Higher
Course
Specification

Higher Chemistry

Course code:	C813 76
Course assessment code:	X813 76
SCQF:	level 6 (24 SCQF credit points)
Valid from:	session 2018–19

This document provides detailed information about the course and course assessment to ensure consistent and transparent assessment year on year. It describes the structure of the course and the course assessment in terms of the skills, knowledge and understanding that are assessed.

This document is for teachers and lecturers and contains all the mandatory information you need to deliver the course.

This edition: April 2018 (version 1.0)

Contents

Course overview

The course consists of 24 SCQF credit points which includes time for preparation for course assessment. The notional length of time for candidates to complete the course is 160 hours.

The course assessment has three components.

Component	Marks	Scaled mark	Duration
Question paper 1: multiple choice	25	not applicable	40 minutes
Question paper 2	95	not applicable	2 hours and 20 minutes
Assignment	20	30	8 hours, of which a maximum of 2 hours is allowed for the report stage

Recommended entry	Progression
Entry to this course is at the discretion of the centre. Candidates should have achieved the National 5 Chemistry course or equivalent qualifications and/or experience prior to starting this course.	♦ Advanced Higher Chemistry ♦ other qualifications in chemistry or related areas ♦ further study, employment and/or training

Conditions of award

The grade awarded is based on the total marks achieved across all course assessment components.

Course rationale

National Courses reflect Curriculum for Excellence values, purposes and principles. They offer flexibility, provide time for learning, focus on skills and applying learning, and provide scope for personalisation and choice.

Every course provides opportunities for candidates to develop breadth, challenge and application. The focus and balance of assessment is tailored to each subject area.

This course allows candidates to acquire a deeper understanding of the central concepts of chemistry. Chemists play a vital role in the production of everyday commodities. Chemistry research and development are essential for the introduction of new products. The study of chemistry is of benefit not only to those intending to pursue a career in science, but also to those intending to work in areas such as the food, health or manufacturing industries.

Experimental and investigative approaches develop knowledge and understanding of chemical concepts, with knowledge of chemical apparatus and techniques being a key course component.

Due to the interdisciplinary nature of the sciences, candidates may benefit from studying chemistry along with other science subjects and mathematics, as this may enhance their skills, knowledge and understanding.

Purpose and aims

The course develops candidates' curiosity, interest and enthusiasm for chemistry in a range of contexts. The skills of scientific inquiry and investigation are developed throughout the course.

Candidates develop an appreciation of the impact of chemistry on their everyday lives by applying their knowledge and understanding of chemical concepts in practical situations. The course provides opportunities for candidates to think analytically, creatively and independently, and to make reasoned evaluations. It allows flexibility and personalisation by offering candidates the choice of topic for their assignment.

Candidates gain an understanding of chemical bonding and intermolecular forces that allows them to predict the physical properties of materials. They apply a knowledge of functional groups and organic reaction types to solve problems in a range of diverse contexts.

Candidates also learn important chemical concepts used to take a chemical process from the researcher's bench through to industrial production. The concept of the mole allows the quantities of reagents required to be calculated, and the quantity of products predicted. By studying energy, rates and equilibria, candidates can suggest how reaction conditions can be chosen to maximise the profitability of an industrial process. Candidates learn about industrial analytical chemistry techniques, such as volumetric analysis and chromatography.

Candidates develop a range of skills that are valued in the workplace, providing a secure foundation for the study of chemistry in further and higher education. The course also provides a knowledge base that is useful in the study of other sciences.

The course enables candidates to make their own decisions on issues within a modern society, where scientific knowledge and its applications and implications are constantly developing.

The course aims 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 assessment
- 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

Who is this course for?

The course is suitable for candidates who are secure in their attainment of National 5 Chemistry or an equivalent qualification. It may also be suitable for those wishing to study chemistry for the first time.

The course emphasises practical and experiential learning opportunities, with a strong skills-based approach to learning. It takes account of the needs of all candidates, and provides sufficient flexibility to enable candidates to achieve in different ways.

Course content

The course content includes the following areas of chemistry:

Chemical changes and structure

The topics covered are:

- periodicity
- structure and bonding
- oxidising and reducing agents

Nature's chemistry

The topics covered are:

- systematic carbon chemistry
- alcohols
- carboxylic acids
- esters
- fats and oils
- soaps
- detergents and emulsions
- proteins
- oxidation of food
- fragrances
- skin care

Chemistry in society

The topics covered are:

- getting the most from reactants
- controlling the rate
- chemical energy
- equilibria
- chemical analysis

Researching chemistry

The topics covered are:

- common chemical apparatus
- general practical techniques
- reporting experimental work

Skills, knowledge and understanding

Skills, knowledge and understanding for the course

The following provides a broad overview of the subject skills, knowledge and understanding developed in the course:

- demonstrating knowledge and understanding of chemistry by making accurate statements
- demonstrating knowledge and understanding of chemistry by describing information, providing explanations and integrating knowledge
- applying knowledge of chemistry to new situations, analysing information and solving problems
- planning, designing and safely carrying out experiments/practical investigations to test given hypotheses or to illustrate particular effects
- carrying out experiments/practical investigation safely, recording detailed observations and collecting data
- selecting information from a variety of sources
- presenting information appropriately in a variety of forms
- processing information (using calculations and units, where appropriate)
- making predictions and generalisations from evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- evaluating experiments/practical investigations and suggesting improvements
- communicating findings/information effectively

Skills, knowledge and understanding for the course assessment

The following provides details of skills, knowledge and understanding sampled in the course assessment:

1 Chemical changes and structure

(a) Periodicity

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. Features of the table are:

- groups: vertical columns within the table contain elements with similar chemical properties resulting from a common number of electrons in the outer shell
- periods: rows of elements arranged with increasing atomic number, demonstrating an increasing number of outer electrons and a move from metallic to non-metallic characteristics

The first 20 elements in the periodic table are 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)

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 first ionisation energy is the energy required to remove one mole of electrons from one mole of gaseous atoms. The second and subsequent ionisation energies refer to the energies required to remove further moles of electrons.

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.

The trends in electronegativity across periods and down groups can be rationalised in terms of covalent radius, nuclear charge and the screening effect due to inner shell electrons.

1 Chemical changes and structure

(b) Structure and bonding

(i) Types of chemical bond

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 (δ^+) and delta negative (δ^-) notation can be used to indicate the partial charges on atoms, which give rise to a dipole.

Ionic formulae can be written giving the simplest ratio of each type of ion in the substance. Ionic bonds are the electrostatic attraction between positive and negative ions. Ionic compounds form lattice structures of oppositely charged ions.

Pure covalent bonding and ionic bonding can be considered as opposite ends of a bonding continuum, with polar covalent bonding lying between these two extremes. The difference in electronegativities between bonded atoms gives an indication of the ionic character. The larger the difference, 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. Physical properties of a compound, such as its state at room temperature, melting point, boiling point, solubility, electrical conductivity, should be used to deduce the type of bonding and structure in the compound.

(ii) Intermolecular forces

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.

Intermolecular forces acting between molecules are known as van der Waals forces. There are several different types of these, such as London dispersion forces and permanent dipole-permanent dipole interactions that 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.

1 Chemical changes and structure

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 fluorine, oxygen or nitrogen are highly polar. Hydrogen bonds are electrostatic forces of attraction between molecules that 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 that 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.

Boiling points, melting points, viscosity and solubility/miscibility in water are properties of substances that are affected by hydrogen bonding.

The anomalous boiling points of ammonia, water and hydrogen fluoride are a result of hydrogen bonding.

Hydrogen bonding between molecules in ice results in an expanded structure that causes the density of ice to be less than that of water at low temperatures.

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.

To predict the solubility of a compound, key features to be considered are the:

- presence in molecules of O-H or N-H bonds, which implies hydrogen bonding
- spatial arrangement of polar covalent bonds, which could result in a molecule possessing a permanent dipole

1 Chemical changes and structure

(c) Oxidising and reducing agents

Reduction is a gain of electrons by a reactant in any reaction.

Oxidation is a loss of electrons by a reactant in any reaction.

In a redox reaction, reduction and oxidation take place at the same time.

An oxidising agent is a substance that accepts electrons.

A reducing agent is a substance that donates electrons.

Oxidising and reducing agents can be identified in redox reactions.

Elements with low electronegativities tend to form ions by losing electrons and so act as reducing agents.

Elements with high electronegativities tend to form ions by gaining electrons and so act as oxidising agents.

In the periodic table, the strongest reducing agents are in group 1, and the strongest oxidising agents are in group 7.

Compounds, group ions and molecules can act as oxidising or reducing agents:

- hydrogen peroxide is a molecule that is an oxidising agent
- dichromate and permanganate ions are group ions that are strong oxidising agents in acidic solutions
- carbon monoxide is a gas that can be used as a reducing agent

Oxidising agents are widely used 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.

The electrochemical series represents a series of reduction reactions.

The strongest oxidising agents are at the bottom of the left-hand column of the electrochemical series.

The strongest reducing agents are at the top of the right-hand column of the electrochemical series.

An ion-electron equation can be balanced by adding appropriate numbers of water molecules, hydrogen ions and electrons.

Ion-electron equations can be combined to produce redox equations.

2 Nature's chemistry

(a) Systematic carbon chemistry

Compounds containing only single carbon–carbon bonds are described as saturated.

Compounds containing at least one carbon–carbon double bond are described as unsaturated. Compounds containing carbon–carbon double bonds can take part in addition reactions. In an addition reaction, two molecules combine to form a single molecule.

It is possible to distinguish an unsaturated compound from a saturated compound using bromine solution. Unsaturated compounds quickly decolourise bromine solution.

The structure of any molecule can be drawn as a full or a shortened structural formula.

Isomers:

- are compounds with the same molecular formula but different structural formulae
- may belong to different homologous series
- usually have different physical properties

Given the name or a structural formula for a compound, an isomer can be drawn. Isomers can be drawn for a given molecular formula.

The solubility, boiling point and volatility (ease of evaporation) of a compound can be predicted by considering:

- the presence of O-H or N-H bonds, which implies hydrogen bonding
- the spatial arrangement of polar covalent bonds which could result in a molecule possessing a permanent dipole
- molecular size which would affect London dispersion forces
- the polarities of solute and solvent. Polar or ionic compounds tend to be soluble in polar solvents, non-polar compounds tend to be soluble in non-polar solvents

Solubility, boiling point and volatility can be explained in terms of the type and strength of intermolecular forces present.

(b) Alcohols

An alcohol is a molecule containing a hydroxyl functional group, –OH group.

Straight-chain and branched alcohols can be systematically named, indicating the position of the hydroxyl group from structural formulae containing no more than eight carbon atoms in their longest chain.

A molecular formula can be written or a structural formula drawn from the systematic name of a straight-chain or branched alcohol that contains no more than eight carbon atoms in its longest chain.

Alcohols can be classified as primary, secondary or tertiary.

2 Nature's chemistry

Alcohols containing two hydroxyl groups are called diols, and those containing three hydroxyl groups are called triols.

Hydroxyl groups make alcohols polar and this gives rise to hydrogen bonding. Hydrogen bonding can be used to explain the properties of alcohols, including boiling points, melting points, viscosity and solubility/miscibility in water.

(c) Carboxylic acids

A carboxylic acid is a molecule containing the carboxyl functional group, –COOH.

Straight-chain and branched carboxylic acids can be systematically named from structural formulae containing no more than eight carbons in the longest chain.

A molecular formula can be written or a structural formula drawn from the systematic name of a straight-chain or branched-chain carboxylic acid that contains no more than eight carbon atoms in its longest chain.

Carboxylic acids can react with bases:

a metal oxide + a carboxylic acid	→	a salt + water
a metal hydroxide + a carboxylic acid	→	a salt + water
a metal carbonate + a carboxylic acid	→	a salt + water + carbon dioxide

The name of the salt produced depends on the acid and base used.

(d) Esters, fats and oils

An ester is a molecule containing an ester link: –COO–.

Esters can be named given the:

- names of their parent alcohol and carboxylic acid
- structural formulae of esters formed from primary, straight-chain alcohols containing no more than eight carbons and straight-chain carboxylic acids containing no more than eight carbons

Molecular formulae can be written and structural formulae drawn for esters given the:

- systematic names of esters formed from primary, straight-chain alcohols containing no more than eight carbons and straight-chain carboxylic acids containing no more than eight carbons
- structural formulae of their parent alcohol and carboxylic acid

Esters are used as flavourings and fragrances as many have pleasant, fruity smells. Esters are also used as solvents for non-polar compounds that do not dissolve in water.

2 Nature's chemistry

Esters are formed by a condensation reaction between an alcohol and a carboxylic acid.

In a condensation reaction, two molecules are joined together with the elimination of a small molecule.

When an ester link is formed by the reaction between a hydroxyl group and a carboxyl group, the small molecule eliminated is water.

Esters can be hydrolysed to produce an alcohol and a carboxylic acid.

In a hydrolysis reaction, a molecule reacts with water to break down into smaller molecules.

The products of the hydrolysis of an ester can be named given the:

- name of the ester
- structural formula of an ester formed from a straight-chain or branched alcohol and a straight-chain or branched carboxylic acid, each containing no more than eight carbons in their longest chain

Molecular formulae can be written and structural formulae can be drawn for the products of the hydrolysis of an ester given the:

- systematic names of esters formed from primary, straight-chain alcohols containing no more than eight carbons and straight-chain carboxylic acids containing no more than eight carbons
- structural formula of the ester

Edible fats and edible 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 can be saturated or unsaturated straight-chain carboxylic acids, usually with long chains of carbon atoms.

Edible oils have lower melting points than edible fats.

Double bonds in fatty acid chains prevent oil molecules from packing closely together, so the greater the number of double bonds present, the weaker the van der Waals forces of attraction. The greater the degree of unsaturation, the lower the melting point.

Unsaturated compounds quickly decolourise bromine solution.

The bromine molecules add across the carbon–carbon double bonds in an addition reaction. The greater the number of double bonds present in a substance, the more bromine solution can be decolourised.

2 Nature's chemistry

Fats and oils are:

- a concentrated source of energy
- essential for the transport and storage of fat-soluble vitamins in the body

(e) Soaps, detergents and emulsions

Soaps are produced by the alkaline hydrolysis of edible fats and edible oils. Hydrolysis produces three fatty acid molecules and one glycerol molecule. The fatty acid molecules are neutralised by the alkali, forming water-soluble, ionic salts called soaps.

Soaps can be used to remove non-polar substances such as oil and grease. Soap ions have long non-polar tails, readily soluble in non-polar compounds (hydrophobic), and ionic heads that are water soluble (hydrophilic). The hydrophobic tails dissolve in the oil or grease. The negatively-charged hydrophilic heads remain in the surrounding water. Agitation causes ball-like structures to form. The negatively-charged ball-like structures repel each other and the oil or grease is kept suspended in the water.

Hard water is a term used to describe water containing high levels of dissolved metal ions. When soap is used in hard water, scum, an insoluble precipitate, is formed.

Soapless detergents are substances with non-polar hydrophobic tails and ionic hydrophilic heads. These remove oil and grease in the same way as soap. Soapless detergents do not form scum with hard water.

An emulsifier can be used to prevent non-polar and polar liquids separating into layers.

An emulsion contains small droplets of one liquid dispersed in another liquid.

Emulsifiers for use in food can be made by reacting edible oils with glycerol. In the molecules formed, only one or two fatty acid groups are linked to each glycerol backbone. The hydroxyl groups present in the emulsifier are hydrophilic whilst the fatty acid chains are hydrophobic. The hydrophobic fatty acid chains dissolve in oil whilst the hydrophilic hydroxyl groups dissolve in water, forming a stable emulsion.

2 Nature's chemistry

(f) Proteins

Proteins are the major structural materials of animal tissue and are also involved in the maintenance and regulation of life processes. Enzymes are proteins which act as biological catalysts.

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.

Proteins are made of many amino acid molecules linked together by condensation reactions. In these reactions, the amino group of one amino acid and the carboxyl group of another amino acid join, with the elimination of water.

The link which forms between two amino acids is known as a peptide link, —CONH—, or also as an amide link.

Proteins which fulfil different roles in the body are formed by linking together differing sequences of amino acids.

The body cannot make all of the amino acids required for protein synthesis and certain amino acids, known as essential amino acids, must be acquired from the diet.

During digestion, enzyme hydrolysis of protein produces amino acids.

The structural formulae of amino acids obtained from the hydrolysis of a protein can be drawn given the structure of a section of the protein.

The structural formula of a section of protein can be drawn given the structural formulae of the amino acids from which it is formed.

Within proteins, the long-chain molecules form spirals, sheets, or 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, these intermolecular bonds are broken, allowing the proteins to change shape (denature). The denaturing of proteins in foods causes the texture to change when it is cooked.

(g) Oxidation of food

For carbon compounds:

- oxidation is an increase in the oxygen to hydrogen ratio
- reduction is a decrease in the oxygen to hydrogen ratio

2 Nature's chemistry

Hot copper(II) oxide or acidified dichromate(VI) solutions can be used to oxidise:

- primary alcohols to aldehydes and then to carboxylic acids
- secondary alcohols to ketones

During these reactions black copper(II) oxide forms a brown solid, and orange dichromate solution turns green.

Tertiary alcohols cannot be oxidised using these oxidising agents.

Aldehydes and ketones are molecules containing a carbonyl functional group $\rangle C{=}O$.
Straight-chain and branched aldehydes and ketones can be systematically named from structural formulae containing no more than eight carbons in the longest chain.

Molecular formulae can be written and structural formulae drawn, from the systematic names of straight-chain and branched aldehydes and ketones, containing no more than eight carbons in the longest chain.

Aldehydes, but not ketones, can be oxidised to carboxylic acids. Oxidising agents can be used to differentiate between an aldehyde and a ketone. With an aldehyde:

- blue Fehling's solution forms a brick red precipitate
- clear, colourless Tollens' reagent forms a silver mirror
- orange acidified dichromate solution turns green

Many flavour and aroma molecules are aldehydes.

Oxygen from the air causes the oxidation of food. The oxidation of edible oils gives food a rancid flavour.

Antioxidants:

- are molecules that prevent unwanted oxidation reactions occurring
- are substances that are easily oxidised, and oxidise in place of the compounds they have been added to protect
- can be identified as the substance being oxidised in a redox equation

(h) Fragrances

Essential oils are concentrated extracts of the volatile, non-water soluble aroma compounds from plants. They are mixtures of many different compounds. They are widely used in perfumes, cosmetic products, cleaning products and as flavourings in foods.

Terpenes are key components in most essential oils. They are unsaturated compounds formed by joining together isoprene (2-methylbuta-1,3-diene) units.

2 Nature's chemistry

Terpenes can be oxidised within plants to produce some of the compounds responsible for the distinctive aromas of spices.

Given the structural formula for a terpene-based molecule:

- an isoprene unit can be identified within the molecule
- the number of isoprene units joined together within the molecule can be stated

(i) Skin care

Ultraviolet (UV) radiation is a high-energy form of light, present in sunlight. UV light can provide sufficient energy to break bonds within molecules. This causes sunburn and accelerates ageing of the skin. Sun-block products prevent UV light reaching the skin.

When UV light breaks bonds, free radicals are formed. Free radicals are atoms or molecules that are highly reactive due to the presence of unpaired electrons.

Free radical chain reactions include the following steps: initiation, propagation and termination.

Equations can be written for reactions involving free radicals.

An equation involving free radicals can be recognised as representing an initiation, propagation or termination step.

Free radical scavengers are molecules that react with free radicals to form stable molecules and prevent chain reactions from occurring. Free radical scavengers are added to many products including cosmetics, food products and plastics.

3 Chemistry in society

(a) Getting the most from reactants

Industrial processes are designed to maximise profit and minimise the impact on the environment.

Factors influencing industrial 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

Chemical equations, using formulae and state symbols, can be written and balanced to show the mole ratio(s) of reactants and products.

The mass of a mole of any substance, in grams (g), is equal to the gram formula mass and can be calculated using relative atomic masses.

Calculations can be performed using the relationship between the mass and the number of moles of a substance.

For solutions, the mass of solute (grams or g), the number of moles of solute (moles or mol), the volume of solution (litres or l), or the concentration of the solution (moles per litre or mol l^{-1}), can be calculated from data provided.

The molar volume (litres mol^{-1}) is the volume occupied by one mole of any gas at a certain temperature and pressure. The molar volume is the same for all gases at the same temperature and pressure.

Calculations can be performed using the relationship between the volume of gas, molar volume and the number of moles of a substance.

3 Chemistry in society

Calculations can be performed given a balanced equation using data including:

- gram formula masses (GFM)
- masses
- numbers of moles
- concentrations and/or volumes of solutions
- molar volumes
- volumes for gases

The efficiency with which reactants are converted into the desired product is measured in terms of the percentage yield and atom economy.

By considering a balanced equation, the limiting reactant and the reactant(s) in excess can be identified by calculation.

In order to ensure that a costly reactant is converted into product, an excess of the less expensive reactant(s) can be used.

The 'theoretical yield' is the quantity of desired product obtained, assuming full conversion of the limiting reagent, as calculated from the balanced equation.

The 'actual yield' is the quantity of the desired product formed under the prevailing reaction conditions.

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.

The percentage yield can be calculated using the equation:

$$\%\ \text{yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Using a balanced equation, calculations involving percentage yield can be performed from data provided.

Given costs for the reactants, a percentage yield can be used to calculate the cost of reactant(s) required to produce a given mass of product.

3 Chemistry in society

The atom economy measures the proportion of the total mass of all starting materials converted into the desired product in the balanced equation.

The percentage atom economy can be calculated using the equation:

$$\%\ \text{atom economy} = \frac{\text{Mass of desired product}}{\text{Total mass of reactants}} \times 100$$

Reactions which have a high percentage yield may have a low atom economy value if large quantities of by-products are formed.

(b) Controlling the rate

(i) Collision theory

Reaction rates must be controlled in industrial processes. If the rate is too low then the process will not be economically viable; if it is too high there will be a risk of explosion.

Calculations can be performed using the relationship between reaction time and relative rate with appropriate units.

Collision theory can be used to explain the effects of the following on reaction rates:

- concentration
- pressure
- surface area (particle size)
- temperature
- collision geometry

(ii) Reaction pathways

A potential energy diagram can be used to show the energy pathway for a reaction.
The enthalpy change is the energy difference between the products and the reactants. The enthalpy change has a negative value for exothermic reactions or a positive value for endothermic reactions.

The activation energy is the minimum energy required by colliding particles to form an activated complex and can be calculated from potential energy diagrams. The activated complex is an unstable arrangement of atoms formed at the maximum of the potential energy barrier, during a reaction.

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.

3 Chemistry in society

(iii) Kinetic energy distribution

Temperature is a measure of the average kinetic energy of the particles in a substance.

The activation energy is the minimum kinetic energy required by colliding particles before a reaction may occur.

Energy distribution diagrams can be used to explain the effect of changing temperature on the kinetic energy of particles and reaction rate.

The effects of temperature and of adding a catalyst can be explained in terms of a change in the number of particles with energy greater than the activation energy.

(c) Chemical energy

Enthalpy is a measure of the chemical energy in a substance.

A reaction or process that releases heat energy is described as exothermic. In industry, exothermic reactions may require heat to be removed to prevent the temperature rising.

A reaction or process that takes in heat energy is described as endothermic. In industry, endothermic reactions may incur costs in supplying heat energy in order to maintain the reaction rate.

The enthalpy change associated with a reaction can be calculated from the quantity of heat energy released.

The quantity of heat energy released can be determined experimentally and calculated using $E_h = cm\Delta T$.

The quantities E_h, c, m or ΔT can be calculated, in the correct units, given relevant data.

The enthalpy of combustion of a substance is the enthalpy change when one mole of the substance burns completely in oxygen.

Hess's law states that the enthalpy change for a chemical reaction is independent of the route taken. The enthalpy change for a reaction can be calculated using Hess's law, given appropriate data.

The molar bond enthalpy is the energy required to break one mole of bonds in a diatomic molecule. A mean molar bond enthalpy is the average energy required to break one mole of bonds, for a bond that occurs in a number of compounds.

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.

3 Chemistry in society

(d) Equilibria

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 move the position of equilibrium in favour of the products.

For a given reversible reaction, the effect of altering temperature or pressure or of adding/removing reactants/products can be predicted.

The addition of a catalyst increases the rates of the forward and reverse reactions equally. The catalyst increases the rate at which equilibrium is achieved but does not affect the position of equilibrium.

(e) Chemical analysis

(i) Chromatography

Chromatography is a technique used to separate the components present within a mixture. Chromatography separates substances by making use of differences in their polarity or molecular size.

The details of any specific chromatographic method or experiment are not required. Depending on the type of chromatography used, 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 of the x-axis.

3 Chemistry in society

(ii) Volumetric analysis

Volumetric analysis involves using a solution of accurately known concentration in a quantitative reaction to determine the concentration of another substance.

Titration is used to determine, accurately, the volumes of solution required to reach the end-point of a chemical reaction. An indicator is normally used to show when the end-point is reached. Titre volumes within 0·2 cm^3 are considered concordant.

Solutions of accurately known concentration are known as standard solutions.

Redox titrations are based on redox reactions. In titrations using acidified permanganate, an indicator is not required, as purple permanganate solution turns colourless when reduced.

Given a balanced equation for the reaction occurring in any titration, the:

- concentration of one reactant can be calculated given the concentration of the other reactant and the volumes of both solutions
- volume of one reactant can be calculated given the volume of the other reactant and the concentrations of both solutions

4 Researching chemistry

(a) Common chemical apparatus

Candidates must be familiar with the use(s) of the following types of apparatus:

- conical flask
- beaker
- measuring cylinder
- delivery tube
- dropper
- test tubes/boiling tubes
- funnel
- filter paper
- evaporating basin
- pipette with safety filler
- burette
- volumetric flask
- distillation flask
- condenser
- thermometer

Labelled, sectional diagrams can be drawn for common chemical apparatus.

4 Researching chemistry

(b) General practical techniques

Candidates must be familiar with the following techniques:

- simple filtration using filter paper and a funnel to separate the residue from the filtrate
- use of a balance, including measuring mass by difference
- methods for the collection of gases including:
  - collection over water (for relatively insoluble gases, or where a dry sample of gas is not required)
  - collection using a gas syringe (for soluble gases or where a dry sample of gas is required)
- safe methods for heating using Bunsen burners, water baths or heating mantles
- determining enthalpy changes using E_h
- volumetric analysis:
  - the volume markings on beakers provide only a rough indication of volume
  - measuring cylinders generally provide sufficient accuracy for preparative work, but for analytical work, burettes, pipettes and volumetric flasks are more appropriate
  - titration is used to accurately determine the volumes of solution required to reach the end-point of a chemical reaction
- preparation of a standard solution
- simple distillation using a flask, condenser and suitable heat source to separate a mixture of liquids with different boiling points

Given a description of an experimental procedure and/or experimental results, an improvement to the experimental method can be suggested and justified.

4 Researching chemistry

(c) Reporting experimental work

Candidates must be able to process experimental results by:

- tabulating data using appropriate headings and units of measurement
- representing data as a scatter graph with suitable scales and labels
- sketching a line of best fit (straight or curved) to represent the trend observed in the data
- calculating average (mean) values
- identifying and eliminating rogue points
- commenting on the reproducibility of results where measurements have been repeated

The uncertainty associated with a measurement can be indicated in the form: measurement ± uncertainty.

Candidates are **not** expected to:

- be able to state uncertainty values associated with any type of apparatus
- calculate uncertainties
- conduct any form of quantitative error analysis

Skills, knowledge and understanding included in the course are appropriate to the SCQF level of the course. The SCQF level descriptors give further information on characteristics and expected performance at each SCQF level, and can be found on the SCQF website.

Skills for learning, skills for life and skills for work

This course helps candidates to develop broad, generic skills. These skills are based on SQA's Skills Framework: Skills for Learning, Skills for Life and Skills for Work and draw from the following main skills areas:

1 Literacy

1.2 Writing

2 Numeracy

2.1 Number processes
2.2 Money, time and measurement
2.3 Information handling

5 Thinking skills

5.3 Applying
5.4 Analysing and evaluating
5.5 Creating

Teachers and/or lecturers must build these skills into the course at an appropriate level, where there are suitable opportunities.

Course assessment

Course assessment is based on the information provided in this document.

The course assessment meets the key purposes and aims of the course by addressing:

- breadth — drawing on knowledge and skills from across the course
- challenge — requiring greater depth or extension of knowledge and/or skills
- application — requiring application of knowledge and/or skills in practical or theoretical contexts as appropriate

This enables candidates to apply:

- breadth and depth of skills, knowledge and understanding from across the course to answer questions in chemistry
- skills of scientific inquiry, using related knowledge, to carry out a meaningful and appropriately challenging investigation in chemistry and communicate findings

The course assessment has three components: two question papers and an assignment. The relationship between these three components is complementary, to ensure full coverage of the knowledge and skills of the course.

Course assessment structure: question papers

Question paper 1: multiple choice 25 marks

Question paper 2 95 marks

The question papers have a total mark allocation of 120 marks. This is 80% of the overall marks for the course assessment.

The majority of marks are awarded for demonstrating and applying knowledge and understanding. The other marks are awarded for applying scientific inquiry and analytical thinking skills.

The question papers assess breadth, challenge and application of skills, knowledge and understanding from across the course. They assess scientific inquiry skills and analytical thinking skills.

The question papers give candidates an opportunity to demonstrate the following skills, knowledge and understanding:

- making accurate statements
- describing information, providing explanations and integrating knowledge
- applying knowledge of chemistry to new situations, analysing information and solving problems
- planning, designing and safely carrying out experiments/practical investigations to test given hypotheses or to illustrate particular effects

- selecting information from a variety of sources
- presenting information appropriately in a variety of forms
- processing information (using calculations and units, where appropriate)
- making predictions and generalisations from evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- evaluating experiments and suggesting improvements

A data booklet containing relevant data and formulae is provided.

Question paper 1: multiple choice

Question paper 1 contains multiple-choice questions.

Question paper 2

Question paper 2 contains restricted-response and extended-response questions.

Setting, conducting and marking the question papers

The question papers are set and marked by SQA, and conducted in centres under conditions specified for external examinations by SQA.

Candidates have 40 minutes to complete question paper 1.

Candidates have 2 hours and 20 minutes to complete question paper 2.

Specimen question papers for Higher courses are published on SQA's website. These illustrate the standard, structure and requirements of the question papers candidates sit. The specimen papers also include marking instructions.

Course assessment structure: assignment

Assignment 20 marks

The assignment has a total mark allocation of 20 marks. This is scaled to 30 marks by SQA to represent 20% of the overall marks for the course assessment.

The assignment assesses the application of skills of scientific inquiry and related chemistry knowledge and understanding.

It allows assessment of skills that cannot be assessed by a question paper, for example handling and processing data gathered through experimental and research skills.

Assignment overview

The assignment gives candidates an opportunity to demonstrate the following skills, knowledge and understanding:

- applying knowledge of chemistry to new situations, interpreting information and solving problems
- planning, designing and safely carrying out experiments/practical investigations to test given hypotheses or to illustrate particular effects
- selecting information from a variety of sources
- presenting information appropriately in a variety of forms
- processing the information (using calculations and units, where appropriate)
- making predictions and generalisations based on evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- evaluating experiments/practical investigations and suggesting improvements
- communicating findings/information effectively

The assignment offers challenge by requiring candidates to apply skills, knowledge and understanding in a context that is one or more of the following:

- unfamiliar
- familiar but investigated in greater depth
- integrating a number of familiar contexts

Candidates research and report on a topic that allows them to apply skills and knowledge in chemistry at a level appropriate to Higher.

The topic must be chosen with guidance from teachers and/or lecturers and must involve experimental work.

The assignment has two stages:

- research
- report

The research stage must involve experimental work which allows measurements to be made. Candidates must also gather data/information from the internet, books or journals.

Candidates must produce a report on their research.

Setting, conducting and marking the assignment

Setting

The assignment is:

- set by centres within SQA guidelines
- set at a time appropriate to the candidate's needs
- set within teaching and learning and includes experimental work at a level appropriate to Higher

Conducting

The assignment is:

- an individually produced piece of work from each candidate
- started at an appropriate point in the course
- conducted under controlled conditions

Marking

The assignment has a total of 20 marks. The table gives details of the mark allocation for each section of the report.

Section	Expected response	Marks
Aim	An aim that describes clearly the purpose of the investigation.	1
Underlying chemistry	An account of chemistry relevant to the aim of the investigation.	3
Data collection and handling	A brief summary of the approach used to collect experimental data.	1
	Sufficient raw data from the candidate's experiment.	1
	Data presented in correctly produced table(s) and correct units shown for calculated values.	1
	Values calculated correctly using a chemical relationship	1
	Data relevant to the experiment obtained from an internet/literature source.	1
	A citation and reference for a source of the internet/literature data.	1
Graphical presentation	An appropriate format from the options of scatter graph, line graph or bar graph.	1
	The axis/axes of the graph has/have suitable scale(s).	1
	The axes of the graph have suitable labels and units.	1
	Accurately plotted data points and, where appropriate, a line of best fit.	1
Analysis	A valid comparison of the experimental data with data from the internet/literature source.	1
Conclusion	A valid conclusion that relates to the aim and is supported by all the data in the report.	1
Evaluation	Evaluation of the investigation	3
Structure	A clear and concise report with an informative title.	1
TOTAL		**20**

The report is submitted to SQA for external marking.

All marking is quality assured by SQA.

Assessment conditions

Controlled assessment is designed to:

- ensure that all candidates spend approximately the same amount of time on their assignments
- prevent third parties from providing inappropriate levels of guidance and input
- mitigate concerns about plagiarism and improve the reliability and validity of SQA awards
- allow centres a reasonable degree of freedom and control
- allow candidates to produce an original piece of work

Detailed conditions for assessment are given in the assignment assessment task.

Time

It is recommended that no more than 8 hours is spent on the **whole** assignment. A maximum of 2 hours is allowed for the report stage.

Supervision, control and authentication

There are two levels of control.

Under a high degree of supervision and control	Under some supervision and control
♦ the use of resources is tightly prescribed ♦ all candidates are within direct sight of the supervisor throughout the session(s) ♦ display materials which might provide assistance are removed or covered ♦ there is no access to e-mail, the internet or mobile phones ♦ candidates complete their work independently ♦ interaction with other candidates does not occur ♦ no assistance of any description is provided	♦ candidates do not need to be directly supervised at all times ♦ the use of resources, including the internet, is not tightly prescribed ♦ the work an individual candidate submits for assessment is their own ♦ teachers and/or lecturers can provide reasonable assistance

The assignment has two stages.

Stage	Level of control
♦ research	conducted under some supervision and control
♦ report	conducted under a high degree of supervision and control

Resources

Please refer to the instructions for teachers and lecturers within the assignment assessment task.

It is not permitted at any stage to provide candidates with a template or model answers.

In the research stage:

- teachers and/or lecturers must agree the choice of topic with the candidate
- teachers and/or lecturers must provide advice on the suitability of the candidate's aim
- teachers and/or lecturers can supply instructions for the experimental procedure
- candidates must undertake research using websites, journals and/or books
- a wide list of URLs and/or a wide range of books and journals may be provided

Teachers and/or lecturers must not:

- provide an aim
- provide candidates with experimental data
- provide candidates with a blank or pre-populated table for experimental results
- provide candidates with feedback on their research

The only materials which can be used in the report stage are:

- the instructions for candidates, which must not have been altered
- the candidate's raw experimental data
- data/information taken from the internet or literature
- a record of the source(s) of internet or literature data/information
- extract(s) from the internet/literature sources to support the underlying chemistry
- the experimental method, if appropriate

Candidates must not have access to a previously prepared:

- draft of a report
- draft of a description of the underlying chemistry
- specimen calculation or set of calculations for mean or derived values
- specimen calculation or set of calculations for values calculated using a chemical relationship
- graph
- comparison of data
- conclusion
- evaluation

In addition, candidates must not have access to the assignment marking instructions during the report stage.

Candidates must not have access to the internet during the report stage.

Teachers and/or lecturers must not provide any form of feedback to a candidate on their report.

Following completion of the report stage candidates must not be given an opportunity to redraft their report.

Teachers and/or lecturers must not read the reports before they are submitted to SQA.

Reasonable assistance

The term 'reasonable assistance' is used to describe the balance between supporting candidates and giving them too much assistance. Candidates must undertake the assessment independently. However, reasonable assistance may be provided before the formal assessment process (research stage and report stage) takes place. If candidates have been entered for the correct level of qualification, they will not require more than a reasonable level of assistance to carry out the assignment.

Evidence to be gathered

The following candidate evidence is required for this assessment:

- a report

The report is submitted to SQA, within a given timeframe, for marking.

The same report cannot be submitted for more than one subject.

Volume

There is no word count.

Grading

Candidates' overall grades are determined by their performance across the course assessment. The course assessment is graded A–D on the basis of the total mark for all course assessment components.

Grade description for C

For the award of grade C, candidates will typically have demonstrated successful performance in relation to the skills, knowledge and understanding for the course.

Grade description for A

For the award of grade A, candidates will typically have demonstrated a consistently high level of performance in relation to the skills, knowledge and understanding for the course.

Equality and inclusion

This course is designed to be as fair and as accessible as possible with no unnecessary barriers to learning or assessment.

For guidance on assessment arrangements for disabled candidates and/or those with additional support needs, please follow the link to the assessment arrangements web page: www.sqa.org.uk/assessmentarrangements.

Further information

The following reference documents provide useful information and background.

- Higher Chemistry subject page
- Assessment arrangements web page
- Building the Curriculum 3–5
- Guide to Assessment
- Guidance on conditions of assessment for coursework
- SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work
- Coursework Authenticity: A Guide for Teachers and Lecturers
- Educational Research Reports
- SQA Guidelines on e-assessment for Schools
- SQA e-assessment web page

The SCQF framework, level descriptors and handbook are available on the SCQF website.

Administrative information

Published: April 2018 (version 1.0)

History of changes

Version	Description of change	Date

Note: you are advised to check SQA's website to ensure you are using the most up-to-date version of this document.