Course Support Notes

Higher Chemistry Course Support Notes

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Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

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Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Higher Chemistry Course. They are intended for teachers and lecturers who are delivering the Course and its Units. They should be read in conjunction with the *Course Specification*, the *Course Assessment Specification* and the Unit Specifications for the Units in the Course.

General guidance on the Course

Aims

As stated in the Course Specification, the aims of the Course are to enable learners to:

- develop and apply knowledge and understanding of chemistry
- develop an understanding of chemistry's role in scientific issues and relevant applications of chemistry, including the impact these could make in society and the environment
- develop scientific inquiry and investigative skills
- develop scientific analytical thinking skills, including scientific evaluation, in a chemistry context
- develop the use of technology, equipment and materials, safely, in practical scientific activities, including using risk assessments
- develop planning skills
- develop problem solving skills in a chemistry context
- use and understand scientific literacy to communicate ideas and issues and to make scientifically informed choices
- develop the knowledge and skills for more advanced learning in chemistry
- develop skills of independent working

Progression into this Course

Entry to this Course is at the discretion of the centre. However, learners would normally be expected to have attained some relevant skills and knowledge through prior experience.

Skills and knowledge developed through any of the following, while **not mandatory**, are likely to be helpful as a basis for further learning in this Course:

- National 5 Chemistry Course

More detail is contained in the Chemistry Progression Framework. The Chemistry Progression Framework shows the development of the key areas throughout the suite of Courses.

Skills, knowledge and understanding covered in this Course

Note: teachers and lecturers should refer to the *Course Assessment Specification* for mandatory information about the skills, knowledge and understanding to be covered in this Course.

Progression from this Course

This Course or its components may provide progression to:

- Advanced Higher Chemistry or related areas
- further study, employment and/or training

Hierarchies

Hierarchy is the term used to describe Courses and Units which form a structured sequence involving two or more SCQF levels.

It is important that any content in a Course and/or Unit at one particular SCQF level is not repeated (unless required for consolidation) if a learner progresses to the next level of the hierarchy. The skills and knowledge should be able to be applied to new content and contexts to enrich the learning experience. This is for centres to manage.

- Chemistry Courses from National 3 to Advanced Higher are hierarchical.
- Courses from National 3 to National 5 have Units with the same structure and title.

Approaches to learning and teaching

The purpose of this section is to provide you with advice and guidance on learning and teaching. It is essential that you are familiar with the mandatory information within the Higher Chemistry *Course Assessment Specification*.

Teaching should involve an appropriate range of approaches to develop knowledge and understanding and skills for learning, life and work. This can be integrated into a related sequence of activities, centred on an idea, theme or application of chemistry, based on appropriate contexts, and need not be restricted to the Unit structure. Learning should be experiential, active, challenging and enjoyable, and include appropriate practical experiments/activities and could be learner-led. The use of a variety of active learning approaches is encouraged, including peer teaching and assessment, individual and group presentations, role-playing and game-based learning, with learner-generated questions.

When developing your Chemistry Course there should be opportunities for learners to take responsibility for their learning. Learning and teaching should build on learners' prior knowledge, skills and experiences. The Units and the key areas identified within them may be approached in any appropriate sequence, at the centre's discretion. The distribution of time between the various Units is a matter for professional judgement and is entirely at the discretion of the centre. Each Unit is likely to require an approximately equal time allocation, although this may depend on the learners' prior learning in the different key areas.

Learning and teaching, within a class, can be organised, in a flexible way, to allow a range of learners' needs to be met, including learners achieving at different levels. The hierarchical nature of the new Chemistry qualifications provides improved continuity between the levels. Centres can, therefore, organise learning and teaching strategies in ways appropriate for their learners.

Within a class, there may be learners capable of achieving at a higher level in some aspects of the Course. Where possible, they should be given the opportunity to do so. There may also be learners who are struggling to achieve in all aspects of the Course, and may only achieve at the lower level in some areas.

Teachers/lecturers need to consider the Course and Unit Specifications, and *Course Assessment Specifications* to identify the differences between Course levels. It may also be useful to refer to the Chemistry Progression Framework.

When delivering this Course to a group of learners, with some working towards different levels, it may be useful for teachers to identify activities covering common key areas and skills for all learners, and additional activities required for some learners. In some aspects of the Course, the difference between levels is defined in terms of a higher level of skill.

The key areas which could be helpful to be covered before doing this Course are: atomic structure, bonding, balanced ion-electron equations, moles and calculations, homologous series of hydrocarbons, rates of reaction, electrochemical series, electrochemical cells and titrations

An investigatory approach is encouraged in Chemistry, with learners actively involved in developing their skills, knowledge and understanding by investigating a range of relevant chemistry applications and issues.
A holistic approach should be adopted to encourage simultaneous development of learners' conceptual understanding and skills.

Where appropriate, investigative work/experiments, in Chemistry, should allow learners the opportunity to select activities and/or carry out extended study. Investigative and experimental work is part of the scientific method of working and can fulfil a number of educational purposes.

All learning and teaching should offer opportunities for learners to work collaboratively. Practical activities and investigative work can offer opportunities for group work, which should be encouraged. Group work approaches can be used within Units and across Courses where it is helpful to simulate real-life situations, share tasks and promote team working skills. However, there must be clear evidence for each learner to show that the learner has met the required assessment standards for the Unit or Course.

Laboratory work should include the use of technology and equipment that reflects current scientific use in chemistry. Appropriate risk assessment must be undertaken. Learners should also have the opportunity to become familiar with the apparatus, practical techniques and data-analysis strategies indicated below.

Learners would benefit from being familiar with the following apparatus, practical techniques and activities:	Learners should be able to process experimental results by:
♦ Filtration ♦ Use of a balance ♦ Safe methods of heating ♦ Titration ♦ Preparation of a standard solution ♦ Methods for following rates of reactions ♦ Degree of unsaturation ♦ Chromatography ♦ Organic analysis of structure ♦ Distillation ♦ Solvent extraction ♦ Determining E_h /mol ♦ Simple gravimetric analysis ♦ Volumetric analysis	♦ Representing experimental data using a scatter graph. ♦ Sketching lines or curves of best fit. ♦ Calculating averages (means) for experiments. ♦ Identifying and eliminating rogue points from the analysis of results. ♦ Qualitative appreciation of the relative accuracy of apparatus used to measure the volume of liquids. Learners would be expected to know that the volume markings on beakers provide only a rough indication of volume. While measuring cylinders generally provide sufficient accuracy for preparative work, for analytic work, burettes, pipettes and volumetric flasks are more appropriate. ♦ Appreciating that when a measurement has been repeated, any variations in the value obtained give an indication of the reproducibility of the technique. ♦ Knowing that the uncertainty associated

	with a measurement can be indicated in the form, *measurement ± uncertainty.* Learners are not expected to conduct any form of quantitative error analysis. ♦ Quantitative mole calculations

Learners would be expected to contribute their own time in addition to programmed learning time.

Effective partnership working can enhance the science experience. Where feasible, locally relevant contexts should be studied, with visits where this is possible. Guest speakers from industry, further and higher education could be used to bring the world of chemistry into the classroom.

Information and Communications Technology (ICT) can make a significant contribution to practical work in Higher Chemistry, in addition to the use of computers as a learning tool. Computer interfacing equipment can detect and record small changes in variables allowing experimental results to be recorded over long or short periods of time. Results can also be displayed in real-time helping to improve understanding. Data-logging equipment and video cameras can be set up to record data and make observations, over periods of time longer than a class lesson, which can then be downloaded and viewed for analysis.

Learning about Scotland and Scottish culture will enrich the learners' learning experience and help them to develop the skills for learning, life and work they will need to prepare them for taking their place in a diverse, inclusive and participative Scotland and beyond. Where there are opportunities to contextualise approaches to learning and teaching to Scottish contexts, teachers and lecturers should consider this.
Assessment should be integral to and improve learning and teaching. The approach should involve learners and provide supportive feedback. Self- and peer-assessment techniques should be encouraged, wherever appropriate. Assessment information should be used to set learning targets and next steps.

Suggestions for possible contexts and learning activities, to support and enrich learning and teaching, are detailed in the table below.

The **Mandatory Course key areas** are from the **Course Assessment Specification**. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities.

Exemplification of key areas is not mandatory. It provides an outline of the level of demand and detail of the key areas.

Risk assessment should always be carried out by teachers/lecturers prior to doing any of the experiments and demonstrations listed in the table.

Chemical Changes and Structure		
Mandatory Course key areas	**Suggested learning activities**	**Exemplification of key areas**
Controlling the rate Collision theory explaining rates of reaction and activation energy. Relative rate of reaction	Several experiments and animations can be used to demonstrate factors that affect reaction rates. Learners can investigate the effect of concentration on reaction rate by dropping a strip of magnesium into various concentrations of hydrochloric acid and recording the time taken for the effervescence to stop. An unusual experiment demonstrating the effect of concentration on reaction rate is provided in the decolourisation of permanganate using rhubarb as described in the Practical Chemistry website from the Royal Society of Chemistry and the Nuffield Foundation.	Reaction rates can be controlled by chemists. If they are too low a manufacturing process will not be economically viable, too high and there is a risk of thermal explosion. Collision theory can be used to explain the effects of concentration, pressure, surface area (particle size), temperature and collision geometry on reaction rates.
Controlling the rate Reaction profiles	A number of animations showing reaction profiles are available. Entering the search terms ‘Activation energy	A potential energy diagram can be used to show the energy pathway for a reaction. The enthalpy change is

Potential energy diagrams, energy pathways, activated complex, activation energy and enthalpy changes.	animation' into an internet search engine will produce a large number of hits. The phET initiative from the University of Colorado also has an interactive simulation.	the energy difference between products and reactants. It can be calculated from a potential energy diagram. The enthalpy change has a negative value for exothermic reactions and a positive value for endothermic reactions. The activated complex is an unstable arrangement of atoms formed at the maximum of the potential energy barrier, during a reaction. The activation energy is the energy required by colliding particles to form an activated complex. It can be calculated from potential energy diagrams.
Controlling the rate Catalysts Reaction pathway, activation energy.	A large number of experiments are available to demonstrate the action of catalysts including: ♦ a demonstration of the catalytic decomposition of hydrogen peroxide ♦ a practical problem solving exercise based on the catalytic decomposition of hydrogen peroxide ♦ a visually attractive and colourful reaction between sodium thiosulfate and hydrogen peroxide in the presence of universal indicator ♦ the attention-grabbing classic cannon fire experiment A common misconception is that 'catalysts speed up reactions without taking part'. An experiment which could help to address this issue is the Rochelle salt/sodium tartrate reaction in which the cobalt compound used as the	A catalyst provides an alternative reaction pathway with a lower activation energy. A potential energy diagram can be used to show the effect of a catalyst on activation energy.

	catalyst changes colour during reaction, but returns to its original colour when the reaction is over.	
Controlling the rate Temperature and kinetic energy Energy distribution diagrams showing effect of temperature changes on successful collisions. The effect of temperature on the reaction rate	Learners can investigate the effect of temperature by using the reaction between sodium thiosulfate and acid in which a sulfur precipitate forms, or the reaction of potassium iodate and bisulfite/starch solution. Descriptions of both these activities are found in *Classic Chemistry Experiments*, Kevin Hutchings (2000), available free online from the Royal Society of Chemistry. Learners can produce rate versus temperature graphs illustrating the exponential increase in rate with temperature.	Temperature is a measure of the average kinetic energy of the particles of a substance. The activation energy is the minimum kinetic energy required by colliding particles before reaction may occur. Energy distribution diagrams can be used to explain the effect of changing temperature on the kinetic energy of particles. The effect of temperature on reaction rate can be explained in terms of an increase in the number of particles with energy greater than the activation energy.
Periodicity The first 20 elements in the Periodic Table are categorised according to bonding and structure. Periodic trends and underlying patterns and principles.	Many examples of catalysis can be found on website such as the catalysis website run by the Chemical Industry Education Centre (CIEC), part of the University of York. Computer simulations (available online from such sites as the PhET initiative from the University of Colorado) can be used to visualise models of chemical reactions and to explore the effects on reaction rate of changing reaction conditions. Periodic trends can be illustrated by graphing properties such as first ionisation energy or covalent radius against atomic number. Interactive Periodic Tables are available online.	Elements are arranged in the Periodic Table in order of increasing atomic number. The Periodic Table allows chemists to make accurate predictions of physical properties and chemical behaviour for any element based on its position. The first 20 elements in the Periodic Table can be categorised according to bonding and structure: ♦ metallic (Li, Be, Na, Mg, Al, K, Ca) ♦ covalent molecular (H_2, N_2, O_2, F_2, Cl_2, P_4, S_8 and fullerenes (eg C_{60})) ♦ covalent network (B, C (diamond, graphite), Si) ♦ monatomic (noble gases)

	Element cards can be prepared showing atomic number, element name and symbol, properties and/or electronic arrangements, learners can lay out the cards on a large table or lab floor and experiment with different arrangements. The story of the development of the modern Periodic Table could be explored. Elements can be extracted from their compounds: Silicon can be extracted from sand using magnesium. (See *Classic Chemistry Demonstrations*, Lister, T., The Royal Society of Chemistry (1995), pp. 127–129. A video can also be found on the RSC website.)	
Periodicity Covalent radius, ionisation energy, electronegativity and trends in groups and periods, related to atomic structure.	The molecular nature of sulfur can be discussed during an exploration of the allotropes of sulfur. (See *Classic Chemistry Demonstrations*, Lister T., The Royal Society of Chemistry (1995), pp. 191–195). Molecular models can be constructed or viewed. Entertaining video portraits of all of the elements in the Periodic Table can also be viewed online. A bonding simulation from the PhET initiative from the University of Colorado can be used in which you can adjust the electronegativity of each atom, and view the effect of the resulting electron cloud.	The covalent radius is a measure of the size of an atom. The trends in covalent radius across periods and down groups can be explained in terms of the number of occupied shells, and the nuclear charge. The trends in ionisation energies across periods and down groups can be explained in terms of the atomic size, nuclear charge and the screening effect due to inner shell electrons. Atoms of different elements have different attractions for bonding electrons. Electronegativity is a measure of the attraction an atom involved in a bond has for the electrons of the bond. Electronegativity values increase

	The story of Linus Pauling, after whom the most commonly used electronegativity scale is named, is available from the RSC. The RSC interactive Periodic Table can be very useful for showing trends.	across a period and decrease down a group. Electronegativity trends can be rationalised in terms of nuclear charge, covalent radius and the presence of 'screening' inner electrons.
Structure and bonding Bonding continuum Polar covalent bonds and their position on the bonding continuum, dipole formation and notation. $\delta^+ \delta^-$, eg $H^{\delta+}–Cl^{\delta-}$	Learners should encounter covalent molecular compounds that contain a metal. Tin(IV) iodide can be formed by gently heating tin and iodine in toluene in a small conical flask. When the mixture is allowed to cool, yellow-brown crystals form which can be collected by filtration. Melting point of SnI_4 is. 143 $^{\circ}$C. Tin has an electronegativity of 1.8 and iodine has an electronegativity of 2.6 so this molecule contains polar covalent bonds. A creative problem solving exercise of the 'four white powders' type could be used where learners have white powders and must devise their own experimental method to tell them apart. The powders are: silicon dioxide, glucose, sodium chloride and calcium carbonate. Common misunderstandings arise when learners focus upon covalent and ionic bonding and fail to appreciate other types of interaction at play. The two activities 'Interactions' and 'Spot the Bonding' allow consolidation and discussion of intramolecular and intermolecular interactions (*Chemical misconceptions: prevention, diagnosis and cure* (Volume 2), Keith Taber, Royal Society of Chemistry, 2002) also available online for free.	In a covalent bond, atoms share pairs of electrons. The covalent bond is a result of two positive nuclei being held together by their common attraction for the shared pair of electrons. Polar covalent bonds are formed when the attraction of the atoms for the pair of bonding electrons is different. Delta positive and delta negative notation can be used to indicate the partial charges on atoms, which give rise to a dipole. Pure covalent bonding and ionic bonding can be considered as being at opposite ends of a bonding continuum with polar covalent bonding lying between these two extremes. The larger the difference in electronegativities between bonded atoms, the more polar the bond will be. If the difference is large then the movement of bonding electrons from the element of lower electronegativity to the element of higher electronegativity is complete resulting in the formation of ions. Compounds formed between metals and non-metals are often, but not always ionic.

Structure and bonding Intermolecular forces called vdW forces. London dispersion forces, permanent dipole-dipole, hydrogen bonding and the resulting physical properties including solubility.	London forces are named after Fritz Wolfgang London (1900–1954) a German-born American theoretical physicist. The relationship between the strength of London forces and the number of electrons can be shown by plotting the melting or boiling points for the noble gases or for the halogens — information available from websites such as Web Elements. A practical demonstration of the polarity of molecules is provided by experiments in which liquids are deflected by a static charge. Classic experiments would include allowing learners to experiment with the use of charged rods to deflect a stream of polar liquid flowing from a burette, but there are also more unusual variations such as the deflection of syrup by a charged balloon. The effect of the polarity of a molecule on the strength of intermolecular forces can be illustrated by comparing molecules with similar numbers of electrons but differing polarity, for example bromine and iodine monochloride. (Br_2, 70 electrons, non-polar, mp –7 ºC) (ICl, 70 electrons, polar, mp +27 ºC) Computer animations showing the formation of a hydrogen bond are available.	All molecular elements and compounds and monatomic elements condense and freeze at sufficiently low temperatures. For this to occur, some attractive forces must exist between the molecules or discrete atoms. Any 'intermolecular' forces acting between molecules are known as van der Waals' forces. There are several different types of van der Waals' forces such as London dispersion forces and permanent dipole: permanent dipole interactions, which include hydrogen bonding. London dispersion forces are forces of attraction that can operate between all atoms and molecules. These forces are much weaker than all other types of bonding. They are formed as a result of electrostatic attraction between temporary dipoles and induced dipoles caused by movement of electrons in atoms and molecules. The strength of London dispersion forces is related to the number of electrons within an atom or molecule. A molecule is described as polar if it has a permanent dipole. The spatial arrangement of polar covalent bonds can result in a molecule being polar. Permanent dipole-permanent dipole interactions are additional electrostatic forces of attraction between polar molecules. Permanent dipole-permanent dipole interactions are stronger than London dispersion forces for molecules with similar numbers of electrons. Bonds consisting of a hydrogen atom bonded to an atom of a strongly electronegative element such as

	Water can be placed into sealed glass bottles and frozen, demonstrating the formation of the hydrogen bonded lattice structure which causes the anomalously large volume for frozen water. Hydrogen bonding is also responsible for the surface tension of water can be demonstrated using classic experiments such as the floating needle on the surface of a glass of water, or adding coins to a wine glass full of water to demonstrate the level rising above the rim of the glass. Hydrogen bonding is at the heart of 'hydrogel' materials. Examples of which are easily obtained from disposable nappies (see *Inspirational Chemistry*, Vicky Wong, Royal Society of Chemistry, 2006, pp. 115–120). Teachers may wish to outline the role of hydrogen bonding in maintaining the shape of DNA molecules and proteins. Learners could explore the Fold It website to explore how hydrogen bonds maintain the shape adopted by proteins. The anomalous density of ice can be demonstrated by showing that wax beads sink when dropped into molten wax in contrast to ice, which floats on water. An alternative experiment from the RSC involves placing ice cubes into vegetable oil. The ice cube floats, but on melting the liquid water descends through the oil to form a layer at the bottom of the vessel. Coloured ice can be used to enhance the visual effect. In an investigative variation, a glass containing a layer of oil on water is placed in the freezer to see what happens.	fluorine, oxygen or nitrogen are highly polar. Hydrogen bonds are electrostatic forces of attraction between molecules which contain these highly polar bonds. A hydrogen bond is stronger than other forms of permanent dipole-permanent dipole interaction but weaker than a covalent bond. Melting points, boiling points and viscosity can all be rationalised in terms of the nature and strength of the intermolecular forces which exist between molecules. By considering the polarity and number of electrons present in molecules, it is possible to make qualitative predictions of the strength of the intermolecular forces. The melting and boiling points of polar substances are higher than the melting and boiling points of non-polar substances with similar numbers of electrons. The anomalous boiling points of ammonia, water and hydrogen fluoride are a result of hydrogen bonding. Boiling points, melting points, viscosity and solubility/miscibility in water are properties of substances which are affected by hydrogen bonding. Hydrogen bonding between molecules in ice results in an expanded structure which causes the density of ice to be less than that of water at low temperatures.

	Learners can explore the relationship between polarity and viscosity using 'Bubble tubes' (*Classic Chemistry Experiments*, Kevin Hutchings, 2000, pp. 4, 5). Learners can explore the effect of the number of O-H bonds in a molecule on the strength of the intermolecular forces by dropping small balls simultaneously into test-tubes of propan-1-ol, propane-1,2-diol and propane-1,2,3-triol, and comparing the rate with which they sink to the bottom of the tubes. Learners could investigate the solubility of molecular compounds in different solvents. (The compounds used should include examples with O-H or N-H bonds, and shapes which would result in permanent dipoles.)	Ionic compounds and polar molecular compounds tend to be soluble in polar solvents such as water and insoluble in non-polar solvents. Non-polar molecular substances tend to be soluble in non-polar solvents and insoluble in polar solvents.

Nature's Chemistry		
Mandatory Course key areas	**Suggested learning activities**	**Exemplification of key areas**
Esters, fats and oils Esters — naming, structural formulae and uses. Fats and oils, esters condensation and hydrolysis reactions. Saturated and unsaturated fats and oils. Melting points of oils and fats, through intermolecular bonding.	Ethyl ethanoate is an example of a solvent used to extract caffeine from coffee and tea. Decaffeinated products produced with ethyl ethanoate are often described as 'naturally decaffeinated' because ethyl ethanoate occurs in fruits. Caffeine can be extracted from tea by learners using an aqueous solution of sodium carbonate and ethyl ethanoate and a rough percentage of caffeine in the tea leaves calculated. Esters are also used as solvents for dyes, inks, paints and varnishes. Learners will have encountered ester-type smells from non-food products such as car spray paints, permanent marker pens, whiteboard pens and nail varnish removers. Esters are volatile and this leads to high concentrations in air. Further information on current moves to reduce the use of esters as solvents can be found by searching for 'VOC reduction' or 'low VOC' on the internet. An ester is added to distilled water. After 30 minutes, the pH of the mixture can be tested to demonstrate that an acid is forming. Old bottles of perfume can also be an interesting illustration of ester hydrolysis as the fruity notes in	An ester can be identified from the ester group and by the name containing the –'yl-oate' endings. An ester can be named given the names of the parent carboxylic acid and alcohol or from structural formulae. Structural formulae for esters can be drawn given the names of the parent alcohol and carboxylic acid or the names of esters. Esters have characteristic smells and are used as flavourings and fragrances. Esters are also used as industrial solvents. **Making esters** Esters are formed by the condensation reaction between carboxylic acid and an alcohol. The ester link is formed by the reaction of a hydroxyl group and the carboxyl group. In condensation reactions, the molecules join together with the elimination of a small molecule, in this case water. **Hydrolysis of esters** Esters can be hydrolysed to produce a carboxylic acid and alcohol. Given the name of an ester or its structural formula, the hydrolysis products can be named and their structural formulae drawn. The parent carboxylic acid and the parent alcohol can be obtained by hydrolysis of an ester. In a hydrolysis reaction, a molecule reacts with

	fragrances have frequently hydrolysed leaving the unpleasant stench of carboxylic acids. Learners can be given the opportunity to examine examples of edible fats and oils, which could include fish oils, vegetable oils and animal fats. Vegetable oil samples can be burned to demonstrate that they are stores of chemical energy. Carrying out a demonstration fat-fire underlines the considerable energy released when fats and oils are oxidised. In addition, it underlines the risks associated with cooking techniques using deep oil baths. Learners can also consider the wider use of edible oils as, for example, the use of edible oils as fuels and lubricants for some agricultural machinery in order to prevent any risk of harmful mineral oils contaminating future food stuffs. The degree of unsaturation in fats and oils can be determined by counting the number of drops of bromine solution which can be decolourised by equal quantities of oil, or by a very simple titration in which the fat is dissolved. Alternatively, iodine values can be determined by standard methods including the use of Wij's reagent. This solution of iodine monochloride adds rapidly to the carbon=carbon double bonds present. The unreacted iodine monochloride is then treated with an excess of aqueous potassium iodide solution, forming iodine. The liberated iodine is determined by titration with sodium	water breaking down into smaller molecules. Fats and oils are a concentrated source of energy. They are essential for the transport and storage of fat-soluble vitamins in the body. Fats and oils are esters formed from the condensation of glycerol (propane-1,2,3-triol) and three carboxylic acid molecules. The carboxylic acids are known as 'fatty acids' and are saturated or unsaturated straight-chain carboxylic acids, usually with long chains of carbon atoms. The lower melting points of oils compared to those of fats is related to the higher degree of unsaturation of oil molecules. The low melting points of oils are a result of the effect that the shapes of the molecules have on close packing, hence on the strength of van der Waals' forces of attraction.

	thiosulfate.	
Proteins Enzymes as biological catalysts, amino acids, dietary proteins, condensation reactions to make proteins and amide link, peptide link. Digestion, enzyme hydrolysis of dietary proteins.	The shapes of protein molecules can be viewed with a range of free-of-charge browser plug-ins such as Chime or Jmol. There are around twenty common amino acids. Only eight amino acids are regarded as being essential for humans although a further two are required in childhood. The amino acids in fruit juices can be identified by paper chromatography. There is also an activity on the amino acid aspartame in artificial sweeteners in *In Search of More Solutions*, Janet Taylor, Royal Society of Chemistry, 1994. Learners can investigate the detection of protein in synthetic urine samples as a practical activity. Paper chromatography of the amino acid mixture produced by the hydrolysis of hair or egg whites can be used to identify amino acids	Proteins are the major structural materials of animal tissue. Proteins are also involved in the maintenance and regulation of life processes. Enzymes are proteins. Amino acids, the building blocks from which proteins are formed, are relatively small molecules which all contain an amino group (NH_2), and a carboxyl group (COOH). The body cannot make all the amino acids required for body proteins and is dependent on dietary protein for supply of certain amino acids known as essential amino acids. Proteins are made of many amino acid molecules linked together by condensation reactions. In these condensation reactions, the amino group on one amino acid and the carboxyl group on a neighbouring amino acid join together, with the elimination of water. The link which forms between the two amino acids can be recognised as an amide link (CONH) also known as the peptide link. Proteins which fulfil different roles in the body are formed by linking differing sequences of amino acids together. During digestion, enzyme hydrolysis of dietary proteins can produce amino acids. The structural formulae of amino acids obtained from the hydrolysis of proteins can be identified from the structure of a section of the protein.

Chemistry of cooking Flavours in foods. Influence of functional groups on solubility, boiling points and volatility. Aldehydes as sources of flavour and aroma. For aldehydes and ketones: For compounds with no more than eight carbon atoms in their longest chain. For straight and branch chained aldehydes and ketones systematic names, structural formulae and isomers. Oxidation reactions of aldehydes and ketones. Effect of heat on proteins, denature of proteins.	The role of volatile molecules in flavour can be illustrated by an experiment where foods are tasted while your nose is blocked. Strawberry jam works well. A blindfolded taster is fed a small amount of strawberry jam with a teaspoon. While holding his/her nose, the taster can detect the sweetness of the jam (which is detected with the tongue) but will be unable to tell the flavour of the jam which is caused by volatile molecules detected by the nose. On releasing his/her nose, the taster will be able to tell the flavour of the jam. Other foods which can be used in this experiment include apple, parsnip, and even different flavours of crisp. In this variation the taster is given a plain crisp to taste but, without telling them, a flavoured crisp is held under their nose. The taster will report that the crisp they are tasting has the flavour of that held under their nose. A major issue in cooking is to retain molecules responsible for flavour in the food — overcooking can result in loss of these molecules. One destination for lost flavour molecules is in the cooking water. This will occur if the flavour molecules are water-soluble. This is the case for asparagus, for example, which should be cooked in oil or butter in which the flavour molecules are less soluble. In broccoli or green beans, the flavour molecules are more soluble in oil than in water and should be cooked in water. 'The Chemistry of Flavour', Kitchen Chemistry, Ted Lister and Heston Blumenthal, Royal Society of Chemistry	Many flavour and aroma molecules are aldehydes. Aldehydes and ketones both contain the carbonyl functional group. Aldehydes and ketones can be identified from the '-al' and '-one' name endings respectively. Straight-chain and branched-chain aldehydes and ketones, with no more than eight carbon atoms in their longest chain, can be named from structural formulae. Given the names of straight-chain or branched-chain aldehydes and ketones, structural formulae can be drawn and molecular formulae written. Aldehydes, but not ketones, can be oxidised to carboxylic acids. Fehling's solution, Tollens' reagent and acidified dichromate solution can be used to differentiate between an aldehyde and a ketone. Within proteins, the long-chain molecules may be twisted to form spirals, folded into sheets, or wound around to form other complex shapes. The chains are held in these forms by intermolecular bonding between the side chains of the constituent amino acids. When proteins are heated, during cooking, these intermolecular bonds are broken allowing the proteins to change shape (denature).These changes alter the texture of foods.

	(2005), contains a number of problem solving exercises that allow learners to predict the best cooking methods using the structural formulae of the molecules responsible for flavour in different foods. Examples of flavour molecules are provided on websites. When using internet search engines to search for flavour compounds, use both the UK and US spelling of 'flavour/flavor' to locate the maximum number of sites. Kitchen Chemistry (Lister and Blumenthal) has a video explaining how different temperatures are required for cooking meats with different levels of connective tissue. Joints with a lot of connective tissue become tender if cooked at over 60 °C as the collagen forming the tough connective tissue denatures. The tender lean meat found in cuts such as fillet steaks, should not be cooked at too high a temperature, because in this case the protein molecules start to bunch together resulting in the meat becoming tougher. The effect of temperature on modifying protein structures can also be explored using egg whites. In uncooked egg white, the protein molecules are globular. During cooking, the protein is denatured and the protein chains unwind and, as they can now form intermolecular bonds with neighbouring protein molecules, a network of interconnected proteins forms causing the egg white to solidify.	

Oxidation of food For compounds with no more than eight carbon atoms in their longest chain. Alcohols. For branch chained alcohols systematic names, structural formulae and isomers. Hydrogen bonding. Diol, triols and the effect of hydrogen bonding on properties of these molecules. Primary, secondary and tertiary alcohols, oxidation reactions and products, oxidising agents. For branch chained carboxylic acids systematic names, structural formulae and isomers. Reactions of carboxylic acids to include reduction and reactions with bases to form salts.	The action of CuO as an oxidising agent for alcohols can be shown by placing a small amount of ethanol in an evaporating basin. A 2p coin is then heated to just below red heat in a Bunsen and then wafted in the air allowing the surface to become coated in black copper(II) oxide. The warm coin is then carefully lowered into the ethanol. Instantly the bright shiny surface of the coin is restored as the CuO is reduced to copper. The process of heating the coin — forming the oxide — and reducing the oxide in alcohol is repeated until little liquid is left in the dish. At this point, if pH indicator is added, it shows that an acid has formed whilst the distinctive smell of ethanal can be detected. In an alternative experiment, samples of primary, secondary and tertiary alcohols can be warmed with acidified dichromate (VI) to illustrate that only the primary and secondary will be oxidised. Ethanol can be oxidised by acidified sodium dichromate in a test-tube reaction, firstly to form ethanal (acetaldehyde), and with further oxidation, ethanoic acid (acetic acid). Using a microscale well-plate, learners add acidified dichromate(VI) to primary, secondary and tertiary alcohols to observe the difference in their oxidation reactions. This experiment can be done by learners in 20 minutes. The colour change of the dichromate(VI) indicates where reaction is occurring. Primary, secondary and tertiary alcohols can be distinguished by the rate of	For compounds with no more than eight carbon atoms in their longest chain. Branched-chain alcohols, can be named from structural formulae. Given the names of branched-chain alcohols, structural formulae can be drawn and molecular formulae written. Primary alcohols are oxidised, first to aldehydes and then to carboxylic acids. Secondary alcohols are oxidised to ketones. When applied to carbon compounds, oxidation results in an increase in the oxygen to hydrogen ratio. In the laboratory, hot copper(II) oxide or acidified dichromate(VI) solutions can be used to oxidise primary and secondary alcohols. Tertiary alcohols cannot be oxidised. Oxygen reacts with edible oils giving the food a rancid flavour. Antioxidants are molecules which will prevent these oxidation reactions taking place. Ion-electron equations can be written for the oxidation of many antioxidants. Branched-chain carboxylic acids, with no more than eight carbon atoms in their longest chain, can be named from structural formulae. Given the names of branched-chain carboxylic acids, structural formulae can be drawn and molecular formulae written.

Reaction of oxygen with edible oils. Antioxidants. Ion-electron equations for the oxidation of antioxidants.	reaction, though no attempt is made to identify the products. Aldehydes are key components in whisky. Much of the flavour is developed as oxygen diffuses into the cask forming aldehydes. The toxicity of aldehydes can result in unfortunate symptoms such as severe headaches. Aldehydes and ketones can be differentiated by testing with acidified dichromate or Tollen's reagent. In the 'giant silver mirror' experiment a solution of ammoniacal silver nitrate is reduced by aldehydes to silver, which forms a silver mirror on the inside of a large flask. In crisp manufacture, potatoes are typically fried under an atmosphere of steam and packaged under nitrogen. The website Understanding Food Additives has many animations and good, jargon-free text and a number of downloadable classroom activities. There is also an A-level practical investigation on the oxidation of fats and oils available from the University of York. The concentration of antioxidants in foods can be measured by a variety of means. Vitamin C (antioxidant) levels in fruit juices can be compared semi-quantitatively using a very simple method by measuring the number of drops of fruit juice needed to reduce one drop of iodine solution to iodide using starch as an indicator. □This	

	simple method can be used in investigative work exploring the effect that cooking methods have on the antioxidants in foods. For more quantitative results, one possible method is to use a microscale redox back titration. In this experiment a measured amount of fruit drink is added to an excess of iodine solution. The ascorbic acid in the drink reacts quantitatively with some of the iodine. The excess iodine is then titrated against standard thiosulfate solution. In a more straightforward redox titration, the level of vitamin C in a vitamin tablet can be determined by direct redox titration with an acidified permanganate(VII) solution.	
Soaps, detergents and emulsions Hydrolysis of esters. Structure of soap ions including covalent tail, (hydrophobic), and an ionic head (hydrophilic) Cleansing action of soaps. Production, action and use of detergents. Emulsion and emulsifiers and their formation and use in	There is a number of soap making experiments which have been developed to reduce the time taken for soap to form, and to use less corrosive alkalis. One method, producing soap from castor oil, takes approximately 40 minutes. 5 cm^3 of ethanol is added dropwise to 2 cm^3 of castor oil. 10 cm^3 of 5 mol l^{-1} sodium hydroxide is added, and the solution warmed in a water bath containing near-boiling water for five minutes. 10 cm^3 of saturated sodium chloride solution is then added to the beaker and the mixture stirred. The mixture is cooled in a cold water bath (or an ice bath if available). Soft, white lumps of the soap will gradually form in the mixture. Leave for a few minutes to improve the yield.	**Soaps** Production of soaps by the alkaline hydrolysis of fats and oils to form water-soluble ionic salts called soaps. Soap ions have a long covalent tail, readily soluble in covalent compounds (hydrophobic), and an ionic carboxylate head which is negatively charged and water soluble (hydrophilic). During cleaning using soaps and detergents, the hydrophobic tails dissolve in a droplet of oil or grease, whilst the hydrophilic heads face out into the surrounding water. Agitation of the mixture results in ball-like structure forming with the hydrophobic tails on the inside and the negative hydrophilic head on the

food.	During this time, the soap may rise to the surface and form a soft crust on cooling. One of the quickest soap preparations takes under five minutes. In this method, around 2 g of mutton fat is dissolved in 8 cm^3 of ethanol in a boiling tube. One pellet of KOH is added, and the mixture boiled in a water bath for 2 minutes during which the cloudy mixture becomes clear. When the contents of the tube are poured into a beaker containing saturated NaCl solution the soap precipitates and floats on the surface. Many web animations are available showing this process. An experiment can be used to demonstrate the detergent action of soaps. In this experiment, very finely divided MnO_2 or very finely divided charcoal plays the part of 'dirt'. 50 cm^3 of water is placed in one 100 cm^3 measuring cylinder, and 50 cm^3 of soap solution in another. A pinch of simulated 'dirt' is added to each, and the two cylinders shaken. The two cylinders are set aside for some time. In the control cylinder containing water, the 'dirt' settles down on the bottom of the cylinder, whilst in the soap solution the powder remains suspended. An experiment showing how detergents lower the surface tension of water can be found on the website Practical Chemistry. Video clips on how detergents clean can be found on YouTube. Emulsifiers are added to a very large range of foods including sauces, bread, biscuits, ice cream, low-fat spread and even dried pastas where they help to prevent	outside. Repulsion between these negative charges results in an emulsion being formed and the dirt released. Detergents are particularly useful in hard water areas. An emulsion contains small droplets of one liquid dispersed in another liquid. Emulsions in food are mixtures of oil and water. To prevent oil and water components separating into layers, a soap-like molecule known as an emulsifier is added. Emulsifiers for use in food are commonly made by reacting edible oils with glycerol to form molecules in which either one or two fatty acid groups are linked to a glycerol backbone rather than the three normally found in edible oils. The one or two hydroxyl groups present in these molecules are hydrophilic whilst the fatty acid chains are hydrophobic.

	pasta pieces sticking to each other during cooking. Learners can investigate the formation of emulsions in foods using the RSC practical experiments from section 3.2 of *Inspirational Chemistry*. This practical is very straightforward and does not take very long, although if learners shake the boiling tubes too vigorously then the mixtures can take a while to separate. Learners place about 2 cm^3 of vegetable oil and about 2 cm^3 of water into a boiling tube. The tube is stoppered and shaken. The oil and water separate into two layers. Learners then experiment with adding a small quantity of substances such as mustard powder, sugar, flour, salt, egg white, egg yolk and washing-up liquid to determine which act as emulsifiers. Eggs have a salmonella risk and only eggs bearing the lion symbol should be used. Raw egg should be handled as little as possible, and a disposable pipette should be used to transfer it to the boiling tubes. The results can be discussed in terms of the molecules present in these substances. The code E471 is one of the most common 'E-numbers' on food packaging and indicates that the food contains an emulsifying agent consisting of mono- and di-glycerides of fatty acids.	
Fragrances Essential oils from plants: properties, uses	Learners can use steam distillation apparatus to extract essential oils from lavender, rosemary, citrus fruit, pine needles etc. If quickfit-type apparatus is unavailable,	Essential oils are concentrated extracts of the volatile, non-water soluble aroma compounds from plants. They are widely used in perfumes, cosmetic products,

and products. Terpenes: functional group, structure and use. Oxidation of terpenes within plants.	steam distillation can be carried out using an ordinary boiling tube, some glass wool and a one-holed bung fitted with an L-shaped delivery tube. A wad of glass wool soaked in water is placed at the bottom of the boiling tube. A second 'plug' of dry glass wool, is lodged about two-thirds of the way up the boiling tube, supporting some lemon peel, lavender or rosemary. The glass wool soaked in water at the bottom of the boiling tube is gently heated, causing steam to rise up through the plant material and pass down the delivery tube. A cold, wet paper towel can be wrapped around the tube, and fastened with an elastic band to help keep the tube cool. The distillate is collected in a small beaker or boiling tube sitting in a tub of ice cold water. Within five minutes, the tube or beaker will contain some scented distillate. Terpenes are responsible for the distinctive flavours of spices such as cloves, cinnamon and ginger. Terpenes can be extracted from many materials in the lab. A common experiment is the extraction of limonene from citrus fruits. Limonene can be extracted from oranges using ethyl ethanoate as a solvent (an example of solvent extraction — see content statement above). More information on the chemistry of terpenes may be found in: 'Making Sense of Terpenes: An Exploration into Biological Chemistry', Kevin W. Glaeske and Paul R. Boehlke, *The American Biology Teacher*, Vol. 64, No. 3 (Mar., 2002), pp. 208–211 (article consists of 4 pages), published by: National Association of Biology Teachers.	cleaning products and as flavourings in foods. Essential oils are mixtures of organic compounds. Terpenes are key components in most essential oils. Terpenes are unsaturated compounds formed by joining together isoprene (2-methylbuta-1,3-diene) units. They are components in a wide variety of fruit and floral flavours and aromas. Terpenes can be oxidised within plants to produce some of the compounds responsible for the distinctive aroma of spices.

Skin care The damaging effect of ultraviolet radiation (UV) in sunlight on skin and the action of sun-block. Formation of free radicals in UV light. Structure, reactivity and reactions of free radicals. Free radical scavengers in cosmetic products, food products and plastics. Reaction of free radical scavengers with free radicals to prevent chain reactions.	UV photography reveals the effects of 'photoaging', or aging of skin caused by sunlight. There are many websites that show this effect. UV-sensitive polymer beads are now available from many educational suppliers. These beads change colour when exposed to UV light. They can provide a fun and cheap way of allowing learners to experiment with the effectiveness of different sun-block molecules. A spectacular demonstration of a free radical chain reaction is provided by the H_2/Cl_2 reaction. Initiation can be provided by a photographic flash unit, demonstrating that light energy is required to generate the initial free radicals. It can easily be shown that bromine will decolourise in the presence of an alkane faster in light than in the dark. Adverts for anti-aging products can be examined to identify the scientific basis of the claim. Melatonin and vitamin E are examples of natural free radical scavengers	Ultraviolet radiation (UV) is a high-energy form of light, present in sunlight. Exposure to UV light can result in molecules gaining sufficient energy for bonds to be broken. This is the process responsible for sunburn and also contributes to aging of the skin. Sun-block products prevent UV light reaching the skin. When UV light breaks bonds, free radicals are formed. Free radicals have unpaired electrons and, as a result, are highly reactive. Free radical chain reactions include the following steps: initiation, propagation and termination. Many cosmetic products contain free radical scavengers; molecules which can react with free radicals to form stable molecules and prevent chain reactions. Free radical scavengers are also added to food products and to plastics.

Chemistry in Society		
Mandatory Course key areas	**Suggested learning activities**	**Exemplification of key areas**
Getting the most from reactants availability, sustainability and cost of feedstock(s); opportunities for recycling; energy requirements; marketability of by-products; product yield. Balanced equations, mole ratio(s) of reactants and products. Determination of quantities of reactants and/or products using balanced equation, the gram formula masses (GFM), mass and moles. Determination of quantities of reactants and/or products using balanced equations,	Learners could consider descriptions or flow diagrams for an industrial process with a view to recognising the various strategies employed to maximise profitability and to reduce the impact on the environment. The RSC 'Alchemy' resource allows learners to look in detail at industrial processes. An industrial case study demonstrating the ways in which concern for the environment has shaped the design of an industrial process is provided for ibuprofen. Some more general industrial chemistry case studies are available. Details of Green Chemistry can be obtained from the Chemistry Teachers website (RSC resources). The mole is a central concept in chemistry. It can be defined in terms of the number of particles present (Avogadro's constant). The quantitative link between the masses of reactants and	Industrial processes are designed to maximise profit and minimise the impact on the environment. Factors influencing process design include: availability, sustainability and cost of feedstock(s); opportunities for recycling; energy requirements; marketability of by-products; product yield. Environmental considerations include: minimising waste; avoiding the use or production of toxic substances; designing products which will biodegrade if appropriate. Balanced equations show the mole ratio(s) of reactants and products. Using the balanced equation and the gram formula masses (GFM), mass to mass calculations can be performed. The quantity of a reactant or product can also be expressed in terms of moles.

concentrations and volumes of solutions and/or masses of solutes. Calculations of mass or volume (for gases) of products, assuming complete conversion of reactants. percentage yield and atom economy. Limiting reactants and excesses identified.	products can be established experimentally. A known mass of magnesium can be burned (forming magnesium oxide) and the relationship between the mass of magnesium metal and magnesium oxide explored. The reduction of copper(II) oxide by methane can be used to confirm the quantitative link between the mass of reactants and products. Details of how to carry out this experiment are provided in *Classic Chemistry Demonstrations*, Lister, T., The Royal Society of Chemistry (1995), pp. 132–135. Videos of this experiment can be viewed. The molar volume of hydrogen can be measured by learners using a method such as that found in *Classic Chemistry Experiments*, Kevin Hutchings (2000), pp. 171–173. Learners can develop their own method of measuring molar volumes in a practical problem solving exercise such as that found in *In Search of More Solutions*, Janet Taylor, Royal Society of Chemistry (1994), number 36. Learners should have the opportunity to engage in a wide range of calculations involving mass, volume and concentration of solution, GFM and balanced equations. Chemical 'egg race' activities can be used to provide opportunities to practise or consolidate the mathematical skills being developed. In the Chemical Egg Timer, teams are given a graph showing how the concentration of potassium iodide affects the time taken for the blue-black colour to appear in a hydrogen peroxide/iodide clock reaction. The challenge for each team is to prepare 50 cm^3	The molar volume (in units of litres mol^{-1}) is the same for all gases at the same temperature and pressure. The volume of a gas can be calculated from the number of moles and vice versa. The volumes of reactant and product gases can be calculated from the number of moles of each reactant and product. The concentration of a solution can be expressed in mol l^{-1}. Balanced equations can be used in conjunction with concentrations and volumes of solutions and/or masses of solutes to determine quantities of reactants and/or products. The efficiency with which reactants are converted into the desired product is measured in terms of the

	of potassium iodide solution for use in a chemical egg-timer which will turn blue-black one minute after the chemicals are mixed. Colour Match Challenge is a far more demanding exercise and allows key calculation types to be consolidated. In the first part of the challenge, each team is given a 100 cm^3 measuring cylinder containing 5 cm^3 of 1 mol l^{-1} $CuSO_4$ solution. The aim of the egg race is to match as closely as possible two different shades of blue. The teacher/lecturer could choose shades from a paint catalogue, photograph or any two blue objects in the lab. The team must slowly add water to their measuring cylinder until the $CuSO_4$ solution matches the darker of the two shades selected. The team make a note of the total volume of solution. Further water is added until the solution matches the lighter of the two target shades. The team must now calculate the concentration of the $CuSO_4$ solutions which matched the two target colours. In the second part of the challenge, the learners must calculate the mass of copper(II) sulfate pentahydrate ($CuSO_4.5H_2O$ GFM 249.7 g mol^{-1}) needed to produce 100 cm^3 of solution matching the darker shade of blue. They must also calculate the mass of zinc powder required to displace sufficient copper ions to lighten the solution to the point where it matches the lighter target shade. The teams weigh out copper(II) sulfate and zinc powder for use in a competition in which each team must try to reproduce the two target shades. If available, a colorimeter can be used to provide an 'impartial' judgement of how close the colours were to the target shades.	percentage yield and atom economy. Percentage yields can be calculated from mass of reactant(s) and product(s) using a balanced equation. Given costs for the reactants, a percentage yield can be used to calculate the feedstock's cost for producing a given mass of product.

	For a particular set of reaction conditions, the percentage yield provides a measure of the degree to which the limiting reagent is converted into the desired product. It is possible to calculate the percentage yield using equations of the type shown below. $$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$ In this expression the 'actual yield' is taken to refer to the quantity of the desired product formed under the prevailing reactions conditions whilst the 'theoretical yield' is the quantity of desired product which would be obtained, assuming full conversion of the limiting reagent, as calculated from the balanced equation. For reactions in which the masses of both the limiting reagent used and the desired product obtained are known, the actual yield and theoretical yields can be expressed in terms of masses. It is equally valid, however, to calculate percentage yields using the actual and theoretical numbers of moles of desired compound. There are strong arguments on either side in the debate over whether learners should be encouraged to perform percentage yield calculations using masses or the numbers of moles. For assessment purposes either method will be awarded equal credit and there is no need for learners to be familiar with both methods. Atom economy figures are of interest because they provide a measure of how successfully all of the reagents, not just	The atom economy measures the proportion of the total mass of all starting materials successfully converted into the desired product. It can be calculated using the formula shown below in which the masses of products and reactants are those appearing in the balanced equation for the reaction. $$\text{atom economy} = \frac{\text{mass of desired product(s)}}{\text{total mass of reactants}} \times 100$$ Reactions which have a high percentage yield may have a low atom economy value if large quantities of

	the limiting reagent, are being converted into the desired product. A case study illustrating how the atom economy and percentage yields for different synthetic routes led to a switch in the method used to produce ibuprofen is available. Learners can synthesise substances of use in everyday contexts and calculate the percentage yield and atom economy achieved. The food additive E331 (sodium citrate) is well suited to this type of exercise. 50.0 cm^3 of 1.0 mol l^{-1} sodium hydroxide are added to 3.50 g of citric acid crystals in a beaker and the mixture stirred until all the crystals have dissolved. The solution is evaporated to dryness and the product weighed. Zinc sulfate is used in mineral supplements and as a paste mixed with zinc oxide to treat acne. Zinc sulfate is also an astringent; it closes up the pores of the skin to keep out bacteria and can be used for this reason to treat some skin conditions or prevent sunburn. Between 4.4 g and 5.0 g of zinc oxide is added, with stirring, to 50 cm^3 of warm 1.0 mol l^{-1} sulfuric acid (50 °C). The reaction mixture is allowed to cool then filtered. The filtrate is evaporated to dryness and the product weighed. Calcium benzoate (E213), a preservative in foods, can be made from the reaction between benzoic acid and calcium carbonate. Aspirin can easily be prepared without the use of quickfit or	unwanted by-products are formed.

	distillation apparatus using only a conical flask or on a test-tube scale using a 20 minute method. A range of esters can be synthesised without the use of quickfit apparatus and the yield determined. Some learners struggle with the concept of excess in the context of identifying which substance(s) is/are present in excess and which is the limiting reagent in a given reaction mixture. A 'roast beef' sandwich analogy has been reported to be useful. To make a sandwich, two slices of bread and one slice of roast beef are required. If, for example, ten slices of roast beef and sixteen slices of bread are available, how many sandwiches can be made? In this case, only eight sandwiches can be made because bread is the limiting reagent and there is excess roast beef. This analogy is part of a computer simulation available from PhET which also includes examples of chemical reactions and a game to test understanding of the concept of excess.	In order to ensure that costly reactant(s) are converted into product, an excess of less expensive reactant(s) can be used. By considering a balanced equation, the limiting reactant and the reactant(s) in excess can be identified. Whilst the use of excess reactants may help to increase percentage yields, this will be at the expense of the atom economy so an economic/environmental balance must be struck.
Equilibria Reversible reactions, dynamic equilibrium, altering equilibrium position. Effect of catalyst on equilibrium and the most favourable reaction conditions.	Learners can investigate reversible reactions for themselves using hydrated copper(II) sulfate. A spectacular demonstration of a reversible reaction involving colour changes and clouds of white fumes can be performed using copper sulfate, concentrated hydrochloric acid and concentrated ammonia solution. The demonstration is started by making a yellow-green copper chloride complex by adding concentrated hydrochloric acid to a very dilute solution of copper sulfate. When concentrated ammonia	Many reactions are reversible, so products may be in equilibrium with reactants. This may result in costly reactants failing to be completely converted into products. In a closed system, reversible reactions attain a state of dynamic equilibrium when the rates of forward and reverse reactions are equal. At equilibrium, the concentrations of reactants and products remain constant, but are rarely equal. To maximise profits, chemists employ strategies to

	solution is added, copious quantities of white smoke are produced as HCl is driven off, heat is generated and a dark blue tetraamminecopper(II) complex forms. Adding concentrated HCl will reverse this reaction again turning the solution yellow-green colour again. Details can be found in 'A spectacular reversible reaction' by Colin Baker in *Education in Chemistry*, vol. 43, n. 3, May 2006. Experiments in which the position of equilibrium can be altered by changing conditions include: $CoCl_2/CoCl_2.2H_2O$ SSERC Bulletin 219, 'Equilibrium and Le Chatelier' SSERC Bulletin 220, 'Equilibrium of Cobalt Chloride (Continued) ICl/ICl_3 equilibrium , NO_2/N_2O_4, CO_2 in soda water Learners should have the opportunity to consider industrial processes where equilibrium conditions are optimised. The RSC Alchemy resource contains video material and activities allowing learners to research processes such as ammonia production (Haber process), Nitric acid (Ostwald process) sulfuric acid (Contact process). Worksheets, fact files and videos for these processes are available. Simulation of the Haber process can also be used.	move the position of equilibrium in favour of products. Changes in concentration, pressure and temperature can alter the position of equilibrium. A catalyst increases the rate of attainment of equilibrium but does not affect the position of equilibrium. The effects of altering pressure, altering temperature, the addition or removal of reactants or products can be predicted for a given reaction.
Chemical energy Enthalpy calculations used for industrial processes The specific heat capacity, mass temperature and moles	Test-tube-scale reactions (for learners to undertake) which can be used to illustrate endo- and exothermic reactions, and which are suitable for use in enthalpy change measurement include: dissolving a spatula of anhydrous copper(II) sulfate in 2 cm^3 of water (exothermic); adding 2	For industrial processes, it is essential that chemists can predict the quantity of heat energy taken in or given out. If reactions are endothermic, costs will be incurred in supplying heat energy in order to maintain the reaction rate. If reactions are exothermic, the heat

used to calculate the enthalpy change for a reaction. Enthalpies of combustion. Hess's law. Calculation of enthalpy changes by application of Hess's law.	cm^3 of water to a dry mixture of one spatula of citric acid and one spatula of sodium hydrogencarbonate (endothermic); adding a spatula of zinc to 5 cm^3 of 0.5 mol l^{-1} copper(II) sulfate solution. Polystyrene cups can also be used by all learners to explore chemical energy changes. 10 cm^3 of sodium hydroxide solution is placed in the cup, the temperature recorded, and 10 cm^3 of dilute hydrochloric acid added. The temperature is recorded whilst stirring. This procedure can be repeated using: sodium hydrogen carbonate solution and citric acid; copper(II) sulfate solution and magnesium powder; dilute sulfuric acid and magnesium ribbon. Spectacular teacher demonstrations of exothermic reactions would including the thermit/thermite reaction or the reaction between zinc and copper(II) oxide. Demonstrations of endothermic reactions are offered by either: the solid-phase reaction between barium hydroxide-8-water and solid ammonium chloride (or ammonium thiocyanate) in which the mixture of stoichiometric quantities results in a reaction producing a liquid, with the temperature dropping to below –20 °C; or when 25 g of ammonium nitrate is added rapidly, with vigorous stirring, to 100 cm^3 of water in a beaker which is resting on paper towel soaked in water. The wet paper towel freezes fixing the beaker to the bench surface. Runaway reactions, such as those resulting in the disasters at Seveso and Bhopal, occur when the rate at which a	produced may need to be removed to prevent the temperature rising. Chemical energy is also known as enthalpy. The change in chemical energy associated with chemical reactions can be measured. The specific heat capacity, mass and temperature can be used to calculate the enthalpy change for a reaction. The enthalpy of combustion of a substance is the enthalpy change when one mole of the substance burns completely in oxygen. These values can often be directly measured using a calorimeter and values for common compounds are available from data books and online databases for use in Hess's law calculations. Hess's law states that the enthalpy change for a chemical reaction is independent of the route taken. Enthalpy changes can be calculated by applying Hess's law.

	chemical reaction releases energy exceeds the capabilities of the plant to remove heat. Internet sources can provide further details of these incidents. The enthalpy of combustion of alcohols can be measured using apparatus available in schools.□ The RSC has an online data book with enthalpy of combustion values. Solid potassium hydroxide can be converted into potassium chloride solution by two different routes: Route 1 is the direct route whereby potassium chloride solution is made by adding solid potassium hydroxide directly to hydrochloric acid. Route 2 is the indirect route and involves two steps. Solid potassium hydroxide is first dissolved in water and then the solution neutralised using hydrochloric acid. Hess's law can be confirmed by comparing the total enthalpy change for single-step route 1 with two-step route 2. Hess's law can be used to determine enthalpy changes that cannot be measured directly. In one challenge, learners are asked to determine the enthalpy change for the reaction in which anhydrous copper(II) sulfate reacts with water to form hydrated copper(II) sulfate. Learners measure the temperature change observed when anhydrous copper(II) sulfate is dissolved in water to produce a solution of copper(II) sulfate. They then measure the temperature change when hydrated copper(II) sulfate is dissolved to form a solution of similar concentration. By applying Hess's law, the learners can then calculate the enthalpy change for a reaction converting anhydrous copper(II) sulfate crystals into hydrated copper(II) sulfate crystals.	

Chemical energy Bond enthalpies for a diatomic molecule The molar bond enthalpy and mean molar bond enthalpies. Enthalpy changes for gas phase reactions can be calculated using bond enthalpies.	Use bond enthalpies to estimate, by calculation, the enthalpy change associated with various gas phase reactions and compare the values obtained with experimental values obtained from literature. A common misunderstanding amongst learners is that bond enthalpies can only be used to estimate the enthalpy change in reactions in which all of the reactants and all of the products are in the gas phase due to the assumption that the only bonds or interactions being broken or formed are covalent bonds.	For a diatomic molecule, XY, the molar bond enthalpy is the energy required to break one mole of XY bonds. Mean molar bond enthalpies are average values which are quoted for bonds which occur in different molecular environments. Bond enthalpies can be used to estimate the enthalpy change occurring for a gas phase reaction by calculating the energy required to break bonds in the reactants and the energy released when new bonds are formed in the products.
Oxidising or reducing agents Elements, molecules, group ions and compounds as oxidising and reducing agents, electrochemical series as reduction reactions. Uses of oxidising agents. Ion-electron for redox, oxidation and reduction equations.	Displacement reactions are a classic way to compare the relative strength of oxidising and reducing agents. Experiments with halogen displacement can be used to compare the strength of elements as oxidising agents. Experiments suitable for candidate use are available in *Classic Chemistry Experiments*, K. Hutchings, Royal Society of Chemistry (2000), halogen displacement pp. 46-48. Videos showing halogen displacement are also available. The relative strengths of other non-metals as oxidising agents can also be compared. Oxygen gas can be bubbled through solutions of potassium sulfide, chloride, bromide and iodide to establish which non-metallic elements are displaced from their compounds by oxygen. Chlorine water is then added to the same solutions to establish which elements are displaced by chlorine.	An oxidising agent is a substance which accepts electrons; a reducing agent is a substance which donates electrons. Oxidising and reducing agents can be identified in redox reactions. The elements with low electronegativities (metals) tend to form ions by losing electrons (oxidation) and so can act as reducing agents; the elements with high electronegativities (non-metals) tend to form ions by gaining electrons (reduction) and so can act as oxidising agents. The strongest reducing agents are found in Group 1 whilst the strongest oxidising agents come from Group 7. The electrochemical series indicates the effectiveness of oxidising and reducing agents. Compounds can also act as oxidising or reducing agents. Electrochemical series contain a number of ions and molecules. The dichromate and permanganate ions are strong oxidising agents in acidic solutions whilst hydrogen peroxide is an

	Metal displacement reactions can be used to compare the strength of elements acting as reducing agents. A typical candidate experiment is described in *Classic Chemistry Experiments*, K. Hutchings, Royal Society of Chemistry (2000), halogen displacement pp. 249–252. Demonstration metal displacement experiments include the well-known 'snow tree' experiment, in which copper foil cut in the shape of a pine tree is lowered into silver nitrate solution causing 'snow' crystals to form on the branches, and the thermit reaction. *Classic Chemistry Demonstrations*, Ted Lister, Royal Society of Chemistry (1995), contains details of two methods for carrying out this dramatic experiment. The thermit reaction is also available on video. The 'elephant's toothpaste' experiment provides an illustration of hydrogen peroxide's ability to act as an oxidising agent. An adaptation of the 'blue bottle' experiment allows learners to see dextrose acting as a reducing agent, and oxygen acting as an oxidising agent. Every time a bottle containing an alkaline solution of methylene blue and dextrose is shaken, the methylene blue is reduced by the dextrose turning the solution colourless, but then reacts with atmospheric oxygen to return to its blue colour. A version for learners to try for themselves is described in *Classic Chemistry Experiments*, Kevin Hutchings, Royal Society of Chemistry (2000).	example of a molecule which is a strong oxidising agent. Carbon monoxide is an example of a gas that can be used as a reducing agent. Oxidising and reducing agents can be selected using an electrochemical series from a data booklet or can be identified in the equation showing a redox reaction. Oxidising agents are widely employed because of the effectiveness with which they can kill fungi and bacteria, and can inactivate viruses. The oxidation process is also an effective means of breaking down coloured compounds making oxidising agents ideal for use as 'bleach' for clothes and hair. Oxidation and reduction reactions can be represented by ion-electron equations. When molecules or group ions are involved, if the reactant and product species are known, a balanced ion-electron equation can be written by adding appropriate numbers of water molecules, hydrogen ions and electrons. (Learners would not be expected to complete and balance ion-electron equations for reactions occurring in alkaline solutions.) Ion-electron equations can be combined to produce redox equations.

	A startling and unusual demonstration of hydrogen peroxide's ability to act as an oxidising agent is demonstrated by the 'luminescent tea' experiment. Ethyl ethanoate and 35% hydrogen peroxide are measured into a beaker in a 5:1 ratio. A small pinch of oxalic acid-bis-(2,3-dinitrophylester) is added along with a peppermint tea bag. The hydrogen peroxide oxidises the oxalic ester producing carbon dioxide in an excited state. The carbon dioxide transfers energy to the chlorophyll in the peppermint tea causing red light to be emitted. If the room is completely darkened, a red glow can be seen every time the beaker is moved. Ethyl ethanoate acts as the solvent in this experiment. (See *Spectacular Chemistry Experiments*, H.W. Roesky, Wiley-VCH (2007) pp. 49-50.) To illustrate the oxidising nature of permanganate ions, glycerol is poured onto potassium permanganate crystals. After a short lag time, the permanganate ions oxidise the glycerol causing steam to be given off. An illustration of chlorate(V) ions' ability to act as oxidising agents is provided in a spectacular demonstration using chlorate(V) salts to oxidise granulated sugar. The potassium ions present result in spectacular pink flames being produced. Instructions on how to carry out this experiment safely are given in *Contemporary Chemistry for Schools and Colleges*, Vanessa Kind, Royal Society of Chemistry (2004), pp. 11–12. Experiments which show the ability of molecules to act as	

	reducing agents include the reduction of copper(II) oxide using methane or hydrogen. Potassium permanganate, $KMnO_4$, is a chemical oxidising agent that will react with any organic matter in a pond including algae, bacteria, fish, particulate and dissolved organic matter, and organic bottom sediments. It has been used in fish ponds to treat common fish pathogens such as gill parasites and external bacterial and fungal infections. Bleaching reactions can be carried out using sulfur dioxide — red roses rapidly decolourise in a gas jar of SO_2. When chorine gas, generated by adding 6M HCl to $KMnO_4$ is bubbled through tomato juice, the red colour quickly disappears. (Details from *Spectacular Chemistry Experiments*, H.W. Roesky Wiley-VCH (2007) pp. 87–88.) Another demonstration which works well uses a household bleach containing sodium hypochlorite. Four drops of yellow food colouring (E102) and four drops of blue food colouring (E 124) are dissolved in 40 cm^3 of water. A solution containing four drops of household bleach in 20 cm^3 of water is added to the solution and the mixture stirred. The hypochlorite oxidises the colourings taking the solution through a number of colour changes. This experiment will work with both thick and thin bleaches. Thicker bleaches tend to give more gradual colour changes which are easier for learners to observe. (Details from *Spectacular Chemistry Experiments*, H.W. Roesky Wiley-VCH (2007) pp. 77–78.) Redox titrations could be used to illustrate quantitatively, the relevance of balanced redox equations. Possible titrations could include: determination of vitamin C in vitamin tablets	

	by titration with acidified permanganate; determination of the concentration of a hydrogen peroxide solution by titration with acidified potassium permanganate. There are a number of methods that allow the concentration of household bleaches to be investigated. Excess hydrogen peroxide can be added to household bleach and the volume of oxygen produced measured. The concentration of sodium hypochlorite in the bleach can be calculated. learners Alternatively, learners can measure the bleach content of a variety of bleaches, and calculate their cost effectiveness, by reacting the chlorine in the bleach with iodide to form iodine and then titrating the iodine solution against sodium thiosulfate.	
Chemical analysis Chromatography Uses of chromatography. Differences in the polarity and/or size of molecules	Many overviews of the key chromatographic techniques are available. A gas chromatograph can be made from a u-tube filled with soap powder. Natural gas acts as the carrier gas, and is burnt after it emerges from the u-tube 'column'. A mixture of alkanes is introduced at the inlet side of the u-tube. The component alkanes each take a different amount of time to travel through the soap powder 'column' and leave the u-tube at different times. Each time a compound leaves the u-tube, the flame formed by the burning carrier gas gets much larger and smokier. Column chromatography can be inexpensively carried out by	In chromatography, differences in the polarity and/or size of molecules are exploited to separate the components present within a mixture. Depending on the type of chromatography in use, the identity of a component can be indicated either by the distance it has travelled or by the time it has taken to travel through the apparatus (retention time). The results of a chromatography experiment can sometimes be presented graphically showing an indication of the quantity of substance present on the *y*-axis and retention time on the *x*-axis. Learners are not required to know the details of any specific chromatographic method or experiment.

	learners. Mixtures of food dyes can be separated using a 20 cm long glass tube or glass dropper containing a slurry of starch. A computer animation showing column chromatography in action is available. An interactive computer simulation of paper chromatography is available. Case studies concerning the use of chromatography are also available. *The National Horseracing Laboratory screens samples from racehorses and other animals to detect and identify traces of prohibited substances. A case study briefly describes gas chromatography and compares it with paper chromatography. There is information and questions for learners, and additional notes and answers for teachers.* *In 1961, the seaside town of Capitola, California became the scene of a disturbing incident in which birds were reported to have flown into glass windows, attacked people on the ground and even, in less measured coverage, 'cry like babies'. The toxin responsible for the birds' altered behaviour was isolated and identified using a series of separation techniques, including chromatography.* A most unusual example of chromatography is provided by wool chromatography. A length of white wool approximately 1 m sulplong, two 100 cm^3 beakers, approximately 20 cm^3 of methylated spirit and two crocodile clips are required. A short section (approximately 1 cm long) of the wool approximately 20 cm from the end of the wool is soaked in	

	ink and allowed to dry. The length of wool between the inked area and the nearest end is soaked in alcohol. Crocodile clips are attached to each end of the wool to act as weights. The beaker containing the alcohol is placed on the edge of the bench. The clip on the end of the wool nearest the inked section is carefully lowered into the alcohol in such a way that the wool then passes over the spout of the beaker and descends towards the floor. The empty beaker is placed on the floor beneath the hanging clip. The alcohol is wicked up the wool, passes over the lip of the beaker and, under the action of gravity, starts to descend through the wool. As the ethanol passes through the inked area the components of the ink are carried by the solvent towards the floor at different rates resulting in a series of coloured bands moving down the wool towards the floor.	
Chemical analysis Volumetric titration Volumetric analysis for quantitative reactions. Standard solutions, acid base and redox titrations.	Experimental work could include any acid/base or redox titration. Interesting examples could include the determination of: ♦ the purity of aspirin ♦ the purity of vitamin C tablets ♦ the concentration of ethanoic acid in vinegars (by titration with sodium hydroxide using phenolphthalein indicator) ♦ the mass of citric acid in chewing gum (by titration with sodium hydroxide solution using phenolphthalein indicator) ♦ the calcium carbonate content of antacid tablets (back titration in which tablet is dissolved in standard	Volumetric analysis involves using a solution of accurately known concentration in a quantitative reaction to determine the concentration of another substance. A solution of accurately known concentration is known as a standard solution. The volume of reactant solution required to complete the reaction is determined by titration. The end-point is the point at which the reaction is just complete. An indicator is a substance which changes colour at the end-point. Redox titrations are based on redox reactions. Substances such as potassium manganate(VII), which

	hydrochloric acid, and the excess acid determined by titration with sodium hydroxide solution using phenolphthalein indicator ♦ the concentration of chloride ions in river water (a precipitation titration using silver nitrate solution and potassium chromate(VI) as the indicator) A 'desert island' style practical problem solving exercise can be provided in which learners investigate whether lemons or oranges contain more acid, using ash from burned plants (which contains potassium carbonate) to neutralise the acid, and an indicator made from plant material such as red cabbage.	can act as their own indicators, are very useful reactants in redox titrations. The concentration of a substance can be calculated from experimental results by use of a balanced equation.
Researching Chemistry		
Candidates should have knowledge of the following pieces of general laboratory apparatus: ♦ Conical flask ♦ Beaker ♦ Measuring cylinder ♦ Delivery tubes ♦ Dropper ♦ Test tubes/Boiling tubes ♦ Evaporating basin ♦ Pipette with safety filler ♦ Burette		

♦ Volumetric flask ♦ Funnel ♦ Thermometer Candidates should be familiar with the following techniques ♦ Filtration ♦ Distillation ♦ Use of a balance ♦ Titration ♦ Methods for the collection of a gas: over water, using a gas syringe ♦ Safe Methods for heating: Bunsen burners, water baths or heating mantles		

Developing skills for learning, skills for life and skills for work

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Course Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and must be built into the Course where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Course.

For this Course, it is expected that the following skills for learning, skills for life and skills for work will be significantly developed:

Literacy

Writing means the ability to create texts which communicate ideas, opinions and information, to meet a purpose and within a context. In this context 'texts' are defined as word-based materials (sometimes with supporting images) which are written, printed, Braille or displayed on screen. These will be technically accurate for the purpose, audience and context.

1.2 Writing

Learners develop the skills to effectively communicate key areas of chemistry, make informed decisions, and describe clearly chemical issues in various media forms.
Learners will have the opportunity to communicate applied knowledge and understanding throughout the Unit with an emphasis on applications and environmental/ethical/social impacts.

There will be opportunities to develop the literacy skills of listening and reading, when gathering and processing information in biology.

Numeracy

This is the ability to use numbers in order to solve problems by counting, doing calculations, measuring, and understanding graphs and charts. This is also the ability to understand the results.
Learners will have opportunities to extract, process and interpret information *presented in numerous formats including tabular and graphical. Practical work* will provide opportunities to develop time and measurement skills.

2.1 Number processes

Number processes mean solving problems arising in everyday life.
Learners will have the opportunity to develop numeracy skills by carrying out and understanding calculations when calculate quantities of reagents and products, excess percentage yield and atom economy.
Learners should deal with data and results from experiments/investigations and everyday class work, making informed decisions based on the results of these calculations and understanding these results

2.2 Money, time and measurement

Using time and measurement in practical work during rates of reaction and chemical analysis

2.3 Information handling

Learners will experience information handling opportunities when dealing with data in tables, charts and other graphical displays to draw conclusions with justifications throughout the Course. It involves interpreting the data and considering its reliability in making reasoned deductions and informed decisions with justifications.

Thinking skills

This is the ability to develop the cognitive skills of remembering and identifying, understanding and applying.

The Course will allow learners to develop skills of applying, analysing and evaluating. Learners can analyse and evaluate practical work and data by reviewing the process, identifying issues and forming valid conclusions. They can demonstrate understanding and application of concepts and explain and interpret information and data.

5.3 Applying

Learners should be given opportunities to plan experiments throughout the Course and to use existing information to solve problems in different contexts.

5.4 Analysing and evaluating

During practical work, learners should be given the opportunity to review and evaluate experimental procedure and identify improvements. Learners will use their judgement when drawing conclusions from experiments.

Analysis is the ability to solve problems in chemistry and make decisions that are based on available information.
It may involve the review and evaluation of relevant information and/or prior knowledge to provide an explanation.

It may build on selecting and/or processing information, so is a higher skill.

5.5 Creating

This is the ability to design something innovative or to further develop an existing thing by adding new dimensions or approaches. Through learning in Chemistry, learners can demonstrate creativity, in particular, when planning and designing experiments/investigations. Learners have the opportunity to be innovative in their approach. Learners also have opportunities to make, write, say or do something new.

In addition, leaners will also have opportunities to develop skills in working with others creating and citizenship.

Working with Others
Learning activities provide many opportunities in all areas of the Course for learners to work with others. Practical activities and investigations offer opportunities for group work, which is an important aspect of science and should be encouraged.

Citizenship
This Course has many opportunities for an extensive range of practical activities which provide learners with the opportunity to work co-operatively with others. Learners will develop citizenship skills when considering the applications of chemistry on society/the environment.

Approaches to assessment

Assessment should cover the mandatory skills, knowledge and understanding of the Course. Assessment is integral to improve learning and teaching. The approach should involve learners and provide supportive feedback. Self- and peer-assessment techniques should be used whenever appropriate.

See the *Unit Support Notes* for guidance on approaches to assessment of the Units of the Course.

Added value

At Higher the added value will be assessed in the Course assessment.

Information given in the *Course Specification* and the *Course Assessment Specification* about the assessment of added value is mandatory.
If the Unit is being taken as part of the Higher Chemistry Course, the learner will be required to draw on, extend and apply the skills and knowledge they have developed during this Unit within the *Course Assessment* (Question Paper and Assignment).

Preparation for Course assessment

Each Course has additional time which may be used at the discretion of the teacher or lecturer to enable learners to prepare for Course assessment. This time may be used near the start of the Course and at various points throughout the Course for consolidation and support. It may also be used for preparation for Unit assessment, and towards the end of the Course, for further integration, revision and preparation and/or gathering evidence for Course assessment.

During delivery of the Course, opportunities should be found:

- for identification of particular aspects of work requiring reinforcement and support
- to practise skills of scientific inquiry and investigation in preparation for the Assignment
- to practise question paper techniques

OPEN ENDED QUESTIONS

In open ended question, the candidate is required to draw on his/ her understanding of key chemical principles in order to solve a problem or challenge. The ‘open-ended’ nature of these questions is such that there is no unique correct answer. In addition to testing the extent of a student’s chemical insight, these questions promote and reward creativity and analytical thinking. The less prescriptive marking instructions focus on rewarding students for their understanding of chemistry.

Open-ended questions give candidates the opportunity to demonstrate their understanding of underpinning chemical concepts and their ability to apply these

ideas creatively in unfamiliar contexts. These questions are signposted for candidates by the use of the phrase, '**using your knowledge of chemistry'** printed in bold text within the question stem.
As there is no one answer candidates could draw on a number of ways of answering the question, ie they could:

- Describe an aspect of chemistry
- Explain the underlying chemistry principles
- Explain the chemistry relationship(s) in a given scenario or context
- Outline the evidence that supports a chemical reaction
- Manipulate chemistry data to fit a situation/context scenario, context or information/data provided
- Identify variables, which may be known, unknown or require an estimation to be made, and solve a chemistry problem.
- Evaluate/analyse the process/outcome of a chemistry investigation, experiment or other such work

Combining assessment across Units

If an integrated approach to Course delivery is chosen then there may be opportunities for combining assessment across Units. If this approach is used then it is necessary to be able to track evidence for individual Outcomes and Assessment Standards.

Transfer for evidence: When the Outcomes and Assessment Standards are the same for the Units of the Course, differing only by context, evidence for Outcome 1 and Assessment Standards 2.2, 2.3 and 2.4 for one Unit in this Course can be used as evidence of the achievement of Outcome 1 and Assessment Standards 2.2, 2.3 and 2.4 in the Chemical Changes and Structure, Nature's Chemistry and Chemistry in Society Units of this Course.

Equality and inclusion

The following should been taken into consideration:

Situation	Reasonable adjustment
Carrying out practical activities	Use could be made of practical helpers if learners with: ♦ physical disabilities, especially manual dexterity when carrying out practical techniques ♦ visual impairment have difficulty in distinguishing colour changes or other visual information
Reading, writing and presenting text, symbolic representation, tables, graphs and diagrams.	Use could be made of ICT, enlarged text, paper and/or print colour and/or practical helpers for learners with visual impairment, specific learning difficulties and physical disabilities
Process information using calculations	Use could be made of practical helpers for learners with specific cognitive difficulties (eg dyscalculia)
Draw a valid conclusion, giving explanations and making generalisation/predictions	Use could be made of practical helpers for learners with specific cognitive difficulties or autism

As far as possible, reasonable adjustments should be made for the Question Paper and/or Assignment, where necessary. All current adjustments currently available for the Question Paper would be available for Component 1. Learners will have a choice of Assignment topic for Component 2 for which reasonable adjustments can be made. This includes the use of 'practical helpers', readers, scribes, adapted equipment or assistive technologies.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in these Course Support Notes is designed to sit alongside these duties but is specific to the delivery and assessment of the Course.

It is important that centres understand SQA's assessment arrangements for disabled learners, and those with additional support needs, when making requests for adjustments to published assessment arrangements. Centres will find more guidance on this in the assessment arrangements section of SQA's website: www.sqa.org.uk/sqa//14977.html.

Appendix 1: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled learners and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- *Building the Curriculum 3: A framework for Learning and Teaching*
- *Building the Curriculum 4: Skills for learning, skills for life and skills for work*
- *Building the Curriculum 5: A framework for assessment*
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment* (June 2008)
- Principles and practice papers for sciences curriculum area
- Science: A Portrait of current practice in Scottish Schools (2008)
- *SCQF Handbook: User Guide* (published 2009) and SCQF level descriptors (to be reviewed during 2011 to 2012): www.sqa.org.uk/sqa/4595.html
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*

Administrative information

Published: June 2014 (version 2.0)

History of changes to Course Support Notes

Course details	Version	Description of change	Authorised by	Date
	2.0	Changes to table from page 7 onwards to add clarification	Qualifications Development Manager	June 2014

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Unit Support Notes

Unit Support Notes — Chemical Changes and Structure (Higher)

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Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Chemical Changes and Structure (Higher) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit is to develop skills of scientific inquiry, investigation, analytical thinking, independent working and knowledge and understanding of chemical changes and structure.

Learners will apply these skills when considering the applications of chemical changes and structure on our lives, as well as the implications on society/the environment. This can be done using a variety of approaches, including investigation and problem solving.

The Unit covers the key areas of:

- controlling the rate
- periodicity
- structure and bonding

Learners will research issues, apply scientific skills and communicate information related to their findings, which will develop skills of scientific literacy.

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by the following or equivalent qualifications and/or experience:

- National 5 Chemistry Course

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the Higher Chemistry *Course Support Notes*.

If this Unit is being delivered on a free-standing basis, teachers and lecturers should cover the mandatory skills and key areas in ways which are most appropriate for delivery in their centres.

Progression from this Unit

This Unit may provide progression to:

- other qualifications in Chemistry or related areas
- further study, employment and/or training

Approaches to learning and teaching

Approaches to learning and teaching and suggested learning activities are covered in the *Course Support Notes*.

Bonding and calculations based on the mole and balanced chemical equations are central to chemistry and are visited in Chemical Changes and Structure, Nature's Chemistry and Chemistry in Society.

Learners should be given the opportunity to practise solving problems relating to the mole and balanced equations throughout the Course. By revisiting the mole and chemical equations at different points of the Course, learners consolidate earlier learning and may progressively develop a more in-depth and secure understanding of the mole concept through applying their knowledge in different contexts.

Safety is integral to all practical work and learners should be encouraged to see risk assessment as a natural part of the planning process for any practical activity. Whilst learners would not be expected to produce a full written risk assessment themselves, Outcome 1 provides an opportunity to assess risks and take informed decisions regarding the use of appropriate control measures during the planning stage of the practical experiment or investigation

Developing skills for learning, skills for life and skills for work

Information about developing skills for learning, skills for life and skills for work in this Unit, is given in the relevant *Course Support Notes*.

Approaches to assessment and gathering evidence

The purpose of this section is to give advice on approaches to assessment for the Unit. There will be other documents produced for centres to provide exemplification of assessments and guidance on how to write them.

Approaches to the assessment of a Unit when it forms part of a Course may differ from approaches to assessing the same Unit when it is not being delivered as part of a Course. If an integrated approach to Course delivery is chosen, then there may be opportunities for combining assessment across Units.

Assessments must be valid, reliable and fit for purpose for the subject and level, and should fit in with learning and teaching approaches.

Unit assessment should support learning and teaching and, where possible, enable personalisation and choice for learners in assessment methods and processes. Teachers and lecturers should select the assessment methods they believe are most appropriate, taking into account the needs of their learners and the requirements of the Unit.

There is no mandatory order for delivery of the Outcomes. These should be overtaken throughout the Unit and are an integral part of learning and teaching.

The table below gives guidance and advice on possible approaches to assessment and gathering evidence.

Strategies for gathering evidence
There may be opportunities in the day-to-day delivery of the Units in a Course to observe learners providing evidence which satisfies completely or partially a Unit or Units. This is naturally occurring evidence and can be recorded as evidence for an Outcome or parts of an Outcome. In some cases, additional evidence may also be required to supplement and confirm the naturally occurring evidence. Approaches to assessment might cover the whole Unit or be combined across Outcomes. A holistic approach can enrich the assessment process for the learner by bringing together different Outcomes and/or Assessment Standards. If a holistic approach is used then it is necessary to be able to track individual Assessment Standard evidence. Strategies for gathering evidence and ensuring that the learners' work is their own, could include: ♦ personal interviews during which the teacher or lecturer can ask additional questions about completed work ♦ oral presentations on their work ♦ written reports ♦ checklists to record authenticity ♦ supplementary sources of evidence, such as witness testimony, film or audio clips Evidence can be gathered from classwork, experiment, investigations and/or research carried out in this unit. It can be obtained using one or more of the strategies outlined above or by alternative methods which could include a test of knowledge, understanding and skills.

Combining assessment within Units

See *Course Support Notes*.

Equality and inclusion

The *Course Support Notes* provide full information on equality and inclusion for this Unit.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in this document is designed to sit alongside these duties but is specific to the delivery and assessment of the Unit.

Alternative approaches to Unit assessment to take account of the specific needs of learners can be used. However, the centre must be satisfied that the integrity of the assessment is maintained and that the alternative approaches to assessment will, in fact, generate the necessary evidence of achievement.

Appendix 1: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled learners and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- *Building the Curriculum 3: A framework for Learning and Teaching*
- *Building the Curriculum 4: Skills for learning, skills for life and skills for work*
- *Building the Curriculum 5: A framework for assessment*
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment* (June 2008)
- Principles and practice papers for sciences curriculum area
- Science: A Portrait of current practice in Scottish Schools (2008)
- *SCQF Handbook: User Guide* (published 2009) and SCQF level descriptors (to be reviewed during 2011 to 2012): www.sqa.org.uk/sqa/4595.html
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*
- SQA Guidelines on e-assessment for Schools
- SQA Guidelines on Online Assessment for Further Education
- SQA e-assessment web page: www.sqa.org.uk/sqa/5606.html

Administrative information

Published: June 2014 (version 1.0)

History of changes to Unit Support Notes

Unit details	Version	Description of change	Authorised by	Date

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Unit Support Notes

Unit Support Notes — Nature's Chemistry (Higher)

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Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Nature's Chemistry (Higher) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit is to develop skills of scientific inquiry, investigation, analytical thinking, independent working and knowledge and understanding of nature's chemistry.

Learners will apply these skills when considering the applications of nature's chemistry on our lives, as well as the implications on society/the environment. This can be done using a variety of approaches, including investigation and problem solving.

The Unit covers the key areas of:

- esters
- fats and oils
- proteins
- the chemistry of cooking
- oxidation of food
- soaps and detergents and emulsions
- fragrances
- skin care

Learners will research issues, apply scientific skills and communicate information related to their findings, which will develop skills of scientific literacy.

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by the following or equivalent qualifications and/or experience:

- National 5 Chemistry Course

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the Higher Chemistry *Course Support Notes*.

If this Unit is being delivered on a free-standing basis, teachers and lecturers should cover the mandatory skills and key areas in ways which are most appropriate for delivery in their centres.

Progression from this Unit

This Unit may provide progression to:

- other qualifications in Chemistry or related areas
- further study, employment and/or training

Approaches to learning and teaching

Approaches to learning and teaching and suggested learning activities are covered in the *Course Support Notes*.

Bonding and calculations based on the mole and balanced chemical equations are central to chemistry and are visited in Chemical Changes and Structure, Nature's Chemistry and Chemistry in Society.

Learners should be given the opportunity to practise solving problems relating to the mole and balanced equations throughout the Course. By revisiting the mole and chemical equations at different points of the Course, learners consolidate earlier learning and may progressively develop a more in-depth and secure understanding of the mole concept through applying their knowledge in different contexts.

Safety is integral to all practical work and learners should be encouraged to see risk assessment as a natural part of the planning process for any practical activity. Whilst learners would not be expected to produce a full written risk assessment themselves, Outcome 1 provides an opportunity to assess risks and take informed decisions regarding the use of appropriate control measures during the planning stage of the practical experiment or investigation.

Developing skills for learning, skills for life and skills for work

Information about developing skills for learning, skills for life and skills for work in this Unit, is given in the relevant *Course Support Notes*.

Approaches to assessment and gathering evidence

The purpose of this section is to give advice on approaches to assessment for the Unit. There will be other documents produced for centres to provide exemplification of assessments and guidance on how to write them.

Approaches to the assessment of a Unit when it forms part of a Course may differ from approaches to assessing the same Unit when it is not being delivered as part of a Course. If an integrated approach to Course delivery is chosen, then there may be opportunities for combining assessment across Units.

Assessments must be valid, reliable and fit for purpose for the subject and level, and should fit in with learning and teaching approaches.

Unit assessment should support learning and teaching and, where possible, enable personalisation and choice for learners in assessment methods and processes. Teachers and lecturers should select the assessment methods they believe are most appropriate, taking into account the needs of their learners and the requirements of the Unit.

There is no mandatory order for delivery of the Outcomes. These should be overtaken throughout the Unit and are an integral part of learning and teaching.

The table below gives guidance and advice on possible approaches to assessment and gathering evidence.

Strategies for gathering evidence
There may be opportunities in the day-to-day delivery of the Units in a Course to observe learners providing evidence which satisfies completely, or partially a Unit or Units. This is naturally occurring evidence and can be recorded as evidence for an Outcome or parts of an Outcome. In some cases, additional evidence may also be required to supplement and confirm the naturally occurring evidence. Approaches to assessment might cover the whole Unit or be combined across Outcomes. A holistic approach can enrich the assessment process for the learner by bringing together different Outcomes and/or Assessment Standards. If a holistic approach is used then it is necessary to be able to track individual Assessment Standard evidence. Strategies for gathering evidence and ensuring that the learners' work is their own, could include: ♦ personal interviews during which the teacher or lecturer can ask additional questions about completed work ♦ oral presentations on their work ♦ written reports ♦ checklists to record authenticity ♦ supplementary sources of evidence, such as witness testimony, film or audio clips Evidence can be gathered from classwork, experiment, investigations and/or research carried out in this unit. It can be obtained using one or more of the strategies outlined above or by alternative methods which could include a test of knowledge, understanding and skills.

Combining assessment within Units

See *Course Support Notes*.

Equality and inclusion

The *Course Support Notes* provide full information on equality and inclusion for this Unit.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in this document is designed to sit alongside these duties but is specific to the delivery and assessment of the Unit.

Alternative approaches to Unit assessment to take account of the specific needs of learners can be used. However, the centre must be satisfied that the integrity of the assessment is maintained and that the alternative approaches to assessment will, in fact, generate the necessary evidence of achievement.

Appendix 1: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled learners and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- *Building the Curriculum 3: A framework for Learning and Teaching*
- *Building the Curriculum 4: Skills for learning, skills for life and skills for work*
- *Building the Curriculum 5: A framework for assessment*
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment* (June 2008)
- Principles and practice papers for sciences curriculum area
- Science: A Portrait of current practice in Scottish Schools (2008)
- *SCQF Handbook: User Guide* (published 2009) and SCQF level descriptors (to be reviewed during 2011 to 2012): www.sqa.org.uk/sqa/4595.html
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*
- SQA Guidelines on e-assessment for Schools
- SQA Guidelines on Online Assessment for Further Education
- SQA e-assessment web page: www.sqa.org.uk/sqa/5606.html

Administrative information

Published: June 2014 (version 1.0)

History of changes to Unit Support Notes

Unit details	Version	Description of change	Authorised by	Date

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Unit Support Notes

Unit Support Notes — Chemistry in Society (Higher)

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Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Chemistry in Society (Higher) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit is to develop skills of scientific inquiry, investigation, analytical thinking, independent working and knowledge and understanding of chemistry in society.

Learners will apply these skills when considering the applications of chemistry in society on our lives, as well as the implications on society/the environment. This can be done using a variety of approaches, including investigation and problem solving.

The Unit covers the key areas of:

- getting the most from reactants
- equilibria
- chemical energies
- oxidising and reducing agents
- chemical analysis

Learners will research issues, apply scientific skills and communicate information related to their findings, which will develop skills of scientific literacy.

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by the following or equivalent qualifications and/or experience:

- National 5 Chemistry Course

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the Higher Chemistry *Course Support Notes*.

If this Unit is being delivered on a free-standing basis, teachers and lecturers should cover the mandatory skills and key areas in ways which are most appropriate for delivery in their centres.

Progression from this Unit

This Unit may provide progression to:

- other qualifications in Chemistry or related areas
- further study, employment and/or training

Approaches to learning and teaching

Approaches to learning and teaching and suggested learning activities are covered in the *Course Support Notes*.

Bonding and calculations based on the mole and balanced chemical equations are central to chemistry and are visited in Chemical Changes and Structure, Nature's Chemistry and Chemistry in Society.

Learners should be given the opportunity to practise solving problems relating to the mole and balanced equations throughout the Course. By revisiting the mole and chemical equations at different points of the Course, learners consolidate earlier learning and may progressively develop a more in-depth and secure understanding of the mole concept through applying their knowledge in different contexts.

Safety is integral to all practical work and learners should be encouraged to see risk assessment as a natural part of the planning process for any practical activity. Whilst learners would not be expected to produce a full written risk assessment themselves, Outcome 1 provides an opportunity to assess risks and take informed decisions regarding the use of appropriate control measures during the planning stage of the practical experiment or investigation.

Developing skills for learning, skills for life and skills for work

Information about developing skills for learning, skills for life and skills for work in this Unit, is given in the relevant *Course Support Notes*.

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Unit Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on *SQA's Skills Framework: Skills for Learning, Skills for Life* and Skills for Work and must be built into the Unit where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Unit.

Approaches to assessment and gathering evidence

The purpose of this section is to give advice on approaches to assessment for the Unit. There will be other documents produced for centres to provide exemplification of assessments and guidance on how to write them.

Approaches to the assessment of a Unit when it forms part of a Course may differ from approaches to assessing the same Unit when it is not being delivered as part of a Course. If an integrated approach to Course delivery is chosen, then there may be opportunities for combining assessment across Units.

Assessments must be valid, reliable and fit for purpose for the subject and level, and should fit in with learning and teaching approaches.

Unit assessment should support learning and teaching and, where possible, enable personalisation and choice for learners in assessment methods and processes. Teachers and lecturers should select the assessment methods they believe are most appropriate, taking into account the needs of their learners and the requirements of the Unit.

There is no mandatory order for delivery of the Outcomes. These should be overtaken throughout the Unit and are an integral part of learning and teaching.

The table below gives guidance and advice on possible approaches to assessment and gathering evidence.

Strategies for gathering evidence
There may be opportunities in the day-to-day delivery of the Units in a Course to observe learners providing evidence which satisfies completely, or partially a Unit or Units. This is naturally occurring evidence and can be recorded as evidence for an Outcome or parts of an Outcome. In some cases, additional evidence may also be required to supplement and confirm the naturally occurring evidence. Approaches to assessment might cover the whole Unit or be combined across Outcomes. A holistic approach can enrich the assessment process for the learner by bringing together different Outcomes and/or Assessment Standards. If a holistic approach is used then it is necessary to be able to track individual Assessment Standard evidence. Strategies for gathering evidence and ensuring that the learners' work is their own, could include: ♦ personal interviews during which the teacher or lecturer can ask additional questions about completed work ♦ oral presentations on their work ♦ written reports ♦ checklists to record authenticity ♦ supplementary sources of evidence, such as witness testimony, film or audio clips Evidence can be gathered from classwork, experiment, investigations and/or research carried out in this unit. It can be obtained using one or more of the strategies outlined above or by alternative methods which could include a test of knowledge, understanding and skills.

Combining assessment within Units

See *Course Support Notes*.

Equality and inclusion

The *Course Support Notes* provide full information on equality and inclusion for this Unit.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in this document is designed to sit alongside these duties but is specific to the delivery and assessment of the Unit.

Alternative approaches to Unit assessment to take account of the specific needs of learners can be used. However, the centre must be satisfied that the integrity of the assessment is maintained and that the alternative approaches to assessment will, in fact, generate the necessary evidence of achievement.

Appendix 1: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled learners and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- *Building the Curriculum 3: A framework for Learning and Teaching*
- *Building the Curriculum 4: Skills for learning, skills for life and skills for work*
- *Building the Curriculum 5: A framework for assessment*
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment* (June 2008)
- Principles and practice papers for science curriculum area
- Science: A Portrait of current practice in Scottish Schools (2008)
- Research Report 4 — Less is More: Good Practice in Reducing Assessment Time
- Coursework Authenticity — a Guide for Teachers and Lecturers
- *SCQF Handbook: User Guide* (published 2009) and SCQF level descriptors (to be reviewed during 2011 to 2012): www.sqa.org.uk/sqa/4595.html
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Administrative information

Published: June 2014 (version 1.0)

History of changes to Unit Support Notes

Unit details	Version	Description of change	Authorised by	Date

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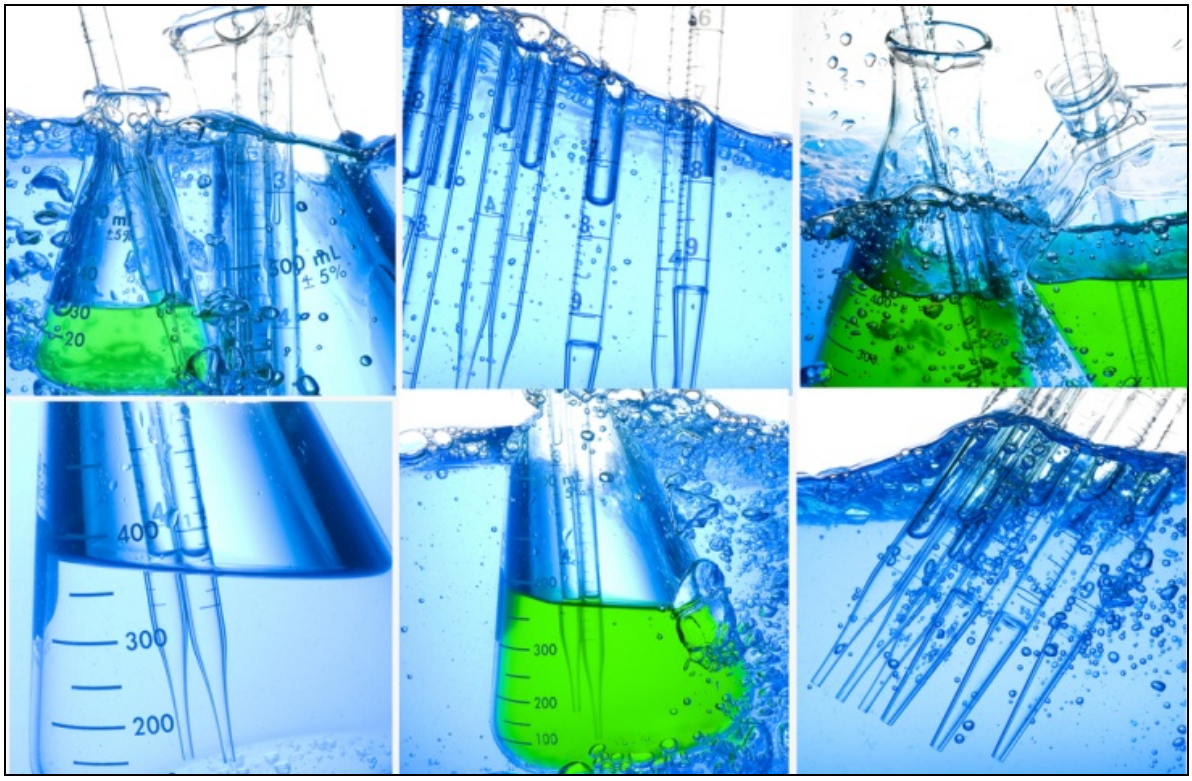
Unit Support Notes

Unit Support Notes — Researching Chemistry (Higher)



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Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Chemistry: Research (Higher) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit is to develop skills of scientific inquiry, investigation and the ability to apply practical skills, chemical theory, analysis, synthesis and thinking skills in order to undertake research in chemistry. Learners will review background information, plan and undertake a practical investigation related to chemistry. They will apply these skills when considering the applications of chemistry as well as implications on society/the environment. Learners will research issues, apply scientific skills and communicate information related to their findings, which will develop skills of scientific literacy.

The Unit offers opportunities for collaborative and independent learning. Learners will develop skills associated with collecting and synthesising information from a number of different sources. Equipped with knowledge of standard laboratory apparatus, they will plan and undertake a practical investigation related to the chemistry involved.

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by the following or equivalent qualifications and/or experience:

- National 5 Chemistry Course

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the Higher Chemistry *Course Support Notes*.

If this Unit is being delivered on a free-standing basis, teachers and lecturers should cover the mandatory skills and key areas in ways which are most appropriate for delivery in their centres.

Progression from this Unit

This Unit may provide progression to:

- other qualifications in Chemistry or related areas
- further study, employment and/or training

Approaches to learning and teaching

Approaches to learning and teaching and suggested learning activities are covered in the *Course Support Notes*.

In this Unit learners will develop the key skills necessary to undertake research in chemistry and demonstrate the relevance of chemical theory to everyday life by exploring the chemistry behind a key area. Learners will develop skills associated with collecting and synthesising information from a number of different sources. Equipped with a knowledge of common chemistry apparatus and techniques they will plan and undertake a practical investigation related to the key area. Learners will prepare a scientific communication presenting the aim, results and conclusions of their practical investigation. The Unit offers opportunities for learners to work in partnership and in teams set within the context of the research topic. This Unit is suitable for learners who are interested in pursuing a career in chemistry, as well as those whose interest is more general.

Exemplar investigation briefs containing focus questions will be provided in the National Assessment Resource and will allow centres to select key areas suited to the available resources and/or the interests of their learners. Centres may wish to develop their own investigation briefs but these must be of a comparable standard.

Outcome 1
Research briefs should allow learners to investigate the chemistry underlying a key area in more depth. The research brief should contain a number of focus questions relating to key points of background information or chemical theory which are likely to be unfamiliar to learners undertaking the Unit. The focus questions should be constructed to give a clear indication of the information required from the learner. The information required to answer the questions must also be readily available using printed resources, video or audio materials, or from websites. Learners must not be provided with extracts from any of these sources compiled by a third party. Prior to undertaking the assessment of Outcome 1, teachers/lecturers should ensure that learners have experience of literature-based research. In particular, if learners are carrying out web-based research, then they should be familiar with issues of reliability and they should be able to clearly state the source of the information they find.

Outcome 2
In order to be able to make informed choices and decisions during the planning stage of the investigation, teachers/lecturers should ensure that learners are familiar with the following practical techniques prior to undertaking the investigation:

- Filtration
- Distillation
- Use of a balance
- Titration
- Methods for the collection of a gas: over water, using a gas syringe
- Safe methods for heating: Bunsen burners, water baths or heating mantles

Learners should have knowledge of the following pieces of general laboratory apparatus:

- Conical flask
- Beaker
- Measuring cylinder
- Delivery tubes
- Dropper
- Test tubes/boiling tubes
- Evaporating basin
- Pipette with safety filler
- Burette
- Volumetric flask
- Funnel
- Thermometer

Learners should take account of the following:

- Representing experimental data using a scatter graph.
- Sketching lines or curves of best fit.
- Calculation of averages (means) for experiments.
- Identification and elimination of rogue points from the analysis of results.
- Qualitative appreciation of the relative accuracy of apparatus used to measure the volume of liquids. Learners would be expected to know that the volume markings on beakers only provide a very rough indication of volume. While measuring cylinders generally provide sufficient accuracy for preparative work, analytic work will normally require the use of burettes, pipettes and volumetric flasks.
- When a measurement has been repeated, learners should appreciate that any variations in the value obtained give an indication of the reproducibility of the technique.
- The uncertainty associated with a measurement can be indicated in the form, measurement ± uncertainty. Learners are not expected to conduct any form of quantitative error analysis.

Teachers/lecturers should note that the external examination for this Course contains questions requiring learners to demonstrate their ability to design and evaluate experimental procedures in addition to questions which test a learner‘s ability to interpret experimental data. The bullet points listed give a clear indication of the likely contexts and data analysis techniques learners may be expected to employ.

The appendix to the Unit Specification provides an example of a record sheet which could be used to record learner success in overtaking the Unit Assessment Standards.

Learners are likely to become familiar with the experimental techniques and basic laboratory apparatus whilst undertaking practical work associated with the other Units of the Higher Chemistry Course. The suggested activities indicated in the learning activities tables provide a rich variety of experimental and investigative experiences which would provide the background knowledge and experience required to allow learners to create appropriate experimental designs.

In order to be able to evaluate the procedures and draw valid conclusions from experimental data, learners should have an opportunity to analyse and discuss experimental data presented in a variety of formats. The Outcome 3 bullet points mentioned in *Guidance on Content and Contexts* provide an indication of the range and depth of experience expected of learners.

Whilst centres are free to deliver this Unit at any point during the Higher Chemistry Course, the suggested activities associated with the other Units of the Course provide ample opportunity for learners to develop the skills required to undertake the activities in this Unit. Many teachers may wish to delay the Unit assessment until the latter stages of the Course in recognition of the considerable exposure to relevant experimental techniques and the development of research skills whilst undertaking the other Higher Chemistry Units.

Classroom management issues will probably dictate that much of the work in this Unit is undertaken through collaborative learning or group work. Working in this way can be extremely beneficial; although consideration needs to be given to ensure that each individual contributes in an appropriate way, and meets the Assessment Standards

For Outcome 1, it is possible for learners to work in groups and for them to allocate focus questions within the group. It is also possible for a group to produce a single report, as long as each individual clearly identifies the focus questions they have answered and the sources that they have used in answering the questions.

For Outcome 2, each candidate must effectively contribute to the planning and carrying out of the investigation. If learners are working as part of a group, it is unlikely that they will take an equal or similar role in the investigation. Teachers/lecturers should exercise professional judgement in deciding if learners have taken an active part in the work.

Safety is integral to all practical work and learners should be encouraged to see risk assessment as a natural part of the planning process for any practical activity. Whilst learners would not be expected to produce a full written risk assessment themselves, Outcome 2 provides an opportunity to assess risks and take informed decisions regarding the use of appropriate control measures during the planning stage of the practical experiment or investigation.
As with all practical investigative work in science, centres must ensure that appropriate risk assessments have been carried out for all practical activities and must comply with current health and safety legislation and regulation.

Developing skills for learning, skills for life and skills for work

Information about developing skills for learning, skills for life and skills for work in this Unit, is given in the relevant *Course Support Notes*.

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Unit Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and*

Skills for Work and must be built into the Unit where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Unit.

Approaches to assessment and gathering evidence

The purpose of this section is to give advice on approaches to assessment for the Unit. There will be other documents produced for centres to provide exemplification of assessments and guidance on how to write them.
Approaches to the assessment of a Unit when it forms part of a Course may differ from approaches to assessing the same Unit when it is not being delivered as part of a Course. If an integrated approach to Course delivery is chosen, then there may be opportunities for combining assessment across Units.
Assessments must be valid, reliable and fit for purpose for the subject and level, and should fit in with learning and teaching approaches.
Unit assessment should support learning and teaching and, where possible, enable personalisation and choice for learners in assessment methods and processes. Teachers and lecturers should select the assessment methods they believe are most appropriate, taking into account the needs of their learners and the requirements of the Unit.
There is no mandatory order for delivery of the Outcomes. These should be overtaken throughout the Unit and are an integral part of learning and teaching.

Outcome 1 is assessed by a written and/or oral report of the learner's review findings. The learner's report should be the result of his/her individual research into one of the focus questions contained in the investigation brief.

- The learner's record should contain an extract or summary of information relevant to a focus question provided in the briefing document.
- The learner's record should mention at least two sources of relevant information. The precise format in which these reference sources are to be recorded is not prescribed and any format that would successfully allow the source to be retrieved by a third party is sufficient.

Outcome 2 requires learners to take an active part in planning, designing and carrying out a practical investigation. Teachers/lecturers may find that observation and discussion with the learners is sufficient to allow them to exercise professional judgement in deciding that each learner has taken an active part in the planning and carrying out the investigation. In practice, the planning cycle is unlikely to be completed in a single stage. Rather, a preliminary plan may need to be modified in the light of initial practical work. In this way, planning and carrying out can be viewed as an iterative cycle in which the strategy for carrying out the investigation is developed as the work is undertaken.

If learners are working as part of a group, it is unlikely that they will take an equal or similar role in the investigation. Teachers/lecturers should exercise professional judgement in deciding if learners have taken an active part in the work.

Combining assessment within Units

See *Course Support Notes*.

Equality and inclusion

The *Course Support Notes* provide full information on equality and inclusion for this Unit.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in this document is designed to sit alongside these duties but is specific to the delivery and assessment of the Unit.

Alternative approaches to Unit assessment to take account of the specific needs of learners can be used. However, the centre must be satisfied that the integrity of the assessment is maintained and that the alternative approaches to assessment will, in fact, generate the necessary evidence of achievement.

Appendix 1: Reference documents

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- *Building the Curriculum 5: A framework for assessment*
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- Principles and practice papers for science curriculum area
- Science: A Portrait of current practice in Scottish Schools (2008)
- Research Report 4 — Less is More: Good Practice in Reducing Assessment Time
- Coursework Authenticity — a Guide for Teachers and Lecturers
- *SCQF Handbook: User Guide (published 2009)* and SCQF level descriptors (to be reviewed during 2011 to 2012): www.sqa.org.uk/sqa/4595.html
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*
- SQA Guidelines on e-assessment for Schools
- SQA Guidelines on Online Assessment for Further Education
- SQA e-assessment web page: www.sqa.org.uk/sqa/5606.html

Appendix 2

Example teacher/lecturer record sheet

This grid may be used to record learners' achievement in the Assessment Standards for each Outcome.

Literature-based research 1.1			**Plan and carry out an investigation**			
Name	Information obtained and recorded	Sources of information recorded	2.1 Contributed to planning	2.2 Contributed to carrying out	2.2 Observations /measurements recorded	2.2 Results recorded correctly

Administrative information

Published: June 2014 (version 2.0)

History of changes to Unit Support Notes

Unit details	Version	Description of change	Authorised by	Date
	2.0	Substantial changes to document. Outcome 3 removed	Qualifications Development Manager	June 2014

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