

Chemistry

Co-teaching Combined Science and Chemistry

April 2016

Area		Spec reference		Both specifications	Chemistry only
		Combined	Chemistry		
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				(HT only)	
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	4.10.2 Life cycle assessment and recycling	5.10.2.1	4.10.2.1	Life cycle assessment	
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Chemistry only content

4.1.3 Properties of transition metals (chemistry only)

4.1.3.1 Comparison with Group 1 elements

Content	Key opportunities for skills development
The transition elements are metals with similar properties which are different from those of the elements in Group 1. Students should be able to describe the difference compared with Group 1 in melting points, densities, strength, hardness and reactivity with oxygen, water and halogens. Students should be able to exemplify these general properties by reference to Cr, Mn, Fe, Co, Ni, Cu.	

4.1.3.2 Typical properties

Content	Key opportunities for skills development
Many transition elements have ions with different charges, form coloured compounds and are useful as catalysts. Students should be able to exemplify these general properties by reference to compounds of Cr, Mn, Fe, Co, Ni, Cu.	

4.2.4 Bulk and surface properties of matter including nanoparticles (chemistry only)

4.2.4.1 Sizes of particles and their properties

Content	Key opportunities for skills development
Nanoscience refers to structures that are 1–100 nm in size, of the order of a few hundred atoms. Nanoparticles, are smaller than fine particles (PM_{2.5}), which have diameters between 100 and 2500 nm (1×10^{-7} m and 2.5×10^{-6} m). Coarse particles (PM₁₀) have diameters between 1×10^{-5} m and 2.5×10^{-6} m. Coarse particles are often referred to as dust. As the side of cube decreases by a factor of 10 the surface area to volume ratio increases by a factor of 10. Nanoparticles may have properties different from those for the same materials in bulk because of their high surface area to volume ratio. It may also mean that smaller quantities are needed to be effective than for materials with normal particle sizes.	WS 1.2, 1.4, 4.1, 4.2, 4.3 4.4, 4.5 MS 2h Make order of magnitude calculations. MS 5c Calculate areas of triangles and rectangles, surface areas and volumes of cubes.

Students should be able to compare 'nano' dimensions to typical dimensions of atoms and molecules.	MS 1b Recognise and use expressions in standard form. MS 1c Use ratios, fractions and percentages. MS 1d Make estimates of the results of simple calculations.
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4.2.4.2 Uses of nanoparticles

Content	Key opportunities for skills development
Nanoparticles have many applications in medicine, in electronics, in cosmetics and sun creams, as deodorants, and as catalysts. New applications for nanoparticulate materials are an important area of research. Students should consider advantages and disadvantages of the applications of these nanoparticulate materials, but do not need to know specific examples or properties other than those specified.	
Students should be able to: • given appropriate information, evaluate the use of nanoparticles for a specified purpose • explain that there are possible risks associated with the use of nanoparticles.	WS 1.3, 1.4, 1.5

4.3.3 Yield and atom economy of chemical reactions (chemistry only)

4.3.3.1 Percentage yield

Content	Key opportunities for skills development
Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because: • the reaction may not go to completion because it is reversible • some of the product may be lost when it is separated from the reaction mixture • some of the reactants may react in ways different to the expected reaction. The amount of a product obtained is known as the yield. When compared with the maximum theoretical amount as a percentage, it is called the percentage yield.	WS 4.2, 4.6 MS 1a Recognise and use expressions in decimal form. MS 1c Use ratios, fractions and percentages. MS 2a Use an appropriate number of significant figures.

$\% \text{ Yield} = \frac{\text{Mass of product actually made}}{\text{Maximum theoretical mass of product}} \times 100$ Students should be able to: - calculate the percentage yield of a product from the actual yield of a reaction (HT only) calculate the theoretical mass of a product from a given mass of reactant and the balanced equation for the reaction.	MS 3b Change the subject of an equation.
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4.3.3.2 Atom economy

Content	Key opportunities for skills development
The atom economy (atom utilisation) is a measure of the amount of starting materials that end up as useful products. It is important for sustainable development and for economic reasons to use reactions with high atom economy. The percentage atom economy of a reaction is calculated using the balanced equation for the reaction as follows: $\frac{\text{Relative formula mass of desired product from equation}}{\text{Sum of relative formula masses of all reactants from equation}} \times 100$ Students should be able to: - calculate the atom economy of a reaction to form a desired product from the balanced equation (HT only) explain why a particular reaction pathway is chosen to produce a specified product given appropriate data such as atom economy (if not calculated), yield, rate, equilibrium position and usefulness of by-products.	WS 4.2, 4.6 MS 1a Recognise and use expressions in decimal form. MS 1c Use ratios, fractions and percentages. MS 3b Change the subject of an equation.

4.3.4 Using concentrations of solutions in mol/dm³ (chemistry only) (HT only)

Content	Key opportunities for skills development
The concentration of a solution can be measured in mol/dm³. The amount in moles of solute or the mass in grams of solute in a given volume of solution can be calculated from its concentration in mol/dm³. If the volumes of two solutions that react completely are known and the concentration of one solution is known, the concentration of the other solution can be calculated. Students should be able to explain how the concentration of a solution in mol/dm³ is related to the mass of the solute and the volume of the	WS 4.2, 4.3, 4.6 MS 1a Recognise and use expressions in decimal form. MS 1c Use ratios, fractions and percentages. MS 3b Change the subject of an

solution.	equation. MS 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities. AT 1, 3, 8 Opportunities within titrations including to determine concentrations of strong acids and alkalis.
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4.3.5 Use of amount of substance in relation to volumes of gases (chemistry only) (HT only)

Content	Key opportunities for skills development
Equal amounts in moles of gases occupy the same volume under the same conditions of temperature and pressure. The volume of one mole of any gas at room temperature and pressure (20°C and 1 atmosphere pressure) is 24 dm³. The volumes of gaseous reactants and products can be calculated from the balanced equation for the reaction. Students should be able to: • calculate the volume of a gas at room temperature and pressure from its mass and relative formula mass • calculate volumes of gaseous reactants and products from a balanced equation and a given volume of a gaseous reactant or product • change the subject of a mathematical equation.	WS 1.2, 4.1, 4.2, 4.3, 4.6 MS 1a Recognise and use expressions in decimal form. MS 1c Use ratios, fractions and percentages. MS 3b Change the subject of an equation. MS 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities.

4.4.2 Reactions of acids (chemistry only)

4.4.2.5 Titrations

Content	Key opportunities for skills development
Acids produce hydrogen ions (H⁺) in aqueous solutions. Aqueous solutions of alkalis contain hydroxide ions (OH⁻). The pH scale, from 0 to 14, is a measure of the acidity or alkalinity of a solution, and can be measured using universal indicator or a pH probe. A solution with pH 7 is neutral. Aqueous solutions of acids have pH values of less than 7 and aqueous solutions of alkalis have pH values greater than 7. In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation: $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \longrightarrow \text{H}_2\text{O}(\text{l})$ Students should be able to: • describe the use of universal indicator or a wide range indicator to measure the approximate pH of a solution • use the pH scale to identify acidic or alkaline solutions. The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator. Students should be able to: • describe how to carry out titrations using strong acids and strong alkalis only (sulfuric, hydrochloric and nitric acids only) to find the reacting volumes accurately • (HT Only) calculate the chemical quantities in titrations involving concentrations in mol/dm³ and in g/dm³.	AT 3 This is an opportunity to investigate pH changes when a strong acid neutralises a strong alkali.

4.5.2 Chemical cells and fuel cells (chemistry only)

4.5.2.1 Cells and batteries

Content	Key opportunities for skills development
Cells contain chemicals which react to produce electricity. The voltage produced by a cell is dependent upon a number of factors including the type of electrode and electrolyte. A simple cell can be made by connecting two different metals in contact with an electrolyte. Batteries consist of two or more cells connected together in series to provide a greater voltage. In non-rechargeable cells and batteries the chemical reactions stop when one of the reactants has been used up. Alkaline batteries are non-rechargeable. Rechargeable cells and batteries can be recharged because the chemical reactions are reversed when an external electrical current is supplied. Students should be able to interpret data for relative reactivity of different metals and evaluate the use of cells. Students do not need to know details of cells and batteries other than those specified.	AT6 Safe and careful use of liquids.

4.5.2.2 Fuel cells

Content	Key opportunities for skills development
Fuel cells are supplied by an external source of fuel (eg hydrogen) and oxygen or air. The fuel is oxidised electrochemically within the fuel cell to produce a potential difference. The overall reaction in a hydrogen fuel cell involves the oxidation of hydrogen to produce water. Hydrogen fuel cells offer a potential alternative to rechargeable cells and batteries. Students should be able to: • evaluate the use of hydrogen fuel cells in comparison with rechargeable cells and batteries • (HT only) write the half equations for the electrode reactions in the hydrogen fuel cell.	

4.7.2 Reactions of alkenes and alcohols (chemistry only)

4.7.2.1 Structure and formulae of alkenes

Content	Key opportunities for skills development
Alkenes are hydrocarbons with a double carbon-carbon bond. The general formula for the homologous series of alkenes is C_nH_{2n} Alkene molecules are unsaturated because they contain two fewer hydrogen atoms than the alkane with the same number of carbon atoms. The first four members of the homologous series of alkenes are ethene, propene, butene and pentene. Alkene molecules can be represented in the following forms: C_3H_6 Or <pre> H H H H — C — C = C H H </pre> Students do not need to know the names of individual alkenes other than ethene, propene, butene and pentene.	WS 1.2 Recognise substances that are alkenes from their names or from given formulae in these forms. MS 5b Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects.

4.7.2.2 Reactions of alkenes

Content	Key opportunities for skills development
Alkenes are hydrocarbons with the functional group $C=C$. It is the generality of reactions of functional groups that determine the reactions of organic compounds. Alkenes react with oxygen in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with smoky flames because of incomplete combustion. Alkenes react with hydrogen, water and the halogens, by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond.	

Students should be able to: • describe the reactions and conditions for the addition of hydrogen, water and halogens to alkenes • draw fully displayed structural formulae of the first four members of the alkenes and the products of their addition reactions with hydrogen, water, chlorine, bromine and iodine.	WS 1.2
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4.7.2.3 Alcohols

Content	Key opportunities for skills development
Alcohols contain the functional group –OH. Methanol, ethanol, propanol and butanol are the first four members of a homologous series of alcohols. Alcohols can be represented in the following forms: CH₃CH₂OH Or $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $ Students should be able to: • describe what happens when any of the first four alcohols react with sodium, burn in air, are added to water, react with an oxidising agent • recall the main uses of these alcohols. Aqueous solutions of ethanol are produced when sugar solutions are fermented using yeast. Students should know the conditions used for fermentation of sugar using yeast. Students should be able to recognise alcohols from their names or from given formulae. Students do not need to know the names of individual alcohols other than methanol, ethanol, propanol and butanol. Students are not expected to write balanced chemical equations for the reactions of alcohols other than for combustion reactions.	AT 2, 5, 6 Opportunities when investigating reactions of alcohols.

4.7.2.4 Carboxylic acids

Content	Key opportunities for skills development
Carboxylic acids have the functional group --COOH. The first four members of a homologous series of carboxylic acids are methanoic acid, ethanoic acid, propanoic acid and butanoic acid. The structures of carboxylic acids can be represented in the following forms: CH_3COOH or $ \begin{array}{c} \text{H} \\ \\ \text{H} - \text{C} - \text{C} = \text{O} \\ \quad \\ \text{H} \quad \text{O} - \text{H} \end{array} $ Students should be able to: - describe what happens when any of the first four carboxylic acids react with carbonates, dissolve in water, react with alcohols (HT only) explain why carboxylic acids are weak acids in terms of ionisation and pH (see Strong and weak acids (HT only) (page 48)). Students should be able to recognise carboxylic acids from their names or from given formulae. Students do not need to know the names of individual carboxylic acids other than methanoic acid, ethanoic acid, propanoic acid and butanoic acid. Students are not expected to write balanced chemical equations for the reactions of carboxylic acids. Students do not need to know the names of esters other than ethyl ethanoate.	AT 2, 5, 6 Opportunities within investigation of the reactions of carboxylic acids.

4.7.3 Synthetic and naturally occurring polymers (chemistry only)

4.7.3.1 Addition polymerisation

Content	Key opportunities for skills development
Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation. In addition polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers). For example: $ \begin{array}{ccc} \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ n \text{ C} = \text{C} \\ \quad \\ \text{H} \quad \text{H} \end{array} & \longrightarrow & \begin{array}{c} \left(\begin{array}{cc} \text{H} & \text{H} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{H} & \text{H} \end{array} \right)_n \\ \text{poly(ethene)} \end{array} \end{array} $ ethene In addition polymers the repeating unit has the same atoms as the monomer because no other molecule is formed in the reaction.	WS 1.2 Use models to represent addition polymerisation.
Students should be able to: • recognise addition polymers and monomers from diagrams in the forms shown and from the presence of the functional group C=C in the monomers • draw diagrams to represent the formation of a polymer from a given alkene monomer • relate the repeating unit to the monomer.	MS 5b Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects.

4.7.3.2 Condensation polymerisation (HT only)

Content	Key opportunities for skills development
Condensation polymerisation involves monomers with two functional groups. When these types of monomers react they join together, usually losing small molecules such as water, and so the reactions are called condensation reactions. The simplest polymers are produced from two different monomers with two of the same functional groups on each monomer.	WS 1.2 Use models to represent condensation polymerisation.

For example: ethane diol $\text{HO} - \text{CH}_2 - \text{CH}_2 - \text{OH} \quad \text{or} \quad \text{HO} - \square - \text{OH}$ and hexanedioic acid $\text{HOOC} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{COOH} \quad \text{or} \quad \text{HOOC} - \square - \text{COOH}$ polymerise to produce a polyester: $n \text{HO} - \square - \text{OH} + n \text{HOOC} - \square - \text{COOH} \rightarrow$ $\left(\square - \text{OOC} - \square - \text{COO} \right)_n + 2n\text{H}_2\text{O}$	
Students should be able to explain the basic principles of condensation polymerisation by reference to the functional groups in the monomers and the repeating units in the polymers.	MS 5b Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects.

4.7.3.3 Amino acids (HT only)

Content	Key opportunities for skills development
Amino acids have two different functional groups in a molecule. Amino acids react by condensation polymerisation to produce polypeptides. For example: glycine is $\text{H}_2\text{NCH}_2\text{COOH}$ and polymerises to produce the polypeptide $(-\text{HNCH}_2\text{COO}-)_n \text{ and } n \text{H}_2\text{O}$ Different amino acids can be combined in the same chain to produce proteins.	

4.7.3.4 DNA (deoxyribonucleic acid) and other naturally occurring polymers

Content	Key opportunities for skills development
DNA (deoxyribonucleic acid) is a large molecule essential for life. DNA encodes genetic instructions for the development and functioning of living organisms and viruses. Most DNA molecules are two polymer chains, made from four different monomers called nucleotides, in the form of a double helix. Other naturally occurring polymers important for life include proteins, starch and cellulose. Students should be able to name the types of monomers from which these naturally occurring polymers are made.	

4.8.3 Identification of ions by chemical and spectroscopic means (chemistry only)

4.8.3.1 Flame tests

Content	Key opportunities for skills development
Flame tests can be used to identify some metal ions (cations). Lithium, sodium, potassium, calcium and copper compounds produce distinctive colours in flame tests: • lithium compounds result in a crimson flame • sodium compounds result in a yellow flame • potassium compounds result in a lilac flame • calcium compounds result in an orange-red flame • copper compounds result in a green flame. If a sample containing a mixture of ions is used some flame colours can be masked.	AT 8 An opportunity to investigate flame colours.
Students should be able to identify species from the results of the tests in 4.8.3.1 to 4.8.3.5. Flame colours of other metal ions are not required knowledge.	WS 2.2

4.8.3.2 Metal hydroxides

Content	Key opportunities for skills development
Sodium hydroxide solution can be used to identify some metal ions (cations). Solutions of aluminium, calcium and magnesium ions form white precipitates when sodium hydroxide solution is added but only the	AT 8 An opportunity to make precipitates of metal hydroxides.

aluminium hydroxide precipitate dissolves in excess sodium hydroxide solution. Solutions of copper(II), iron(II) and iron(III) ions form coloured precipitates when sodium hydroxide solution is added. Copper(II) forms a blue precipitate, iron(II) a green precipitate and iron(III) a brown precipitate.	
Students should be able to write balanced equations for the reactions to produce the insoluble hydroxides. Students are not expected to write equations for the production of sodium aluminate.	WS 2.2

4.8.3.3 Carbonates

Content	Key opportunities for skills development
Carbonates react with dilute acids to form carbon dioxide gas. Carbon dioxide can be identified with limewater.	

4.8.3.4 Halides

Content	Key opportunities for skills development
Halide ions in solution produce precipitates with silver nitrate solution in the presence of dilute nitric acid. Silver chloride is white, silver bromide is cream and silver iodide is yellow.	

4.8.3.5 Sulfates

Content	Key opportunities for skills development
Sulfate ions in solution produce a white precipitate with barium chloride solution in the presence of dilute hydrochloric acid.	

Required practical 7: Use of chemical tests to identify the ions in unknown single ionic compounds covering the ions from sections [Flame tests](#) (page 73) to [Sulfates](#) (page 74).

AT skills covered by this practical activity: 1 and 8.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in [Key opportunities for skills development](#) (page 107).

4.8.3.6 Instrumental methods

Content	Key opportunities for skills development
Elements and compounds can be detected and identified using instrumental methods. Instrumental methods are accurate, sensitive and rapid. Students should be able to state advantages of instrumental methods compared with the chemical tests in this specification.	

4.8.3.7 Flame emission spectroscopy

Content	Key opportunities for skills development
Flame emission spectroscopy is an example of an instrumental method used to analyse metal ions in solutions. The sample is put into a flame and the light given out is passed through a spectroscope. The output is a line spectrum that can be analysed to identify the metal ions in the solution and measure their concentrations.	AT 8 An opportunity to observe flame spectra using a handheld spectroscope.
Students should be able to interpret an instrumental result given appropriate data in chart or tabular form, when accompanied by a reference set in the same form, limited to flame emission spectroscopy.	WS 3.6 MS 4a

4.10.3 Using materials (chemistry only)

4.10.3.1 Corrosion and its prevention

Content	Key opportunities for skills development
Corrosion is the destruction of materials by chemical reactions with substances in the environment. Rusting is an example of corrosion. Both air and water are necessary for iron to rust. Corrosion can be prevented by applying a coating that acts as a barrier, such as greasing, painting or electroplating. Aluminium has an oxide coating that protects the metal from further corrosion. Some coatings are reactive and contain a more reactive metal to provide sacrificial protection, eg zinc is used to galvanise iron.	

Students should be able to: • describe experiments and interpret results to show that both air and water are necessary for rusting • explain sacrificial protection in terms of relative reactivity.	WS 2.2, 7, 3.5 Investigate the conditions for rusting.
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4.10.3.2 Alloys as useful materials

Content	Key opportunities for skills development
Most metals in everyday use are alloys. Bronze is an alloy of copper and tin. Brass is an alloy of copper and zinc. Gold used as jewellery is usually an alloy with silver, copper and zinc. The proportion of gold in the alloy is measured in carats. 24 carat being 100% (pure gold), and 18 carat being 75% gold. Steels are alloys of iron that contain specific amounts of carbon and other metals. High carbon steel is strong but brittle. Low carbon steel is softer and more easily shaped. Steels containing chromium and nickel (stainless steels) are hard and resistant to corrosion. Aluminium alloys are low density.	
Students should be able to: • recall a use of each of the alloys specified • interpret and evaluate the composition and uses of alloys other than those specified given appropriate information.	MS 1a Recognise and use expressions in decimal form. MS 1c Use ratios, fractions and percentages.

4.10.3.3 Ceramics, polymers and composites

Content	Key opportunities for skills development
Most of the glass we use is soda-lime glass, made by heating a mixture of sand, sodium carbonate and limestone. Borosilicate glass, made from sand and boron trioxide, melts at higher temperatures than soda-lime glass. Clay ceramics, including pottery and bricks, are made by shaping wet clay and then heating in a furnace. The properties of polymers depend on what monomers they are made from and the conditions under which they are made. For example, low density (LD) and high density (HD) poly(ethene) are	

produced from ethene. Thermosoftening polymers melt when they are heated. Thermosetting polymers do not melt when they are heated. Students should be able to: • explain how low density and high density poly(ethene) are both produced from ethene • explain the difference between thermosoftening and thermosetting polymers in terms of their structures. Most composites are made of two materials, a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement. Students should be able to recall some examples of composites.	
Students should be able to, given appropriate information: • compare quantitatively the physical properties of glass and clay ceramics, polymers, composites and metals • explain how the properties of materials are related to their uses and select appropriate materials.	WS 1.4, 3.5, 3.8 Compare the properties of thermosetting and thermosoftening polymers.

4.10.4 The Haber process and the use of NPK fertilisers (chemistry only)

4.10.4.1 The Haber process

Content	Key opportunities for skills development
The Haber process is used to manufacture ammonia, which can be used to produce nitrogen-based fertilisers. The raw materials for the Haber process are nitrogen and hydrogen. Students should be able to recall a source for the nitrogen and a source for the hydrogen used in the Haber process. The purified gases are passed over a catalyst of iron at a high temperature (about 450°C) and a high pressure (about 200 atmospheres). Some of the hydrogen and nitrogen reacts to form ammonia. The reaction is reversible so some of the ammonia produced breaks down into nitrogen and hydrogen: <i>nitrogen + hydrogen $\rightleftharpoons$ ammonia</i> On cooling, the ammonia liquefies and is removed. The remaining hydrogen and nitrogen are recycled.	MS 1a Recognise and use expressions in decimal form. MS 1c Use ratios, fractions and percentages.
(HT only) Students should be able to: • interpret graphs of reaction conditions versus rate	MS 1a Recognise and use expressions in decimal form.

	MS 1c Use ratios, fractions and percentages.
• apply the principles of dynamic equilibrium in Reversible reactions and dynamic equilibrium (page 59) to the Haber process • explain the trade-off between rate of production and position of equilibrium • explain how the commercially used conditions for the Haber process are related to the availability and cost of raw materials and energy supplies, control of equilibrium position and rate.	WS 3.5, 3.8

4.10.4.2 Production and uses of NPK fertilisers

Content	Key opportunities for skills development
Compounds of nitrogen, phosphorus and potassium are used as fertilisers to improve agricultural productivity. NPK fertilisers contain compounds of all three elements. Industrial production of NPK fertilisers can be achieved using a variety of raw materials in several integrated processes. NPK fertilisers are formulations of various salts containing appropriate percentages of the elements. Ammonia can be used to manufacture ammonium salts and nitric acid. Potassium chloride, potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser. Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers. Students should be able to: • recall the names of the salts produced when phosphate rock is treated with nitric acid, sulfuric acid and phosphoric acid • compare the industrial production of fertilisers with laboratory preparations of the same compounds, given appropriate information.	AT 4 Prepare an ammonium salt.