g, the 98% degree of accuracy is well within the accepted range and thus the accuracy is high.

Accuracy may be improved by _____

Assessing Reliability and improving reliability

-reliability is whether or not the same result will be achieved in a repeat trial

- an experiment is said to be reliable if it shows consistency within repeat trials

-No repeat trials means reliability CAN NOT BE ASSESSED. It DOES NOT, mean the experiment is not reliable.

-Graphically , the closer the points to the LOBF the better the reliability.

-Mathematically, reliability can be calculated by using the degree of uncertainty.

-Deviation from the mean = $\frac{|x - x_{\text{avg}}|}{x_{\text{accept}}}$

-This is expressed as a PERCENTAGE.

-Give a judgement in WORDS for reliability. Thus the experiment is highly reliable.

-Reliability CAN NOT be improved by simply repeating the experiment

-To improve reliability, the method needs to be improved (made more valid)

-Identify anything in the method that will result in inconsistent results

-Then the experiment should be repeated until CONSISTANT results are achieved.

Secondary Sources and secondary data

- Is the source up to date?

-Is it a REPUTABLE source?

-Have you tested it's information against other sources?

Assessing validity and improving Validity

- Validity is basically whether your experiment is measuring what you aimed to measure

- Validity is in two parts, validity of the method and validity of the result

- Methodology is valid if:

1. Accepted laws and mathematical relationships were applied (give examples)
2. All variables were identified and controlled (give examples of variables and controlled variables)
3. The method included repetitions to test reliability
4. Type of analysis was appropriate. E.g. a graph is appropriate to show a mathematical relationship and a picture is appropriate to show a color change, i.e. indicators.

- Results are valid if

1. Reliability is acceptable
2. Methodology is valid
3. Accuracy was sufficient
4. Conclusion answers the aim. This refers to conclusions, implications and results you draw, not the actual conclusion you write. E.g. if you are aiming to measure acceleration due to g , and you end up measuring the speed of a vehicle, then your result does not refer to your aim and thus is not valid

To improve validity any of the above can be improved

Errors:

- NEVER include human errors

Writing a conclusion:

- Write both your numerical answer and whether or not you achieved your aim.

Task 1A results

2013年3月6日 17:51

Choose the right cleaning agent from equipment list

Don't forget to identify and describe the control before justifying

Don't not see the last page

The control must be the same in everyway (inlcuding putting it into limewater)

The time intervals must be written in the method.

Change Log and notes

2013年3月26日 21:22

Just type here anything you change of anything in any subject , or we can just leave notes to eachother here.

Hi Darryl <3

maths is hard, english is harder, physics is hardest.

Or is it maths is hard, physics is harder, english is hardest.

Please. English is the easiest topic such a joke.

Who cares if maths is hard, ur so good at it.

Btw, syncing english notes from today.

Addd half yearly equations thingy to chem. Basically I just use it to remember equations by writing them everyday, u can use it if u want.

i

Half Yearly Equation Remembering Sheet

2013年3月28日 18:55

General:

Acid + Metal

Acid + Metal Oxide

Acid + carbonate

Production of materials:

Bromine water - hexene + Bromine water,

hexane + bromine water

Write the steps from Petroleum to Polyethylene

Addition reaction of Polyethylene

Polymerisation of Polyethylene

Structure of Glucose:

Structure of Cellulose:

Steps from cellulose to ethene:

Dehydration of Ethanol

Hydration of Ethene

Combustion of Ethanol:

Carbon neutral equations: (photosynthesis, fermentation, combustion)

Fermentation OF glucose:

Anode reaction for Dry cell

Cathode reaction for Dry Cell

Anode reaction for Silver oxide cell

Cathode reaction for silver oxide cell

Example of alpha decay, example of beta decay, example of gamma decay:

Production of (transuranic elements):

Production of (commercial isotope):

Acidic Environement:

Indicator colour change ranges for:

Bromothymol blue:

Litmus

Phenothalein

Methyl Orange

Equation for basic oxide (example) in water:

Equation for acidic Oxide (example) in water:

Equation for an amphoteric oxide in water acting as an acid:

Equation for an amphoteric oxide in water acting as a base:

Give the FOUR soft drink equations:

Melter smelter (heating zinc sulfide):

Sulphur is oxidised to form sulphur dioxide

Lightning forms NO

Combustion chambers forming NO

NO forming NO₂

Formation of carbonic acid

Formation of sulfurous acid

Formation of sulfuric acid from oxidation of sulfurous acid

Formation of nitrous acid and nitric acid

Formation of nitric acid from the oxidation of nitrous acid

Acid rain neutralising limestone

Acid rain corroding iron

Full name for Citric acid, diagram of citric acid:

Common ionisation equations: WATCH OUT FOR DOUBLE ARROW

Ionisation of sulphuric acid

Ionisation of ethanoic acid

Ionisation of citric acid

Ionisation of Hydrochloric acid:

Self ionisation of water

Two amphoteric substances and equations showing they are amphoteric

Derive the net ionic equation of neutralisation of a strong acid and a strong base.

Natural system buffer equations. Include 3

Neutralisation using the holy grail of an acid

Neutralisation using the holy grail of base

General equation for ester formation, CAREFUL, SHOW EVERYTHING

Draw the above equation

Coan quotes

Tuesday, 21 May 2013 11:07 AM

"Bird poo is neither solid or liquid, it is a little bit of both, that mushy stuff"

"Japanese steak costs 100 dollars"

'just because its blue doesn't mean its clean. Oh look its blue, must be clean, lets buy it

"I wouldn't be fishing in Lake Macquarie at all, or anywhere in the harbor, some people fish at their own sheds"

'I wouldn't trust a guy that spells water as w-o-r-t-a'

'If you have a whiter face, it means you are of the upper class because you didn't live outside doing labour"

"I've got no tennis balls, he's got all the tennis balls!"

"One of them should have spent more time in sports development"

"Maybe you spent too much more time doing table tennis rather than what the school wants you to do."

"Should be chatting, if it's a question put your hand up and we will address it"

"Heading caption title same thing"

"No crying over spilt water"

"Whole lotta Billy billy banjo playing Americans"