# Teacher Resource Bank

## GCE Chemistry

## AS Scheme of Work

# AS SCHEME OF WORK

## Assessment of AS Chemistry

**The scheme of work is a suggestion only** and is organised so that Centres may enter candidates for the first unit **(Foundation Chemistry)** in January of Year 12 followed by the second unit **(Chemistry in Action)** in June of Year 12. The work of the third unit **(Investigative and Practical Skills in AS Chemistry)** should be an integral part of the teaching programme regardless of the route to assessment chosen by the Centre.

Where appropriate, **"How Science Works" (HSW)** should be incorporated into the teaching of each unit to set a context in which the study is placed. It is important for centres to appreciate that the HSW contexts are **not extensions to the specification**, but are designed to represent useful areas of work which may facilitate the study of the specification content. Teachers may wish to explore these aspects in their delivery of particular topics or have their students undertake research to broaden their understanding and enjoyment of the subject. The outcome might be a poster or a Powerpoint presentation or a class discussion.

**The only examinable material is that which appears in the left hand column entitled "Specification Content".**

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities should be set in contexts appropriate to, and reflect the demand of, the AS content. These activities should allow candidates to use their knowledge and understanding of Chemistry in carrying out, analysing and evaluating their work.
The specifications for Units 1 and 2 provide a range of different practical topics which may be used for experimental and investigative skills. The experience of dealing with such activities will develop the skills required for the assessment of these skills in Unit 3.

**PSA** and **HSW contexts** are indicated in this scheme of work. Other **possible** practical opportunities and class-based activities are also indicated; these may be class activities (EXPT) or teacher-demonstrations (DEM).

A guide to the teaching objectives is included at the start of each Section.

A **possible** teaching sequence and suggested timing is given, with a total number of weeks allocated at 28. This number of weeks allows for early AS papers and includes time for internal tests in the Centre.

A list of resources is included with this scheme of work. This list is illustrative and AQA bears no responsibility for the accuracy of the content either of textbooks or material on web-sites.

**Possible timing to teach the course**

| Content of Unit 1 (and the first term) | Suggested timing |
|---|---|
| **Unit 1 Foundation Chemistry** | |
| **3.1.1 Atomic structure**<br>**3.1.2 Amount of Substance** | 6 weeks: These two sections could be taught in parallel to allow theory and practical to be developed. |
| **3.1.5 Introduction to organic chemistry**<br>**3.1.6 Alkanes** | 4 weeks: These two sections could be taught next to begin to develop the ideas of organic chemistry. |
| **3.1.3 Bonding**<br>**3.1.4 Periodicity** | 4 weeks: Section 3.1.3 provides an opportunity to continue theoretical work while 3.1.4 provides further practical work. |

| Content of Unit 2 (and the second and third terms) | Suggested timing |
|---|---|
| **Unit 2 Chemistry in Action** | |
| **3.2.1 Energetics**<br>**3.2.2 Kinetics**<br>**3.2.3 Equilibria** | 4 weeks: These three physical chemistry sections provide some new concepts for students and the chance to re-visit ideas from GCSE |
| **3.2.8 The haloalkanes**<br>**3.2.9 Alkenes**<br>**3.2.10 Alcohols**<br>**3.2.11 Analytical techniques** | 5 weeks: The organic chemistry section will require time to be learned and understood and may need a relatively early start and a re-visit later in the year. |
| **3.2.4 Redox reactions**<br>**3.2.5 Group 7, the Halogens** | 2½ weeks: The ideas of redox are relatively demanding, but some of the work on halogens links to Unit 1 with background from GCSE. |
| **3.2.6 Group 2, the alkaline earth metals**<br>**3.2.7 Metal extraction** | 2½ weeks: the learning necessary for metal extraction may be facilitated by a later study. |

## Overview of the assessment weightings for the course

| AS Examination - 1421 |
|---|
| **Unit 1 – Foundation Chemistry**<br><br>Examination paper (70 raw marks/100 UMS). 4 - 5 short answer questions plus 1 longer question.<br><br>1 ¼ hours<br>33 ⅓ % of the total AS marks<br>16 ⅔ % of the total A-level marks |
| **Unit 2 – Chemistry In Action**<br><br>Examination paper (100 raw marks/140 UMS). 6 – 8 short answer questions plus 2 longer questions<br><br>1 ¾ hours<br>46 ⅔ % of the total AS marks<br>23 ⅓ % of the total A-level marks |
| **Unit 3 – Investigative and Practical Skills in AS Chemistry**<br><br>AS Centre-Assessed Unit (50 raw marks/60 UMS)<br>Investigative Skills Assignment (ISA – 38 raw marks)<br>Practical Skills Assessment (PSA – 12 raw marks)<br><br>20% of total AS marks<br>10% of total A-level marks |

**Some possible resources**

This list is illustrative and AQA bears no responsibility for the accuracy of the content either of textbooks or material on web-sites

**Textbooks**

AS and A2 Chemistry from Nelson-Thornes (AQA endorsed)

AS and A2 Chemistry from Collins

AS and A2 Chemistry from Oxford University Press

**Web-sites**

www.chemguide.co.uk
www.rsc.org
www.environment-agency.gov.uk
www.direct.gov.uk/en/Environmentandgreenerliving/index.htm
www.ec.europa.eu/environment/index_en.htm
www.carbontrust.co.uk
www.nas.nasa.gov
www.royalsociety.org
www.bgs.ac.uk
www.a-levelchemistry.co.uk
www.chemsheets.co.uk
www.ciec.org.uk

## AS Unit 1  Foundation Chemistry

This unit explores the fundamental principles that form the basis of Chemistry.

*In Section 3.1.1 (Atomic Structure), students should gain*

- *a theoretical understanding of atomic structure.*
- *an understanding of how mass spectrometry is used to provide information about the existence and relative abundance of isotopes.*
- *an insight into how electrons are arranged in main levels, sub-levels and atomic orbitals, through the study of ionisation energy.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.1.1  Atomic structure** | | |
| Fundamental particles<br>• be able to describe the properties of protons, neutrons and electrons in terms of relative charge and relative mass<br>• know that early models of atomic structure predicted that atoms and ions with noble gas electron-arrangements should be stable | How the ideas of atomic structure were developed (HSW) | |
| Protons, neutrons and electrons<br>• understand the importance of these particles in the structure of the atom and appreciate that there are various models to illustrate atomic structure | | |
| Mass number and isotopes<br>• be able to recall the meaning of mass number (*A*) and atomic (proton) number (*Z*)<br>• be able to explain the existence of isotopes<br>• understand the principles of a simple mass spectrometer, limited to ionisation, acceleration, deflection and detection | A simple illustration of how a mass spectrometer works using ball bearings and a magnet on a slope (DEM) | The uses of isotopes in medicine and in industry (HSW) |

| | | |
|---|---|---|
| • know that the mass spectrometer gives accurate information about relative isotopic mass and also about relative abundance of isotopes<br>• be able to interpret simple mass spectra of elements and calculate relative atomic mass from isotopic abundance, limited to mononuclear ions<br>• know that mass spectrometry can be used to identify elements (as used for example in planetary space probes)<br>• know that mass spectrometry can be used to determine relative molecular mass | The use of mass spectrometry in providing accurate values for relative isotopic masses (HSW) | |
| Electron arrangement<br>• know the electron configurations of atoms and ions up to $Z = 36$ in terms of levels and sub-levels (orbitals) s, p and d<br>• know the meaning of the term *ionisation energy*.<br>• understand how ionisation energies in Period 3 (Na – Ar) and in Group 2 (Be – Ba) give evidence for electron arrangement in sub-levels and in levels | The link between models of atomic structure and experimental ionisation energy data (HSW) | The link between electron energy levels and lasers/ luminescence (HSW) |

*In Section 3.1.2 (Amount of Substance) students should gain*

- *an understanding of the mole concept.*
- *an ability to apply the mole concept in circumstances which involve gases, solutions and solids.*
- *an ability to apply the mole concept to empirical formula analysis.*
- *an ability to use balanced equations.*
- *a range of manipulative skills in practical work associated with titrations.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.1.2 Amount of Substance**<br>• be able to define relative atomic mass ($A_r$) and relative molecular mass ($M_r$) in terms of $^{12}C$. (The term relative formula mass will be used for ionic compounds)<br>• understand the concept of a mole as applied to electrons, atoms, molecules, ions, formulae and equations<br>• understand the concept of the Avogadro constant. (Calculation not required)<br>• be able to recall the ideal gas equation $pV = nRT$ and be able to apply it to simple calculations in S.I. units, for ideal gases<br>• understand the concept of and the relationship between empirical and molecular formulae<br>• be able to calculate empirical formulae from data giving percentage composition by mass<br>• be able to write balanced equations (full and ionic) for reactions studied<br>• be able to balance equations for unfamiliar reactions when reactants and products are specified. (This is an important skill that applies in all modules)<br>• be able to calculate reacting volumes of gases | **Determine the $M_r$ of a volatile liquid or the $M_r$ of a gas (PSA)**<br>e.g. Determine the $M_r$ of hexane or the $M_r$ of carbon dioxide.<br><br>The use of empirical formula as a part of chemical analysis (HSW)<br>. | |

| | | |
|---|---|---|
| • be able to calculate concentrations and volumes for reactions in solutions, limited to titrations of monoprotic acids and bases and examples for which the equations are given.<br><br>• know that<br>$\% \text{ atom economy} = \left(\frac{\text{mass of desired product}}{\text{total mass of reactants}} \times 100\right)$<br><br>• be able to calculate reacting masses,<br>% yields and % atom economies from balanced equations. | **Make up a volumetric solution (PSA)**<br>e.g. The preparation of a standard solution of sodium carbonate.<br><br>**Carry out a simple acid-base titration (PSA)**<br>e.g. Determine the concentration of unknown hydrochloric acid by titration.<br><br>Determine the percentage of ethanoic acid in vinegar (EXPT) | The importance of the idea of an atom economy in the pharmaceutical industry (HSW) |

*In Section 3.1.3 (Bonding), students should gain*

- *an in-depth understanding of bonding extending knowledge from GCSE.*
- *an understanding of intermolecular forces of attraction.*
- *an appreciation of the four types of crystal leading to a study of giant structures.*
- *an understanding of the principles used to determine the shapes of simple molecules.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.1.3 Bonding**<br><br>• understand that ionic bonding involves attraction between oppositely charged ions in a lattice<br>• know that a covalent bond involves a shared pair of electrons<br>• know that co-ordinate bonding is dative covalency<br>• understand that metallic bonding involves a lattice of positive ions surrounded by delocalised electrons<br>• understand that electronegativity is the power of an atom to withdraw electron density from a covalent bond<br>• understand that the electron distribution in a covalent bond may not be symmetrical<br>• know that covalent bonds between different elements will be polar to different extents<br>• understand qualitatively how molecules may interact by permanent dipole–dipole, induced dipole–dipole (van der Waals') forces and hydrogen bonding<br>• understand the importance of hydrogen bonding in determining the boiling points of compounds and the structures of some solids (e.g. ice)<br>• be able to explain the energy changes associated with changes of state<br>• recognise the four types of crystal: ionic, metallic, giant covalent (macromolecular) and molecular<br>• know the structures of the following crystals: sodium chloride, magnesium, diamond, graphite, iodine and ice | The importance of hydrogen bonding in the structure of proteins and in DNA (HSW) | The nature and applications of 'memory metals' (HSW)<br><br>The work of Linus Pauling developing the concept of electronegativity (HSW)<br><br>How solvents interact with solutes (HSW)<br><br>The structure and uses of buckminsterfullerene (HSW) |

| | | |
|---|---|---|
| • be able to relate the physical properties of materials to the type of structure and bonding present<br>• understand the concept of bonding and lone (non-bonding) pairs of electrons as charge clouds.<br>• be able, in terms of electron pair repulsion, to predict the shapes of, and bond angles in, simple molecules and ions, limited to 2, 3, 4, 5 and 6 co-ordination<br>• know that lone pair/lone pair repulsion is greater than lone pair/bonding pair repulsion, which is greater than bonding pair/bonding pair repulsion, and understand the resulting effect on bond angles | Test electrical conductivities of ethanol, deionised water, salt solution, sugar solution,$CaCO_3$ stirred with water (EXPT)<br><br>Use balloons to illustrate the shapes of simple molecules (DEM) | |

*In Section 3.1.4 (Periodicity), students should gain*

- *an overview of the blocks in the Periodic table.*
- *an appreciation of the trends in properties of the elements across Period 3.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.1.4 Periodicity**<br><br>• be able to classify an element as s, p or d block according to its position in the Periodic Table<br>• be able to describe the trends in atomic radius, first ionisation energy, melting and boiling points of the elements Na – Ar<br>• understand the reasons for the trends in these properties | | How new elements are discovered (HSW)<br><br>How the characteristics of s-block and d-block elements influence their use (HSW) |

*In Section 3.1.5 (Introduction to Organic Chemistry), students should gain*

- *an understanding of how organic compounds are represented through formulae.*
- *an understanding of the concept of an homologous series.*
- *an introduction to the method used to name organic compounds.*
- *an overview of structural isomerism.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.1.5 Introduction to Organic Chemistry**<br><br>• know and understand the terms empirical formula, molecular formula, structural formula, displayed formula, homologous series and functional group<br>• be able to apply IUPAC rules for nomenclature to simple organic compounds, limited to chains with up to 6 carbon atoms limited in this module to alkanes, alkenes and haloalkanes<br>• know and understand the meaning of the term structural isomerism<br>• be able to draw the structures of chain, position and functional group isomers. | Use of molecular models (EXPT and HSW) | |

*In Section 3.1.6 (Alkanes), students should gain*

- *an understanding of what is meant by a saturated hydrocarbon.*
- *an appreciation of the processes involved in refining crude oil including fractional distillation and cracking.*
- *an appreciation of the purpose and economic significance of the processes undertaken in refining crude oil.*
- *an understanding of the emissions produced in the burning of fuels and how chemists are working to minimise the impact of these on the environment.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.1.6 Alkanes**<br>• know that alkanes are saturated hydrocarbons<br>• know that petroleum is a mixture consisting mainly of alkane hydrocarbons<br>• understand that different components (fractions) of this mixture can be drawn off at different levels in a fractionating column because of the temperature gradient<br>• understand that cracking involves the breaking of C–C bonds in alkanes<br>• know that thermal cracking takes place at high pressure and high temperature and produces a high percentage of alkenes (mechanism not required)<br>• know that catalytic cracking takes place at a slight pressure, high temperature and in the presence of a zeolite catalyst and is used mainly to produce motor fuels and aromatic hydrocarbons (mechanism not required)<br>• understand the economic reasons for the cracking of alkanes (e.g. ethene used for poly(ethene); conversion of heavy fractions into higher value products) | The main processes in an oil refinery and the supply and demand of different fractions (HSW)<br><br>The range of uses for the different products from oil refineries (HSW) | |

| | | |
|---|---|---|
| • know that alkanes are used as fuels and understand that their combustion can be complete or incomplete and that the internal combustion engine produces a number of pollutants (e.g. $NO_X$, CO and unburned hydrocarbons)<br>• know that these pollutants can be removed using catalytic converters<br>• know that combustion of hydrocarbons containing sulfur leads to sulfur dioxide that causes air pollution and understand how sulfur dioxide can be removed from flue gases using calcium oxide<br>• know that the combustion of fossil fuels (including alkanes) results in the release of carbon dioxide into the atmosphere<br>• know that carbon dioxide, methane and water vapour are referred to as greenhouse gases and that these gases may contribute to global warming | The harmful effects that these pollutants could have on the environment and how chemistry is used to reduce their release (HSW)<br><br>The chemistry of catalytic converters (HSW)<br><br>How coal-fired power stations have applied chemistry to reduce the emission of sulfur compounds but that this may conflict with $CO_2$ emissions (HSW)<br><br>Discuss critically the issues which surround the role of $H_2O$, $CH_4$ and $CO_2$ as greenhouse gases (HSW) | Octane numbers and 'knocking' (HSW)<br><br>The economics of catalytic converters (HSW) |

## AS Unit 2  Chemistry in Action

This unit introduces more of the principles that underpin chemistry and looks at the applications of these principles and those that have been developed in Unit 1.

*In Section 3.2.1 (Energetics), students should gain*

- *an appreciation of what is meant by the idea of enthalpy change.*
- *an appreciation of the way in which thermochemical measurements are taken.*
- *an understanding of the problems associated with measuring enthalpy changes in the laboratory.*
- *an understanding of Hess's law as a special case of the first law of thermodynamics.*
- *an appreciation of the way in which mean bond energy values can be used to inform, for example, the choice of fuel.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.1  Energetics**<br><br>Enthalpy change ( $\Delta H$ )<br>• know that reactions can be endothermic or exothermic<br>• understand that enthalpy change ( $\Delta H$ ) is the heat energy change measured under conditions of constant pressure<br>• know that standard enthalpy changes refer to standard conditions, i.e. 100 kPa and a stated temperature (e.g. $\Delta H_{298}$)<br>• be able to recall the definition of standard enthalpies of combustion ( $\Delta H_c^\ominus$ ) and formation ( $\Delta H_f^\ominus$ )<br>Calorimetry<br>• be able to calculate the enthalpy change from the heat change in a reaction using the equation $q = mc\,\Delta T$ | **Investigate the combustion of alcohols (PSA)**<br>e.g. Use a calorimetric method to measure the enthalpies of combustion in an homologous series of alcohols. | 'Hand warmers' and 'cold packs' (HSW) |

| | | |
|---|---|---|
| Simple applications of Hess's Law<br>• know Hess's Law and be able to use it to perform simple calculations for example calculating enthalpy changes for reactions from enthalpies of combustion or enthalpies of formation.<br><br>Bond enthalpies<br>• be able to determine mean bond enthalpies from given data<br>• be able to use mean bond enthalpies to calculate a value of $\Delta H$ for simple reactions | Determine an enthalpy of neutralisation by reacting sodium hydroxide solution with dilute hydrochloric acid (EXPT)<br><br>Test the validity of Hess's Law by making, for example, sodium chloride solution by different routes (EXPT)<br><br>**Measure an enthalpy change (PSA)**<br>e.g. Use Hess's law to find an unknown enthalpy change, such as the reaction of anhydrous copper(II) sulfate with water to produce hydrated crystals.<br><br>Use data to estimate the energy that different fuels would be expected to release during combustion (HSW) | |

*In Section 3.2.2 (Kinetics), students should gain*

- *an understanding of the way in which collision theory can be used to explain the way in which reactions take place.*
- *an understanding of how the rate of a chemical reaction is affected by changes in conditions.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.2 Kinetics**<br><br>Collision Theory<br>• understand that reactions can only occur when collisions take place between particles having sufficient energy<br>• be able to define the term activation energy and understand its significance<br>• understand that most collisions do not lead to reaction<br>Maxwell-Boltzmann Distribution<br>• have a qualitative understanding of the Maxwell–Boltzmann distribution of molecular energies in gases<br>• be able to draw and interpret distribution curves for different temperatures<br>Effect of temperature on reaction rate<br>• understand the qualitative effect of temperature changes on the rate of reaction<br>• understand how small temperature increases can lead to a large increase in rate<br>Effect of concentration<br>• understand the qualitative effect of changes in concentration on rate of reaction<br>Catalysts<br>• know the meaning of the term catalyst<br>• understand that catalysts work by providing an alternative reaction route of lower activation energy | **Investigate how the rate of a reaction changes with temperature (PSA)**<br>e.g. Investigate the rate of reaction of sodium thiosulfate with acid at different temperatures. | |

*In Section 3.2.3 (Equilibria), students should gain*

- *an understanding of what is meant by the idea of a reaction in equilibrium.*
- *an appreciation the factors that affect the position of equilibrium.*
- *an appreciation of the importance of equilibrium in industrial processes and why compromise conditions are often used.*
- *an overview of some industrial processes which lead to the production of fuels*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.3 Equilibria** | | |
| The dynamic nature of equilibria<br>• know that many chemical reactions are reversible<br>• understand that for a reaction in equilibrium, although the concentrations of reactants and products remain constant, both forward and reverse reactions are still proceeding at equal rates | Consider $CrO_4^{2-}/Cr_2O_7^{2-}$ in acid and alkali (DEM)<br>Consider iron(III) ions and thiocyanate ions (DEM) | |
| Qualitative effects of changes of pressure, temperature and concentration on a system in equilibrium<br>• be able to use Le Chatelier's principle to predict the effects of changes in temperature, pressure and concentration on the position of equilibrium in homogeneous reactions<br>• know that a catalyst does not affect the position of equilibrium | | |
| Importance of equilibria in industrial processes<br>• be able to apply these concepts to given chemical processes<br>• be able to predict qualitatively the effect of temperature on the position of equilibrium from the sign of $\Delta H$ for the forward reaction<br>• understand why a compromise temperature and pressure may be used<br>• know about the hydration of ethene to form ethanol and the reaction of carbon monoxide with hydrogen to form methanol as important industrial examples where these principles can be applied<br>• know the importance of these alcohols as liquid fuels. | The $NO_2/N_2O_4$ equilibrium at different temperatures (DEM)<br><br>Atom economy applied to e.g. the Haber process (HSW)<br><br>The hydration of ethene as a route to ethanol (HSW) | |

*In Section 3.2.4 (Redox Recations), students should gain*
- *a clear appreciation of what is meant by oxidation and reduction.*
- *an understanding of what is meant by the idea of oxidation state.*
- *an ability to construct overall redox equations from half-equations.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.4 Redox Reactions**<br><br>Oxidation and reduction<br>• know that oxidation is the process of electron loss<br>• know that oxidising agents are electron acceptors<br>• know that reduction is the process of electron gain<br>• know that reducing agents are electron donors<br><br>Oxidation states<br>• know and be able to apply the rules for assigning oxidation states in order to work out the oxidation state of an element in a compound from its formula<br>• understand oxidation and reduction reactions of s and p block elements<br>Redox equations<br>• be able to write half-equations identifying the oxidation and reduction processes in redox reactions when the reactants and products are specified<br>• be able to combine half-equations to give an overall redox equation | | Rusting and sacrificial prevention as redox processes (HSW) |

*In Section 3.2.5 (Group 7, the Halogens), students should gain*

- *an appreciation of some of the main trends in the chemistry of the halogens and of the halide ions.*
- *an appreciation of the ways in which the halide ions can be identified through simple chemical tests.*
- *an understanding of the benefits of using chlorine in water treatment.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.5 Group 7, the Halogens** | | |
| Trends in physical properties<br>• understand the trends in electronegativity and boiling point of the halogens | | The extraction of bromine from seawater (HSW) |
| Trends in oxidising abilities of the halogens<br>• understand that the ability of the halogens (from fluorine to iodine) to oxidise decreases down the group (e.g. the displacement reactions with halide ions in aqueous solution) | | |
| Trends in the reducing abilities of the halide ions<br>• understand the trend in reducing ability of the halide ions<br>• know the different products formed by reaction of NaX and $H_2SO_4$ | Reaction of solid NaX with $cH_2SO_4$ (EXPT) | |
| Identification of halide ions using silver nitrate<br>• understand why acidified silver nitrate solution is used as a reagent to identify and distinguish between $F^-$, $Cl^-$, $Br^-$ and $I^-$<br>• know the trend in solubility of the silver halides in ammonia | **Carry out some inorganic tests (PSA)**<br>e.g. Tests for anions. Test for halide ions. | |
| Uses of chlorine and chlorate(I)<br>• know the reactions of chlorine with water and the use of chlorine in water treatment<br>• appreciate that the benefits to health of water treatment by chlorine outweigh its toxic effects<br>• know the reaction of chlorine with cold, dilute, aqueous NaOH and the uses of the solutions formed. | | Alternative methods of water treatment (HSW) |

*In Section 3.2.6 (Group 2, the Alkaline earth metals), students should gain*

- *an understanding of some important trends in the chemistry of Group 2 elements and their compounds.*
- *an appreciation of the use of some Group 2 compounds in medicine and agriculture.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.6 Group 2, the Alkaline Earth metals**<br><br>Trends in physical properties<br>• understand the trends in atomic radius, first ionisation energy and melting point of the elements Mg – Ba<br>Trends in chemical properties<br>• know the reactions of the elements Mg – Ba with water and recognise the trend<br>• know the relative solubilities of the hydroxides of the elements Mg – Ba and that $Mg(OH)_2$ is sparingly soluble<br>• know the use of $Mg(OH)_2$ in medicine and of $Ca(OH)_2$ in agriculture<br>• know the relative solubilities of the sulfates of the elements Mg – Ba<br>• understand why acidified $BaCl_2$ solution is used as a reagent to test for sulfate ions<br>• know the use of $BaSO_4$ in medicine | Reaction of Ca with cold water/ Mg with steam and with cold water (DEM)<br><br>Test for sulphate and carbonate (EXPT)<br><br>Group 2 compounds used in medicine (HSW) | |

*In Section 3.2.7 (Extraction of metals), students should gain*

- *an understanding of why and how metals are extracted.*
- *an appreciation of the potential environmental impact of metal extraction and how it is minimised.*
- *a critical understanding of the advantages and disadvantages of metal recycling.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.7 Extraction of metals**<br><br>Principles of metal extraction<br>• know that metals are found in ores, usually as oxides or sulfides and that sulfide ores are usually converted into oxides by roasting in air<br>• understand the environmental problems associated with the conversion of sulfides into oxides and also that the sulfur dioxide produced can be used to manufacture sulfuric acid<br>• understand that extraction of metals involves reduction<br>• understand that carbon and carbon monoxide are cheap and effective reducing agents that are used in the extraction of iron, manganese and copper (reduction equations and conditions only)<br>• know why carbon reduction is not used for extraction of titanium, aluminium and tungsten<br>• understand how aluminium is manufactured from purified bauxite (energy considerations, electrode equations and conditions only)<br>• understand how titanium is extracted from $TiO_2$ via $TiCl_4$ (equations and conditions only: either Na or Mg as a reducing agent)<br>• understand how tungsten is extracted from $WO_3$ by reduction with hydrogen (equation, conditions and risks only) | The environmental impact of metal extraction (HSW)<br><br>Carbon reduction of copper oxide (DEM) | |

| | | |
|---|---|---|
| Environmental aspects of metal extraction<br>• understand the environmental and economic advantages and disadvantages of recycling scrap metals compared with the extraction of metals<br>• understand the environmental advantages of using scrap iron to extract copper from aqueous solutions compared with the high-temperature carbon reduction of copper oxide<br>• know that the usual source of such aqueous solutions is low grade ore | Discuss critically the advantages and disadvantages of recycling metals (HSW) | |

*In Section 3.2.8 (The Haloalkanes), students should gain*

- *an understanding at the molecular level of how the chlorination of an alkane may take place.*
- *a recognition that haloalkanes may cause environmental problems if handled carelessly, but that some haloalkanes have immense benefit.*
- *an understanding of the way in which haloalkanes are used as synthetic intermediates in organic chemistry.*
- *an appreciation of the way in which ionic reaction mechanisms may take place at a molecular level.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.8 The Haloalkanes**<br><br>Synthesis of chloroalkanes<br>• understand the reaction mechanism of methane with chlorine as a free-radical substitution reaction in terms of initiation, propagation and termination steps<br>• know that chloroalkanes and chlorofluoroalkanes can be used as solvents<br>• understand that ozone, formed naturally in the upper atmosphere is beneficial<br>• be able to use equations such as the following to explain why chlorine atoms catalyse the decomposition of ozone and contribute to the formation of a hole in the ozone layer<br>$Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$ and $ClO^{\bullet} + O_3 \rightarrow 2O_2 + Cl^{\bullet}$<br>• know that chlorine atoms are formed in the upper atmosphere when energy from ultra-violet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break<br>• appreciate that legislation to ban the use of CFCs was supported by chemists and that they have now developed alternative chlorine-free compounds | Discuss critically the issues surrounding CFCs and ozone in the upper atmosphere (HSW) | The anaesthetic story from chloroform to halothane and beyond (HSW) |

| | | |
|---|---|---|
| Nucleophilic substitution<br>• understand that haloalkanes contain polar bonds<br>• understand that haloalkanes are susceptible to nucleophilic attack, limited to $OH^-$, $CN^-$ and $NH_3$<br>• understand the mechanism of nucleophilic substitution in primary haloalkanes<br>• understand that the carbon–halogen bond enthalpy influences the rate of hydrolysis<br>• appreciate the usefulness of these reactions in organic synthesis<br><br>Elimination<br>• understand concurrent substitution and elimination (including mechanisms) in the reaction of a haloalkane (e.g. 2-bromopropane with potassium hydroxide) and the role of the reagent as both nucleophile and base<br>• appreciate the usefulness of this reaction in organic synthesis | Compare the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane (EXPT)<br><br>Compare the rates of hydrolysis of primary, secondary and tertiary chloroalkanes (EXPT) | |

*In Section 3.2.9 (Alkenes), students should gain*

- *an understanding of what is meant by the term unsaturated hydrocarbon.*
- *an appreciation that the structural features of an alkene lead to the possibility of E-Z stereoisomerism.*
- *an understanding at the molecular level how alkenes may react with electrophiles.*
- *a recognition that alkenes are useful precursors in the production of commercially useful compounds.*
- *an appreciation of the structure and properties of addition polymers.*
- *an appreciation of the reasons for the difficulties associated with disposal of addition polymers.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.9 Alkenes** | | |
| Structure, bonding and reactivity<br>• know that alkenes are unsaturated hydrocarbons<br>• know that bonding in alkenes involves a double covalent bond<br>• know that the arrangement >C=C< is planar<br>• know that the alkenes can exhibit E-Z stereoisomerism<br>• be able to draw the structures of E and Z isomers<br>• understand that E-Z isomers exist due to restricted rotation about the C=C bond<br>• understand that the double bond in an alkene is a centre of high electron density | Use of molecular models (EXPT and HSW) | |
| Addition reactions of alkenes<br>• understand the mechanism of electrophilic addition of alkenes with HBr, $H_2SO_4$ and $Br_2$<br>• know that bromine can be used to test for unsaturation<br>• be able to predict the products of addition to unsymmetrical alkenes by reference to the relative stabilities of primary, secondary and tertiary carbocation intermediates | Test for unsaturation with cyclohexene and with ethene (EXPT) | The use of iodine monochloride and the concept of "iodine number" (HSW) |
| • understand that alcohols are produced industrially by hydration of alkenes in the presence of an acid catalyst.<br>• know the typical conditions for the industrial production of ethanol from ethene | Link this study to Section 3.2.3 | |

| | | |
|---|---|---|
| Polymerisation of alkenes<br>• know how addition polymers are formed from alkenes<br>• recognise that poly(alkenes) like alkanes are unreactive<br>• be able to recognise the repeating unit in a poly(alkene)<br>• know some typical uses of poly(ethene) and poly(propene) and know that poly(propene) is recycled | The manufacture and use of thermoplastics by addition polymerisation, appreciating the problems associated with their disposal (HSW) | |

*In Section 3.2.10 (Alcohols), students should gain*

- *an understanding of the two main routes to the production of ethanol.*
- *an appreciation that each route has advantages and disadvantages.*
- *an appreciation of the issues associated with the use of biofuel ethanol.*
- *an understanding that the term alcohol extends to a wide range of compounds.*
- *a recognition of the classes of alcohol and the products which are formed when alcohols are oxidised or undergo elimination reactions.*
- *a range of practical skills associated with the use of semi-micro equipment.*
- *an understanding of the way in which alcohols may prove to be a useful starting point for products, avoiding the need to use crude oil.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.10 Alcohols** | | |
| Ethanol production<br>• know how ethanol is produced industrially by fermentation.<br>• know the conditions for this reaction and understand the economic and environmental advantages and disadvantages of this process compared with the industrial production from ethene | Discuss critically the two main routes to ethanol considering the overall energy and resource use in each case (HSW) | |
| • understand the meaning of the term *biofuel*<br>• know that the term *carbon neutral* refers to "an activity that has no net annual carbon (greenhouse gas) emissions to the atmosphere"<br>• appreciate the extent to which ethanol, produced by fermentation, can be considered to be a carbon-neutral biofuel | Discuss critically the concept of carbon neutral as applied to ethanol from fermentation of sugars and the problems associated with food costs as biofuels become more popular (HSW) | |
| Classification and reactions<br>• understand that alcohols can be classified as primary, secondary or tertiary<br>• understand that tertiary alcohols are not easily oxidised<br>• understand that primary alcohols can be oxidised to aldehydes and carboxylic acids and that secondary alcohols can be oxidised to ketones by a suitable oxidising agent such as acidified potassium dichromate(VI) (equations showing [O] as oxidant are acceptable) | | |
| | **Distil a product from a reaction** | The breathalyser story |

| | | |
|---|---|---|
| • be able to use a simple chemical test to distinguish between aldehydes and ketones (e.g. Fehling's solution or Tollens' reagent)<br><br>Elimination<br>• know that alkenes can be formed from alcohols by acid catalysed elimination reactions (mechanism not required).<br>• appreciate that this method provides a possible route to polymers without using monomers derived from oil | **(PSA)**<br>e.g. The preparation of ethanal from the oxidation of ethanol **or** the preparation of cyclohexene from the dehydration of cyclohexanol.<br><br>**Carry out some organic tests (PSA)**<br>e.g. Tests for alkene, alcohol, acid, aldehyde.<br><br>Polymer production from raw materials other than crude oil (HSW) | (HSW) |

*In Section 3.2.11 (Analytical Techniques), students should gain*

- *an understanding of the precision of mass spectrometry and its use in the production of accurate data about relative molecular masses.*
- *an understanding of the value of infra-red spectroscopy in analysis including "fingerprinting" in drug analysis.*

| Specification Content | Teaching and Learning opportunities | Possible extension work |
|---|---|---|
| **3.2.11 Analytical Techniques**<br><br>Mass spectrometry<br>• understand that high resolution mass spectrometry can be used to determine the molecular formula of a compound from the accurate mass of the molecular ion<br>Infra-red spectroscopy<br>• understand that certain groups in a molecule absorb infra-red radiation at characteristic frequencies<br>• understand that "fingerprinting" allows identification of a molecule by comparison of spectra<br>• be able to use spectra to identify particular functional groups and to identify impurities, limited to data presented in wave-number form<br>• understand the link between absorption of infra-red radiation by bonds in $CO_2$, methane and water vapour to global warming | The use of mass spectrometry and infra-red spectroscopy in chemical analysis (HSW)<br><br>Consider the validity of whether $CO_2$ is a major greenhouse gas by consideration of infra-red spectroscopic data (HSW) | The use of mass spectrometry and infra-red spectroscopy in the fields of forensic science and monitoring drug use (HSW) |