OCR
RECOGNISING ACHIEVEMENT

AS/A Level GCE

GCE Chemistry A

OCR Advanced Subsidiary GCE in Chemistry A H034

OCR Advanced GCE in Chemistry A H434

Vertical black lines indicate a significant change to the previous printed version.

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specification

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1 About these Qualifications

This booklet contains OCR's Advanced Subsidiary (AS) GCE and Advanced GCE specifications in Chemistry A for teaching from September 2008.

This specification allows teachers to adopt a flexible approach to the delivery of AS and A Level Chemistry. The course has been designed to enable centres to deliver the designated units (F321–F326) using the framework provided or to design a customised course. This flexible approach is also reflected in the assessment model. All units apart from Unit F323 and Unit F326 are available in both January and June. In both AS and A2, one unit is deliberately shorter, allowing the realistic possibility of using the January assessment series. Thus centres can adopt either a staged or terminal assessment model. There is also a choice of assessed practical tasks available to all centres.

The specification is divided into chemical topics, each containing different key concepts of chemistry. Once the key features of a chemical topic have been developed, applications are considered. For assessment purposes, knowledge and understanding of key concepts are treated separately at AS; important links between different areas of chemistry are largely assessed synoptically at A2. While the teaching of practical skills may be integrated with the theoretical topics, they are assessed separately. This allows skills to be developed in a way suited to each individual centre.

This specification incorporates the QCA Subject Criteria for Chemistry.

1.1 The Three-Unit AS

The AS GCE is both a 'stand-alone' qualification and also the first half of the corresponding Advanced GCE. The AS GCE is assessed at a standard appropriate for candidates who have completed the first year of study (both in terms of teaching time and content) of the corresponding two-year Advanced GCE course, ie between GCSE and Advanced GCE.

From September 2008 the AS GCE is made up of **three** mandatory units, of which **two** are externally assessed and **one** is internally assessed. These units form 50% of the corresponding six-unit Advanced GCE.

1.2 The Six-Unit Advanced GCE

From September 2008 the Advanced GCE is made up of **three** mandatory units at AS and **three** further mandatory units at A2.

Two of the AS and **two** of the A2 units are externally assessed.

The third AS unit F323 and the third A2 unit F326 are internally assessed and will include the assessment of practical skills.

1.3 Qualification Titles and Levels

These qualifications are shown on a certificate as:

- OCR Advanced Subsidiary GCE in Chemistry.
- OCR Advanced GCE in Chemistry.

Both qualifications are Level 3 in the National Qualification Framework (NQF).

1.4 Aims

The aims of these specifications are to encourage candidates to:

- develop their interest in, and enthusiasm for chemistry, including developing an interest in further study and careers in chemistry;
- appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society;
- develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of *How Science Works*;
- develop essential knowledge and understanding of different areas of chemistry and how they relate to each other.

1.5 Prior Learning/Attainment

These specifications have been developed for students who wish to continue with a study of chemistry at Level 3 in the National Qualifications Framework (NQF). The AS specification has been written to provide progression from GCSE Science and GCSE Additional Science, or from GCSE Chemistry; achievement at a minimum of grade C in these qualifications should be seen as the normal requisite for entry to AS Chemistry. However, students who have successfully taken other Level 2 qualifications in Science or Applied Science with appropriate chemistry content may also have acquired sufficient knowledge and understanding to begin the AS Chemistry course. Other students without formal qualifications may have acquired sufficient knowledge of chemistry to enable progression onto the course.

Recommended prior learning for the AS units is shown in the introduction to each AS unit. The A2 units build upon the knowledge and understanding acquired at AS.

Recommended prior learning for the A2 course is successful performance at AS Chemistry.

2 Summary of Content

2.1 AS Units

Unit F321: *Atoms, Bonds and Groups*

- Atoms and reactions
- Electrons, bonding and structure
- The Periodic Table

Unit F322: *Chains, Energy and Resources*

- Basic concepts and hydrocarbons
- Alcohols, halogenoalkanes and analysis
- Energy
- Resources

Unit F323: *Practical Skills in Chemistry 1*

- This AS (practical skills) unit is teacher assessed and externally moderated by OCR.
- Candidates are assessed on one task from each of the following categories: qualitative, quantitative and evaluative tasks.

2.2 A2 Units

Unit F324: *Rings, Polymers and Analysis*

- Rings, acids and amines
- Polymers and synthesis
- Analysis

Unit F325: *Equilibria, Energetics and Elements*

- Rates, equilibrium and pH
- Energy
- Transition elements

Unit F326: *Practical Skills in Chemistry 2*

- This A2 (practical skills) unit is teacher assessed and externally moderated by OCR.
- Candidates are assessed on one task from each of the following categories: qualitative, quantitative and evaluative tasks.

3 Unit Content

3.1 AS Unit F321: *Atoms, Bonds and Groups*

This unit builds upon the chemical concepts that have been developed at Key Stage 4.

The material in F321, Atoms, Bonds and Groups, underpins much of the chemistry encountered in other chemistry units. It is recommended that unit F321 is taught first.

This unit consists of **three** teaching modules:

- Module 1: **Atoms and Reactions**
  - 1.1.1 Atoms
  - 1.1.2 Moles and equations
  - 1.1.3 Acids
  - 1.1.4 Redox

- Module 2: **Electrons, Bonding and Structure**
  - 1.2.1 Electron structure
  - 1.2.2 Bonding and structure

- Module 3: **The Periodic Table**
  - 1.3.1 Periodicity
  - 1.3.2 Group 2
  - 1.3.3 Group 7

Candidates are expected to apply knowledge, understanding and other skills gained in this unit to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should:

- have achieved Grade C or above in both GCSE Science and GCSE Additional Science, or GCSE Chemistry, or an equivalent standard in other appropriate Level 2 qualifications.

Links

Science in the National Curriculum

This unit expands upon the Key Stage 4: Programme of Study in Science.

3.7 GCSE Science

(ii) Chemical and Material Behaviour

(a) chemical change takes place by the rearrangement of atoms in substances;

(b) there are patterns in the chemical reactions between substances;

(c) new materials are made from natural resources by chemical reactions;

(d) the properties of a material determine its uses.

3.7 GCSE Additional Science

(ii) Chemistry

(a) Structure and Bonding

The outer electrons of atoms are involved in chemical reactions. The structure and properties of a substance are strongly dependent on the nature of the bonding that results from the forces between the electrons and nuclei of atoms.

(b) Chemical Synthesis

Raw materials are converted into new and useful substances by chemical reactions. The theoretical yield of a chemical reaction can be calculated.

1.1 Module 1: Atoms and Reactions

This module provides candidates with a knowledge and understanding of atomic structure and the chemical ideas that underpin the study of quantitative chemistry:

1.1.1 Atoms
  - atomic structure;
  - relative masses.

1.1.2 Moles and Equations
  - the mole;
  - reacting masses and equations.

1.1.3 Acids
  - acids and bases;
  - salts.

1.1.4 Redox
  - oxidation number;
  - redox reactions.

1.1.1 Atoms

Context and exemplification	Assessable learning outcomes
Atomic structure	Candidates should be able to:
• The mass of an electron can be assumed to be 1/2000th the mass of a proton.	(a) describe protons, neutrons and electrons in terms of relative charge and relative mass; (b) describe the distribution of mass and charge within an atom;
How Science Works 1, 7a: • Modern development of the structure of the atom; the changing accepted view of the structure of the atom; acceptance (and	(c) describe the contribution of protons and neutrons to the nucleus of an atom, in terms of atomic (proton) number and mass (nucleon) number;

rejection) of different theories for the structure of the atom from the Greeks, Dalton, Thompson and Rutherford, Moseley, *et al*.	(d) deduce the numbers of protons, neutrons and electrons in: (i) an atom given its atomic and mass number, (ii) an ion given its atomic number, mass number and ionic charge; (e) explain the term *isotopes* as atoms of an element with different numbers of neutrons and different masses;
Relative masses • For simple molecules, the term relative molecular mass will be used. • For compounds with giant structures, the term *relative formula mass* will be used. How Science Works 3: • Use of spreadsheets in calculating relative atomic masses from data; • Definitions of relative molecular mass and relative formula mass will not be required.	(f) state that ^{12}C is used as the standard measurement of relative masses; (g) define the terms *relative isotopic mass* and *relative atomic mass*, based on the ^{12}C scale; (h) calculate the relative atomic mass of an element given the relative abundances of its isotopes; (i) use the terms *relative molecular mass* and *relative formula mass* and calculate values from relative atomic masses.

1.1.2 Moles and Equations

Context and exemplification	**Assessable learning outcomes**
The mole	Candidates should be able to: (a) explain the terms: (i) *amount of substance*, (ii) *mole* (symbol 'mol'), as the unit for amount of substance, (iii) the *Avogadro constant*, N_A, as the number of particles per mole (6.02×10^{23} mol^{-1}); (b) define and use the term *molar mass* (units g mol^{-1}) as the mass per mole of a substance;
Empirical and molecular formulae	(c) explain the terms: (i) *empirical formula* as the simplest whole number ratio of atoms of each element present in a compound, (ii) *molecular formula* as the actual number of atoms of each element in a molecule; (d) calculate empirical and molecular formulae, using composition by mass and percentage compositions;

Chemical equations

(e) construct balanced chemical equations for reactions studied and for unfamiliar reactions given reactants and products;

Calculation of reacting masses, mole concentrations and volumes of gases

- Candidates will be expected to calculate the above for reactants and products from chemical equations.

(f) carry out calculations, using amount of substance in mol, involving:
  (i) mass,
  (ii) gas volume,
  (iii) solution volume and concentration;

(g) deduce stoichiometric relationships from calculations;

(h) use the terms *concentrated* and *dilute* as qualitative descriptions for the concentration of a solution.

1.1.3 Acids

Context and exemplification | **Assessable learning outcomes**

Acids and bases

Candidates should be able to:

(a) explain that an acid releases H^+ ions in aqueous solution;

(b) state the formulae of the common acids: hydrochloric, sulfuric and nitric acids;

(c) state that common bases are metal oxides, metal hydroxides and ammonia;

(d) state that an alkali is a soluble base that releases OH^- ions in aqueous solution;

(e) state the formulae of the common alkalis: sodium hydroxide, potassium hydroxide and aqueous ammonia;

Salts

(f) explain that a salt is produced when the H^+ ion of an acid is replaced by a metal ion or NH_4^+;

(g) describe the reactions of an acid with carbonates, bases and alkalis, to form a salt;

(h) explain that a base readily accepts H^+ ions from an acid: eg OH^- forming H_2O; NH_3 forming NH_4^+;

(i) explain the terms *anhydrous*, *hydrated* and *water of crystallisation*;

(j) calculate the formula of a hydrated salt from given percentage composition, mass composition or experimental data;

(k) perform acid–base titrations, and carry out structured titrations.

1.1.4 Redox

Context and exemplification	Assessable learning outcomes
Oxidation number • Candidates will not be expected to use oxidation numbers in peroxides or metal hydrides. • Ionic equations will only be required in Group 7 chemistry.	Candidates should be able to: (a) apply rules for assigning oxidation number to atoms in elements, compounds and ions; (b) describe the terms *oxidation* and *reduction* in terms of: (i) electron transfer, (ii) changes in oxidation number; (c) use a Roman numeral to indicate the magnitude of the oxidation state of an element, when a name may be ambiguous, eg nitrate(III) and nitrate(V); (d) write formulae using oxidation numbers;
Redox reactions	(e) explain that: (i) metals generally form ions by losing electrons with an increase in oxidation number to form positive ions, (ii) non-metals generally react by gaining electrons with a decrease in oxidation number to form negative ions;
• For nitric acid, reactions of metals are not expected. • Ionic equations not required.	(f) describe the redox reactions of metals with dilute hydrochloric and dilute sulfuric acids; (g) interpret and make predictions from redox equations in terms of oxidation numbers and electron loss/gain.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Making up a standard solution.
- NaOH or Na_2CO_3/HCl titration.
- NaOH/H_2SO_4 to illustrate difference in stoichiometry.
- Titration involving a dilution – citric acid in lime juice cordial.
- Determination of the percentage of water of crystallisation in a hydrated salt.
- Determination of the relative atomic mass of an unknown metal by gas collection.
- Determination of the concentration of lime water.
- Determination of the relative formula mass of washing soda by titration.
- Reactions of the bases, alkalis and carbonates with acids.
- Preparation of salts from an acid and a base, eg copper(II) sulfate, ammonium sulphate.
- Reactions of metals with acids.

1.2 Module 2: Electrons, Bonding and Structure

In addition to the aims of the scheme, this module provides candidates with a knowledge and understanding of chemical ideas that underpin the study of inorganic chemistry:

1.2.1 Electron Structure

- ionisation energies;
- energy levels, shells, sub-shells, orbitals and electron configuration.

1.2.2 Bonding and Structure

- ionic bonding;
- covalent bonding;
- the shapes of simple molecules and ions;
- electronegativity and polarity;
- intermolecular forces.

1.2.1 Electron Structure

Context and exemplification	**Assessable learning outcomes**
Ionisation energies • Ionisation energy definitions are in terms of one mole of gaseous atoms or ions. How Science Works 1: • Evidence for the electron configuration of the atom from successive ionisation energies.	Candidates should be able to: (a) Define the terms *first ionisation energy* and *successive ionisation energy*; (b) Explain that ionisation energies are influenced by nuclear charge, electron shielding and the distance of the outermost electron from the nucleus; (c) predict from successive ionisation energies of an element: (i) the number of electrons in each shell of an atom, (ii) the group of the element;
Electrons: electronic energy levels, shells, sub-shells, atomic orbitals, electron configuration • For AS, the electron configurations of Cr and Cu, and their ions, will not be tested. • Candidates should use sub-shell notation, ie for oxygen: $1s^22s^22p^4$. How Science Works 1, 7a: • Modern development of the structure of the atom (see also 1.1).	(d) state the number of electrons that can fill the first four shells; (e) describe an orbital as a region that can hold up to two electrons, with opposite spins; (f) describe the shapes of s and p orbitals; (g) state the number of: (i) orbitals making up s-, p- and d-sub-shells, (ii) electrons that occupy s-, p- and d-sub-shells; (h) describe the relative energies of s-, p- and d-orbitals for the shells 1, 2, 3 and the 4s and 4p orbitals;

(i) deduce the electron configurations of:
  (i) atoms, given the atomic number, up to $Z = 36$,
  (ii) ions, given the atomic number and ionic charge, limited to s and p blocks up to $Z = 36$;

(j) classify the elements into s, p and d blocks.

1.2.2 Bonding and Structure

Context and exemplification	**Assessable learning outcomes**
Ionic bonding	Candidates should be able to: (a) describe the term *ionic bonding* as electrostatic attraction between oppositely-charged ions; (b) construct '*dot-and-cross*' diagrams, to describe ionic bonding; (c) predict ionic charge from the position of an element in the Periodic Table; (d) state the formulae for the following ions: NO_3, CO_3^{2-}, SO_4^{2-} and NH_4^+;
Covalent bonding and dative covalent (coordinate) bonding	(e) describe the term *covalent bond* as a shared pair of electrons; (f) construct '*dot-and-cross*' diagrams to describe: (i) single covalent bonding, eg as in H_2, Cl_2, HCl, H_2O, NH_3, CH_4, BF_3 and SF_6, (ii) multiple covalent bonding, eg as in O_2, N_2 and CO_2, (iii) dative covalent (coordinate) bonding, eg as in NH_4^+, (iv) molecules and ions analogous to those specified in (i), (ii) and (iii);
The shapes of simple molecules and ions How Science Works 3: • Three-dimensional molecular shapes.	(g) explain that the shape of a simple molecule is determined by repulsion between electron pairs surrounding a central atom; (h) state that lone pairs of electrons repel more than bonded pairs; (i) explain the shapes of, and bond angles in, molecules and ions with up to six electron pairs (including lone pairs) surrounding a central atom, eg as in: (i) BF_3 (trigonal planar), (ii) CH_4 and NH_4^+ (tetrahedral), (iii) SF_6 (octahedral), (iv) NH_3 (pyramidal),

    (v) H_2O (non-linear),
    (vi) CO_2 (linear);

(j) predict the shapes of, and bond angles in, molecules and ions analogous to those specified in (i);

Electronegativity and bond polarity

(k) describe the term *electronegativity* as the ability of an atom to attract the bonding electrons in a covalent bond;

(l) explain that a permanent dipole may arise when covalently-bonded atoms have different electronegativities, resulting in a polar bond;

Intermolecular forces

(m) describe intermolecular forces based on permanent dipoles, as in hydrogen chloride, and induced dipoles (van der Waals' forces), as in the noble gases;

(n) describe *hydrogen bonding*, including the role of a lone pair, between molecules containing –OH and –NH groups, ie as in H_2O, NH_3 and analogous molecules;

(o) describe and explain the anomalous properties of H_2O resulting from hydrogen bonding, eg:
    (i) the density of ice compared with water,
    (ii) its relatively high freezing point and boiling point;

Metallic bonding

- No details of cubic or hexagonal packing required.

(p) describe *metallic bonding* as the attraction of positive ions to delocalised electrons;

Bonding and physical properties

(q) describe structures as:
    (i) giant ionic lattices, with strong ionic bonding, ie as in NaCl,
    (ii) giant covalent lattices, ie as in diamond and graphite,
    (iii) giant metallic lattices,
    (iv) simple molecular lattices, ie as in I_2 and ice;

(r) describe, interpret and/or predict physical properties, including melting and boiling points, electrical conductivity and solubility in terms of:
    (i) different structures of particles (atoms, molecules, ions and electrons) and the forces between them,

(ii) different types of bonding (ionic bonding, covalent bonding, metallic bonding, hydrogen bonding, other intermolecular interactions);

(s) deduce the type of structure and bonding present from given information.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Bonding, structure and physical properties of substances (polarity, electrical conductivity, boiling points, solubility in polar and non-polar solvents).

1.3 Module 3: The Periodic Table

In addition to the aims of the scheme, this module provides candidates with a knowledge and understanding of chemical ideas that underpin the study of inorganic chemistry:

1.3.1 Periodicity
- the Periodic Table;
- trends in physical properties.

1.3.2 Group 2
- redox reactions of Group 2 metals;
- Group 2 compounds.

1.3.3 Group 7
- redox reactions of Group 7 elements;
- halide tests.

1.3.1 Periodicity

Context and exemplification	**Assessable learning outcomes**
The structure of the Periodic Table in terms of groups and periods How Science Works 1, 7a, 7b: • Development of the Periodic Table from Döbereiner, Newlands, Mendeleev, Moseley, Seaborg, *et al*.	Candidates should be able to: (a) describe the Periodic Table in terms of the arrangement of elements: (i) by increasing atomic (proton) number, (ii) in periods showing repeating trends in physical and chemical properties, (iii) in groups having similar physical and chemical properties; (b) describe *periodicity* in terms of a repeating pattern across different periods; (c) explain that atoms of elements in a group have similar outer shell electron configurations, resulting in similar properties;
Periodicity of physical properties of elements • Periodic trends in ionisation energies will consider s and p blocks only. No consideration of the periodic decreases between Groups 2 and 3, and 5 and 6, will be tested.	(d) describe and explain the variation of the first ionisation energies of elements shown by: (i) a general increase across a period, in terms of increasing nuclear charge, (ii) a decrease down a group in terms of increasing atomic radius and increasing electron shielding outweighing increasing nuclear charge; [See also unit F321: 1.2.1(a)–(c)] (e) for the elements of Periods 2 and 3: (i) describe the variation in electron

configurations, atomic radii, melting points and boiling points,

(ii) explain variations in melting and boiling points in terms of structure and bonding;

(f) interpret data on electron configurations, atomic radii, first ionisation energies, melting points and boiling points to demonstrate periodicity.

1.3.2 Group 2

Context and exemplification	Assessable learning outcomes
Redox reactions of Group 2 metals	Candidates should be able to: (a) describe the redox reactions of the Group 2 elements Mg → Ba: (i) with oxygen, (ii) with water; (b) explain the trend in reactivity of Group 2 elements down the group due to the increasing ease of forming cations, in terms of atomic size, shielding and nuclear attraction;
Reactions of Group 2 compounds	(c) describe the action of water on oxides of elements in Group 2 and state the approximate pH of any resulting solution;
• No explanation of thermal decomposition required.	(d) describe the thermal decomposition of the carbonates of elements in Group 2 and the trend in their ease of decomposition; (e) interpret and make predictions from the chemical and physical properties of Group 2 elements and compounds; (f) explain the use of $Ca(OH)_2$ in agriculture to neutralise acid soils; the use of $Mg(OH)_2$ in some indigestion tablets as an antacid.

1.3.3 Group 7

Context and exemplification	Assessable learning outcomes
Characteristic physical properties	Candidates should be able to: (a) explain, in terms of van der Waals' forces, the trend in the boiling points of Cl_2, Br_2 and I_2;
Redox reactions and trends in reactivity of Group 7 elements and their compounds	(b) describe the redox reactions, including ionic equations, of the Group 7 elements Cl_2, Br_2 and I_2 with other halide ions, in the presence of an organic solvent, to illustrate the relative reactivity of Group 7 elements;

How Science Works 6a, 6b: • Health benefits of chlorine use in water; • Ethical implications of adding chlorine to public water supplies (also fluorine in drinking water).	(c) explain the trend in reactivity of Group 7 elements down the group from the decreasing ease of forming negative ions, in terms of atomic size, shielding and nuclear attraction; (d) describe the term *disproportionation* as a reaction in which an element is simultaneously oxidised and reduced, illustrated by: (i) the reaction of chlorine with water as used in water purification, (ii) the reaction of chlorine with cold, dilute aqueous sodium hydroxide, as used to form bleach, (iii) reactions analogous to those specified in (i) and (ii); (e) interpret and make predictions from the chemical and physical properties of the Group 7 elements and their compounds; (f) contrast the benefits of chlorine use in water treatment (killing bacteria) with associated risks (hazards of toxic chlorine gas and possible risks from formation of chlorinated hydrocarbons);
Characteristic reactions of halide ions • Complexes with ammonia are not required.	(g) describe the precipitation reactions, including ionic equations, of the aqueous anions Cl^-, Br^- and I^- with aqueous silver ions, followed by aqueous ammonia; (h) describe the use of the precipitation reactions in (g) as a test for different halide ions.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Reactions of some Group 2 metals with oxygen and water.
- Action of water on Group 2 oxides and testing pH of resulting solutions.
- Thermal decomposition of Group 2 carbonates.
- Halogen displacement reactions.
- Testing for the presence of halide ions in solution using silver nitrate.

3.2 AS Unit F322: *Chains, Energy and Resources*

This unit builds upon the chemical concepts that have been developed at Key Stage 4.

This unit consists of **four** teaching modules:

Module 1: **Basic Concepts and Hydrocarbons**
- 2.1.1 Basic Concepts
- 2.1.2 Alkanes
- 2.1.3 Alkenes

Module 2: **Alcohols, Halogenoalkanes and Analysis**
- 2.2.1 Alcohols
- 2.2.2 Halogenoalkanes
- 2.2.3 Modern Analytical Techniques

Module 3: **Energy**
- 2.3.1 Enthalpy Changes
- 2.3.2 Rates and Equilibrium

Module 4: **Resources**
- 2.4.1 Chemistry of the Air
- 2.4.2 Green Chemistry

Candidates are expected to apply knowledge, understanding and other skills gained in this unit to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should:

- have achieved Grade C or above in both GCSE Science and GCSE Additional Science, or GCSE Chemistry, or an equivalent standard in other appropriate Level 2 qualifications;
- have studied Unit F321: *Atoms, Bonds and Groups*.

Links

Science in the National Curriculum

This unit expands upon the Key Stage 4: Programme of Study in Science.

3.7 GCSE Science

(ii) Chemical and Material Behaviour

(a) chemical change takes place by the rearrangement of atoms in substances;

(b) there are patterns in the chemical reactions between substances;

(c) new materials are made from natural resources by chemical reactions;

(d) the properties of a material determine its uses.

(iv) Environment, Earth and Universe

(a) the effects of human activity on the environment can be assessed using living and non-living indicators;

(b) the surface and the atmosphere of the Earth have changed since the Earth's origin and are changing at present.

3.7 GCSE Additional Science

(ii) Chemistry

(a) Structure and Bonding

The outer electrons of atoms are involved in chemical reactions. The structure and properties of a substance are strongly dependent on the nature of the bonding which results from the forces between the electrons and nuclei of atoms.

(b) Chemical Synthesis

Raw materials are converted into new and useful substances by chemical reactions. The theoretical yield of a chemical reaction can be calculated.

2.1 Module 1: Basic Concepts and Hydrocarbons

This module provides a foundation for the study of organic chemistry and to illustrate and raise issues regarding the applications of organic chemistry to everyday life.

This module provides candidates with a knowledge and understanding of chemical ideas that underpin the study of organic chemistry:

2.1.1 Basic Concepts

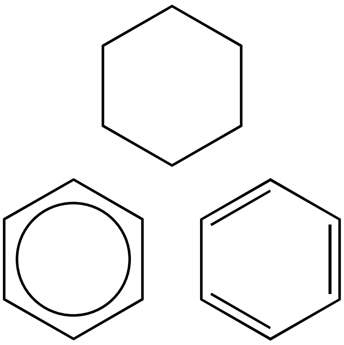
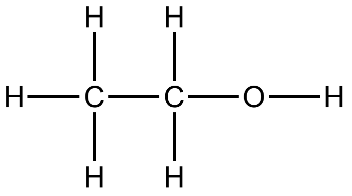
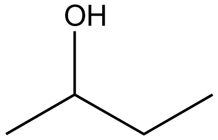
- nomenclature and formula representation;
- functional groups, organic reactions and isomerism;
- reaction mechanisms, percentage yield and atom economy.

2.1.2 Alkanes

- hydrocarbons from crude oil;
- hydrocarbons as fuels.

2.1.3 Alkenes

- addition reactions;
- polymers and industrial importance of alkenes.

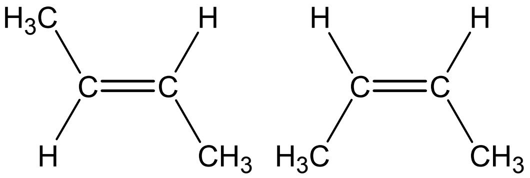
Context and exemplification	**Assessable learning outcomes**
Representing formulae of organic compounds • See also unit F321: 1.1.2.c,d. • In structural formulae, the carboxyl group will be represented as COOH and the ester group as COOR. • The symbols below will be used for cyclohexane and benzene. 	Candidates should be able to: (a) interpret and use the terms: (i) *empirical formula* as the simplest whole number ratio of atoms of each element present in a compound, (ii) *molecular formula* as the actual number of atoms of each element in a molecule, (iii) *general formula* as the simplest algebraic formula of a member of a homologous series, ie for an alkane: C_nH_{2n+2}, (iv) *structural formula* as the minimal detail that shows the arrangement of atoms in a molecule, eg for butane: $CH_3CH_2CH_2CH_3$ or $CH_3(CH_2)_2CH_3$, (v) *displayed formula* as the relative positioning of atoms and the bonds between them, ie for ethanol:  (vi) *skeletal formula* as the simplified organic formula, shown by removing hydrogen atoms from alkyl chains, leaving just a carbon skeleton and associated functional groups, ie for butan-2-ol:  ;
Functional groups and the naming of organic compounds	(b) interpret, and use, the terms: (i) *homologous series* as a series of organic compounds having the same functional group but with each successive member differing by CH_2, (ii) *functional group* as a group of atoms responsible for the characteristic reactions of a compound; (c) use the general formula of a homologous series to predict the formula of any member of the series; (d) state the names of the first ten members of the alkanes homologous series;

- For AS, nomenclature will be limited to the functional groups studied, ie $CH_3CH_2CH(CH_3)CH_2OH$ has the systematic name: 2-methylbutan-1-ol.

(e) use IUPAC rules of nomenclature for systematically naming organic compounds;

Isomerism

- Knowledge of *E*/*Z* isomerism is restricted to understanding that this system is needed where there are more than two different substituents around the double bond, ie 1,-bromo-2-chloropropene.
- Candidates are required to identify the *E* and *Z* stereoisomers in examples that also have *cis* and *trans* isomers such as but-2-ene.



E-but-2-ene (*trans*) *Z*-but-2-ene (*cis*)

For more complex examples, candidates may be required to identify the feature giving *E*/*Z* isomerism, or to draw the *E*/*Z* stereoisomers but they will not be required to use Cahn–Ingold–Prelog priority rules to identify which stereoisomer is which.

- Note that the term *geometric isomer* is no longer recommended by IUPAC.

(f) describe and explain the terms:
  (i) *structural isomers* as compounds with the same molecular formula but different structural formulae,
  (ii) *stereoisomers* as compounds with the same structural formula but with a different arrangement in space,
  (iii) *E*/*Z* isomerism as an example of stereoisomerism, in terms of restricted rotation about a double bond and the requirement for two different groups to be attached to each carbon atom of the C=C group,
  (iv) *cis-trans isomerism* as a special case of *E*/*Z* isomerism in which two of the substituent groups are the same;

(g) determine the possible structural formulae and/or stereoisomers of an organic molecule, given its molecular formula;

Reaction mechanisms

(h) describe the different types of covalent bond fission:
  (i) homolytic fission forming two radicals,
  (ii) heterolytic fission forming a cation and an anion;

- Any relevant dipoles should be included.
- Curly arrows should start from a bond, a lone pair of electrons or a negative charge.

(i) describe a ‘curly arrow’ as the movement of an electron pair, showing either breaking or formation of a covalent bond;

(j) outline reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with ‘curly arrows’;

Percentage yields and atom economy

How Science Works 6a, 7c:

- Benefits to society of a high atom economy: see also sustainability: unit F322: 2.4.2.

(k) carry out calculations to determine the percentage yield of a reaction;

(l) explain the *atom economy* of a reaction as:

$$\frac{\text{molecular mass of the desired products}}{\text{sum of molecular masses of all products}} \times 100\%;$$

(m) explain that addition reactions have an atom economy of 100%, whereas substitution reactions are less efficient;

(n) carry out calculations to determine the atom

	economy of a reaction;
	(o) describe the benefits of developing chemical processes with a high atom economy in terms of fewer waste materials;
	(p) explain that a reaction may have a high percentage yield but a low atom economy.

2.1.2 Alkanes

Context and exemplification	**Assessable learning outcomes**
Hydrocarbons from crude oil	Candidates should be able to:
	(a) explain that a *hydrocarbon* is a compound of hydrogen and carbon only;
	(b) explain the use of crude oil as a source of hydrocarbons, separated as fractions with different boiling points by fractional distillation, which can be used as fuels or for processing into petrochemicals;
	(c) state that alkanes and cycloalkanes are saturated hydrocarbons;
	(d) state and explain the tetrahedral shape around each carbon atom in alkanes (see also unit F321: 1.2.2.i);
	(e) explain, in terms of van der Waals' forces, the variations in the boiling points of alkanes with different carbon-chain length and branching;
Hydrocarbons as fuels	(f) describe the combustion of alkanes, leading to their use as fuels in industry, in the home and in transport;
How Science Works 6b: • Toxicity from CO production during incomplete combustion of fuels.	(g) explain, using equations, the incomplete combustion of alkanes in a limited supply of oxygen and outline the potential dangers arising from production of CO in the home and from car use;
• Candidates should be aware that a catalyst is required but no detail is expected.	(h) describe the use of catalytic cracking to obtain more useful alkanes and alkenes;
	(i) explain that the petroleum industry processes straight-chain hydrocarbons into branched alkanes and cyclic hydrocarbons to promote efficient combustion;
How Science Works 6a, 7b: • Desirability of renewable fuels by 'rich' countries may lead to problems of food supply for countries supplying the 'crops for fuel'.	(j) contrast the value of fossil fuels for providing energy and raw materials with: (i) the problem of an over-reliance on non-renewable fossil fuel reserves and the importance of developing renewable plant-based fuels, ie alcohols and biodiesel (see also 2.4.2), (ii) increased CO_2 levels from combustion of fossil fuels leading to global warming and climate change (see also 2.4.1.d);

Substitution reactions of alkanes • Candidates are not required to use 'half curly arrows' in this mechanism. Equations should show which species are radicals using a single 'dot' to represent the unpaired electron.	(k) describe the substitution of alkanes using ultraviolet radiation, by Cl_2 and by Br_2, to form halogenoalkanes; (l) define the term *radical* as a species with an unpaired electron; (m) describe how homolytic fission leads to the mechanism of radical substitution in alkanes in terms of initiation, propagation and termination reactions (see also 2.1.1.h); (n) explain the limitations of radical substitution in synthesis, arising from further substitution with formation of a mixture of products.

2.1.3 Alkenes

Context and exemplification	**Assessable learning outcomes**
Properties of alkenes • Hybridisation not required.	Candidates should be able to: (a) state that alkenes and cycloalkenes are unsaturated hydrocarbons; (b) describe the overlap of adjacent p-orbitals to form a π-bond; (c) state and explain the trigonal planar shape around each carbon in the C=C of alkenes (see also unit F321: 1.2.2.i);
Addition reactions of alkenes • Candidates are expected to realise that addition to an unsymmetrical alkene such as propene may result in two isomeric products. However, candidates will not be required to predict the relative proportions of these isomers, nor to apply or explain Markovnikoff's rule.	(d) describe addition reactions of alkenes, ie by ethene and propene, with: (i) hydrogen in the presence of a suitable catalyst, ie Ni, to form alkanes, (ii) halogens to form dihalogenoalkanes, including the use of bromine to detect the presence of a double C=C bond as a test for unsaturation, (iii) hydrogen halides to form halogenoalkanes, (iv) steam in the presence of an acid catalyst to form alcohols; (e) define an *electrophile* as an electron pair acceptor; (f) describe how heterolytic fission leads to the mechanism of electrophilic addition in alkenes (see also 2.1.1.h–j.);
Polymers from alkenes	(g) describe the addition polymerisation of alkenes; (h) deduce the repeat unit of an addition polymer obtained from a given monomer; (i) identify the monomer that would produce a given section of an addition polymer;
Industrial importance of alkenes	(j) outline the use of alkenes in the industrial production of organic compounds: (i) the manufacture of margarine by catalytic hydrogenation of unsaturated vegetable

oils using hydrogen and a nickel catalyst,

(ii) the formation of a range of polymers using unsaturated monomer units based on the ethene molecule, ie $H_2C{=}CHCl$, $F_2C{=}CF_2$;

How Science Works 6a, 6b, 7c:

- Benefits from processing of alkenes to produce polymers and plastics; drawbacks from waste polymers.
- Increased political and social desire to reduce plastic waste, to recycle or to use for energy production.
- Developments of new degradable plastics produced from renewable resources.

(k) outline the processing of waste polymers (see also 2.4.2) by:
  (i) separation into types (ie PTFE, etc.) and recycling,
  (ii) combustion for energy production (see 2.1.2.f),
  (iii) use as a feedstock for cracking (see 2.1.2.h) in the production of plastics and other chemicals;

(l) outline the role of chemists in minimising environmental damage by:
  (i) removal of toxic waste products, ie removal of HCl formed during disposal by combustion of halogenated plastics (ie PVC),
  (ii) development of biodegradable and compostable polymers, ie from isoprene (2-methyl-1,3-butadiene), maize and starch (see also 2.4.2).

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

For simplicity, this module refers to reactions of methane, ethane and propene. It is more convenient to use liquid alkanes and alkenes in practical work. For example, cyclohexane and cyclohexene can be used instead of these gaseous alkanes.

- Cracking of paraffin oil.
- Test-tube reactions of alkanes and alkenes with bromine.
- Extraction of limonene from orange peel.

2.2 Module 2: Alcohols, Halogenoalkanes and Analysis

This module extends the knowledge base in organic chemistry by study of two further functional groups:

2.2.1 Alcohols
- properties of alcohols and the preparation of ethanol;
- reactions, including oxidation, esterification and elimination.

2.2.2 Halogenoalkanes
- substitution reactions and uses.

2.2.3 Modern Analytical Techniques
- infrared spectroscopy;
- mass spectrometry.

This analytical work is developed further in Advanced GCE Chemistry.

Links

AS Unit F321: *Atoms, Bonds and Groups*
- 1.2.2 Bonding and Structure (intermolecular forces)

AS Unit F322: *Chains, Energy and Resources*
- 2.1.1 Basic Concepts
- 2.1.2 Alkanes
- 2.1.3 Alkenes
- 2.4.1 Chemistry of the Air

2.2.1 Alcohols

Context and exemplification	Assessable learning outcomes
Properties and preparation of ethanol	Candidates should be able to:
	(a) explain, in terms of hydrogen bonding, the water solubility and the relatively low volatility of alcohols;
	(b) describe the industrial production of ethanol by: (i) fermentation from sugars, ie from glucose,
• H_3PO_4 is usually used as the acid catalyst.	(ii) the reaction of ethene with steam in the presence of an acid catalyst;
	(c) outline, for alcohols: (i) the use of ethanol in alcoholic drinks and as a solvent in the form of methylated spirits,

	(ii) the use of methanol as a petrol additive to improve combustion and its increasing importance as a feedstock in the production of organic chemicals;
Reactions of alcohols	(d) classify alcohols into primary, secondary and tertiary alcohols; (e) describe the combustion of alcohols;
• Equations should use [O] to represent the oxidising agent.	(f) describe the oxidation of alcohols using $Cr_2O_7^{2-}/H^+$ (ie $K_2Cr_2O_7/H_2SO_4$), including: (i) the oxidation of primary alcohols to form aldehydes and carboxylic acids; the control of the oxidation product using different reaction conditions, (ii) the oxidation of secondary alcohols to form ketones, (iii) the resistance to oxidation of tertiary alcohols; (g) describe the esterification of alcohols with carboxylic acids in the presence of an acid catalyst;
• Mechanism for elimination not required. • H_3PO_4 or H_2SO_4 is usually used as the acid catalyst.	(h) describe elimination of H_2O from alcohols in the presence of an acid catalyst and heat to form alkenes.

2.2.2 Halogenoalkanes

Context and exemplification	**Assessable learning outcomes**
Substitution reactions of halogenoalkanes	Candidates should be able to: (a) describe the hydrolysis of halogenoalkanes as a substitution reaction; (b) define the term *nucleophile* as an electron pair donor; (c) describe the mechanism of nucleophilic substitution in the hydrolysis of primary halogenoalkanes with hot aqueous alkali (see also 2.1.1.i,j);
• Aqueous silver nitrate in ethanol can be used to compare these rates. In this reaction, H_2O can be assumed to be the nucleophile. • Alternatively, hot aqueous alkali can be used (followed by neutralisation and addition of aqueous silver nitrate). In this reaction, OH^- is the nucleophile.	(d) explain the rates of hydrolysis of primary halogenoalkanes in terms of the relative bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I);
Uses of halogenoalkanes How Science Works 6a, 6b, 7a–c: • Initial use of CFCs as harmless aerosol propellants offset when scientists discovered that CFCs damaged the ozone layer.	(e) outline the uses of chloroethene and tetrafluoroethene to produce the plastics PVC and PTFE (see also 2.1.3.g–i); (f) explain that CFCs: (i) were developed as aerosols, refrigerants, and in air-conditioning

• This provided important evidence which enabled international action to be taken to reduce and phase out CFC use. • This has subsequently led to development of ozone-friendly alternatives and natural repair of the ozone layer.	because of their low reactivity, volatility and non-toxicity, (ii) have caused environmental damage to the ozone layer (see also 2.4.1.g); (g) outline the role of green chemistry in minimising damage to the environment by promoting biodegradable alternatives to CFCs, such as hydrocarbons and HCFCs; CO_2 as a blowing agent for expanded polymers (see also 2.4.2).

2.2.3 Modern Analytical Techniques

Context and exemplification	**Assessable learning outcomes**
Infrared spectroscopy • In examinations, infrared absorption data will be provided on the *Data Sheet*. • Candidates should be aware that most organic compounds produce a peak at approximately 3000 cm^{-1} due to absorption by C–H bonds. How Science Works 7c: • Use of analytical techniques to inform decision making, ie breathalysers in drink driving cases.	Candidates should be able to: (a) state that absorption of infrared radiation causes covalent bonds to vibrate; (b) identify, using an infrared spectrum of an organic compound: (i) an alcohol from an absorption peak of the O–H bond, (ii) an aldehyde or ketone from an absorption peak of the C=O bond, (iii) a carboxylic acid from an absorption peak of the C=O bond and a broad absorption peak of the O–H bond; (c) state that modern breathalysers measure ethanol in the breath by analysis using infrared spectroscopy;
Mass spectrometry How Science Works 3: • Is there life on Mars?, how much lead/pesticides enters the food chain via vegetables, etc. • Knowledge of the mass spectrometer is **not** required. • Limited to ions with single charges. • Rearrangement reactions are not required. • Mass spectra limited to alkanes, alkenes and alcohols.	(d) outline the use of mass spectrometry: (i) in the determination of relative isotopic masses, (ii) as a method for identifying elements, ie use in the Mars space probe and in monitoring levels of environmental pollution, such as lead; (e) interpret mass spectra of elements in terms of isotopic abundances; (f) use the molecular ion peak in a mass spectrum of an organic molecule to determine its molecular mass; (g) suggest the identity of the major fragment ions, ie m/z = 29 as $CH_3CH_2^+$, in a given mass spectrum (limited to alkanes, alkenes and alcohols); (h) use molecular ion peaks and fragmentation peaks to identify structures (limited to

unipositive ions);

(i) explain that a mass spectrum is essentially a fingerprint for the molecule that can be identified by computer using a spectral database.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Fermentation of glucose.
- Oxidation of ethanol to aldehyde and carboxylic acid.
- Elimination of water from cyclohexanol.
- Preparation of esters on a test-tube scale.
- Rates of hydrolysis of different halogenoalkanes.
- Interpretation of spectra – spectra available at: http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/cre_index.cgi?lang=eng

2.3 Module 3: Energy

This module provides candidates with a knowledge and understanding of chemical reasoning that underpins the study of physical chemistry.

2.3.1 Enthalpy Changes

- enthalpy changes of reaction, combustion and formation;
- bond enthalpies;
- Hess' law and enthalpy cycles.

2.3.2 Rates and Equilibrium

- collision theory, the Boltzmann distribution and catalysis;
- a qualitative study of reaction rates;
- dynamic equilibrium and le Chatelier's principle.

Links

AS Unit F321: Atoms, Bonds and Groups

- 1.1.2 Moles and Equations
- 1.3.2 Group 2 (acid reactions with metals, carbonates and bases)

AS Unit F322: Chains, Energy and Resources

- 2.1.2 Alkanes (combustion of fuels)
- 2.2.1 Alcohols (combustion of alcohols)

2.3.1 Enthalpy Changes

Context and exemplification	Assessable learning outcomes
Enthalpy changes: Δ*H* of reaction, formation and combustion	Candidates should be able to: (a) explain that some chemical reactions are accompanied by enthalpy changes that can be exothermic (Δ*H*, negative) or endothermic (Δ*H*, positive); (b) describe the importance of oxidation as an exothermic process in the combustion of fuels and the oxidation of carbohydrates such as glucose in respiration; (c) describe that endothermic processes require an input of heat energy, eg the thermal decomposition of calcium carbonate; (d) construct a simple enthalpy profile diagram for a reaction to show the difference in the enthalpy of the reactants compared with that of the products; (e) explain qualitatively, using enthalpy profile diagrams, the term *activation energy*;

- Standard conditions can be considered as 100 kPa and a stated temperature, 298 K.

(f) define and use the terms:
  (i) *standard conditions*,
  (ii) *enthalpy change of reaction*,
  (iii) *enthalpy change of formation*,
  (iv) *enthalpy change of combustion*;

(g) calculate enthalpy changes from appropriate experimental results directly, including use of the relationship: energy change = $mc\Delta T$;

Bond enthalpies

(h) explain exothermic and endothermic reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds;

(i) define and use the term *average bond enthalpy* (ΔH positive; bond breaking of one mole of bonds);

(j) calculate an enthalpy change of reaction from average bond enthalpies;

Hess' law and enthalpy cycles

- Unfamiliar enthalpy cycles will be provided.

(k) use Hess' law to construct enthalpy cycles and carry out calculations to determine:
  (i) an enthalpy change of reaction from enthalpy changes of combustion,
  (ii) an enthalpy change of reaction from enthalpy changes of formation,
  (iii) an enthalpy change of reaction from an unfamiliar enthalpy cycle.

2.3.2 Rates and Equilibrium

Context and exemplification	**Assessable learning outcomes**

Simple collision theory

Candidates should be able to:

(a) describe qualitatively, in terms of collision theory, the effect of concentration changes on the rate of a reaction;

(b) explain why an increase in the pressure of a gas, increasing its concentration, may increase the rate of a reaction involving gases;

Catalysts

How Science Works 6a:

- Benefits of catalysis in terms of possible lower production costs but also implications for their disposal (toxicity).
- Details of processes are not required.

(c) state that a catalyst speeds up a reaction without being consumed by the overall reaction;

(d) explain that catalysts:
  (i) affect the conditions that are needed, often requiring lower temperatures and reducing energy demand and CO_2 emissions from burning of fossil fuels,

- (ii) enable different reactions to be used, with better atom economy and with reduced waste,
- (iii) are often enzymes, generating very specific products, and operating effectively close to room temperatures and pressures,
- (iv) have great economic importance, eg iron in ammonia production, Ziegler–Natta catalyst in poly(ethene) production, platinum/palladium/rhodium in catalytic converters (see also 2.4.1.i);

(e) explain, using enthalpy profile diagrams, how the presence of a catalyst allows a reaction to proceed via a different route with a lower activation energy, giving rise to an increased reaction rate;

The Boltzmann distribution

How Science Works 1:

- The Boltzmann distribution as a theoretical model arising from kinetic theory.

(f) explain qualitatively the Boltzmann distribution and its relationship with activation energy;

(g) describe qualitatively, using the Boltzmann distribution, the effect of temperature changes on the proportion of molecules exceeding the activation energy and hence the reaction rate;

(h) interpret the catalytic behaviour in (e), in terms of the Boltzmann distribution;

Dynamic equilibrium and le Chatelier's principle

(i) explain that a dynamic equilibrium exists when the rate of the forward reaction is equal to the rate of the reverse reaction;

(j) state le Chatelier's principle;

(k) apply le Chatelier's principle to deduce qualitatively (from appropriate information) the effect of a change in temperature, concentration or pressure, on a homogeneous system in equilibrium;

(l) explain, from given data, the importance in the chemical industry of a compromise between chemical equilibrium and reaction rate.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments.

- Direct enthalpy changes of reaction for simple reactions:
  Zn + $CuSO_4$ (exo); $NaHCO_3$ + citric acid (endo); NaOH + HCl (exo).
- Enthalpy change of combustion of alcohols.
- Indirect enthalpy change of reaction:
  $2KHCO_3 \rightarrow K_2CO_3 + H_2O + CO_2$ indirectly using HCl.
- Rate graphs for gas products, eg $CaCO_3$ + HCl; Mg + HCl
- Changing equilibrium position with heat: $[Cu(H_2O)_6]^{2+} \rightleftharpoons CuCl_4^{2-}$
- Changing equilibrium position with concentration: Fe^{3+} and SCN^-

2.4 Module 4: Resources

The emphasis here is on the application of chemical facts and principles to processes occurring in the environment and to the difficulties in providing solutions to pollution. It is important that candidates should appreciate this aspect, bearing in mind the increasing concern, both national and international, for protecting the environment and promoting ‘Green Chemistry’.

2.4.1 Chemistry of the Air

- the ‘Greenhouse Effect’;
- the ozone layer;
- controlling pollution.

2.4.2 Green Chemistry

- sustainability.

Links

AS Unit F322: *Chains, Energy and Resources*

- 2.1.2 Alkanes (radicals; combustion of fuels)
- 2.2.2 Halogenoalkanes (CFCs)
- 2.2.3 Modern Analytical Techniques
- 2.3.2 Rates and Equilibrium (reversible reactions; catalysts)

2.4.1 Chemistry of the Air

Context and exemplification

The ‘Greenhouse Effect’

How Science Works 7a, 7c:

- Collecting data to confirm whether or not climate change is occurring; monitoring measures to abate the change; modelling the potential damage.

Assessable learning outcomes

Candidates should be able to:

(a) explain that infrared radiation is absorbed by C=O, O–H and C–H bonds in H_2O, CO_2 and CH_4, and that these absorptions contribute to global warming;

(b) explain that the ‘Greenhouse Effect’ of a given gas is dependent both on its atmospheric concentration and its ability to absorb infrared radiation;

(c) outline the importance of controlling global warming resulting from atmospheric increases in greenhouse gases;

(d) outline the role of chemists in minimising climate change resulting from global warming by:

  (i) providing scientific evidence to governments to verify that global warming is taking place,

  (ii) investigating solutions to environmental problems, such as *carbon capture and* *storage, CCS,* ie the removal of waste carbon dioxide as a liquid injected deep in the oceans, storage in deep geological formations, by reaction with metal oxides to form stable carbonate minerals,

(iii) monitoring progress against initiatives such as the Kyoto protocol;

The ozone layer

(e) explain that ozone is continuously being formed and broken down in the stratosphere by the action of ultraviolet radiation;

(f) using the chemical equilibrium, below:

$$O_2 + O \rightleftharpoons O_3$$

(i) describe and explain how the concentration of ozone is maintained in the ozone layer, including the role of ultraviolet radiation,

(ii) outline the role of ozone in the absorption of harmful ultraviolet radiation and the essential benefit of this process for life on Earth;

How Science Works 6a, 6b:

- Benefits of use of CFCs and consequent breakdown of ozone layer.
- No specific equations will be required beyond this simple representation of this catalysis.

(g) understand that radicals, eg from CFCs, and NO_x from thunderstorms or aircraft, may catalyse the breakdown of ozone by the following simple representation:

$$R + O_3 \rightarrow RO + O_2$$
$$RO + O \rightarrow R + O_2$$

where R represents $Cl^{\bullet}$ from a CFC or NO from nitrogen oxides;

Controlling air pollution

- No details are required of the chemical processes involved in formation of photochemical smog.

(h) for carbon monoxide, oxides of nitrogen and unburnt hydrocarbons:

(i) explain their formation from the internal combustion engine,

(ii) state environmental concerns from their toxicity and contribution to low-level ozone and photochemical smog;

- Candidates should understand that bonding to the catalyst surface must be weak enough for adsorption and desorption to take place but strong enough to weaken bonds and allow reaction to take place.

(i) outline how a catalytic converter decreases carbon monoxide and nitrogen monoxide emissions from internal combustion engines by:

(i) adsorption of CO and NO to the catalyst surface,

(ii) chemical reaction,

(iii) desorption of CO_2 and N_2 from the catalyst surface;

(j) outline the use of infrared spectroscopy in monitoring air pollution.

2.4.2 Green Chemistry

How Science Works 6a, 6b, 7c:

- The use of context case studies such as those below to demonstrate current principles of chemical sustainability; desirability of such processes economically and environmentally; appreciation that legislation may be required to enforce environmentally desirable processes; the inbuilt desirability from within the chemical community to clean up their act.

Context and exemplification

Sustainability

Examples for (a) (not examinable):

- Lead has largely been eliminated from use in petrol, paints and electrical components.
- New foams such as Pyrocool® FEF have been invented to put out fires effectively without producing the toxic or ozone-depleting waste products found in other halogenated fire-fighting materials.
- Solvent-free reactions, ie use of reagent as solvent.
- For dry cleaning, liquid ‘supercritical’ CO_2 can be used as a safer solvent than chlorinated hydrocarbons.
- Fossil fuels are being replaced or supplemented by renewable fuels, such as biodiesel, alcohol and fuel cells.
- Increased use of recycling of manufactured materials such as plastics, glass and metals.

Examples for (b) (not examinable):

- Production of biodiesel uses grain crops and land needed for food, with poorer countries being worse affected.

Examples for (c) (not examinable):

- Montreal Protocol on Substances that Deplete the Ozone Layer.
- Global Treaty on Persistent Organic Pollutants.
- Rio Declaration on Environment and Development.

Assessable learning outcomes

Candidates should be able to:

(a) describe principles of chemical sustainability:
  (i) using industrial processes that reduce or eliminate hazardous chemicals and which involve the use of fewer chemicals,
  (ii) designing processes with a high atom economy that minimise the production of waste materials,
  (iii) using renewable resources such as plant-based substances,
  (iv) seeking alternative energy sources such as solar energy, rather than consuming finite resources such as fossil fuels that will eventually be exhausted,
  (v) ensuring that any waste products produced are non-toxic, and can be recycled or biodegraded by being broken down into harmless substances in the environment;

(b) explain that the apparent benefits may be offset by unexpected and detrimental side-effects;

(c) explain the importance of establishing international cooperation to promote the reduction of pollution levels;

(d) discuss issues of sustainability in contexts based on the principles in a–c;

3.3 AS Unit F323: *Practical Skills in Chemistry 1*

This unit assesses practical and investigative skills developed within contexts encountered during AS Chemistry. Further information on the assessment of the tasks is provided as Appendix D.

Candidates are required to carry out **three** tasks:

1.	Qualitative task	[10 marks]
2.	Quantitative task	[15 marks]
3.	Evaluative task	[15 marks]

Tasks will be chosen from a selection provided by OCR.

The Qualitative and Quantitative tasks will test skills of observation and measurement.

Candidates will carry out these tasks under controlled conditions.

Each task will be internally assessed using a mark scheme provided by OCR.

Candidates may attempt more than one task from each category with the best mark from each category being used to make up the overall mark.

Centres will supply OCR with a single mark out of 40.

How Science Works

5a Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.

5b Analyse and interpret data to provide evidence, recognising correlations and causal relationships.

5c Evaluate methodology, evidence and data, and resolve conflicting evidence.

The mark schemes supplied by OCR will be based on the following generic criteria:

	Assessable Learning outcomes
1. **Qualitative Task** • Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate skilful and safe practical techniques using suitable qualitative methods; (b) make and record valid observations, organise results suitably.
2. **Quantitative Task** • Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate skilful and safe practical techniques using suitable quantitative methods; (b) make and record accurate measurements to an appropriate precision; (c) analyse, interpret and evaluate experimentally derived results quantitatively to reach valid conclusions.
3. **Evaluative Task** • This task may extend one of the qualitative or quantitative tasks. • Candidates will evaluate the quality of the data and procedures. • Evaluative tasks will **not** require additional data collection.	Candidates should be able to: (a) analyse and interpret data, identify anomalies and reach valid conclusions; (b) assess the reliability and accuracy of an experimental task, identify significant weaknesses in experimental procedures and measurements; (c) understand and select simple improvements to experimental procedures and measurements.

The Tasks

Tasks, mark schemes and guidance for teachers and technicians can be downloaded from the OCR Interchange site.

Further advice and guidance on the use and marking of the tasks can be found in the Practical Skills Handbook.

3.4 A2 Unit F324: *Rings, Polymers and Analysis*

This unit builds upon the chemical concepts that have been developed during AS Chemistry.

This unit consists of **three** teaching modules:

- Module 1: **Rings, Acids and Amines**
    - 4.1.1 Arenes
    - 4.1.2 Carbonyl Compounds
    - 4.1.3 Carboxylic Acids and Esters
    - 4.1.4 Amines

- Module 2: **Polymers and Synthesis**
    - 4.2.1 Amino Acids and Proteins
    - 4.2.2 Polyesters and Polyamides
    - 4.2.3 Synthesis

- Module 3: **Analysis**
    - 4.3.1 Chromatography
    - 4.3.2 Spectroscopy

Candidates are expected to apply knowledge, understanding and other skills gained in this unit to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should:

- have studied AS Chemistry.

4.1 Module 1: Rings, Acids and Amines

This module provides candidates with a deeper knowledge and understanding of how organic chemistry shapes the natural world and how organic chemicals provide many important materials.

This module provides candidates with a knowledge and understanding of organic chemistry:

4.1.1 Arenes

- structure of benzene, electrophilic substitution;
- phenols.

4.1.2 Carbonyl Compounds

- reactions and characteristic tests.

4.1.3 Carboxylic Acids and Esters

- properties;
- esters, triglycerides, unsaturated and saturated fats.

4.1.4 Amines

- basicity and preparation;
- azo dyes.

The material covered in this module builds on, and develops, the knowledge and understanding of functional groups encountered in AS Chemistry.

Unit F322 should be consulted for important information about formulae (2.1.1) and reaction mechanisms (2.1.1.h–j).

Links

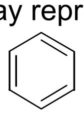
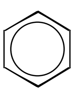
AS Unit F321: *Atoms, Bonds and Groups*

- 1.1.2 Moles and Equations
- 1.2.2 Bonding and Structure

AS Unit F322: *Chains, Energy and Resources*

- 2.1.1 Basic Concepts
- 2.1.2 Alkanes
- 2.1.3 Alkenes
- 2.2.1 Alcohols
- 2.2.2 Halogenoalkanes
- 2.4.1 Chemistry of the Air

4.1.1 Arenes

Context and exemplification	**Assessable learning outcomes**
Structure of benzene How Science Works 1, 7a: • The development and acceptance of models for the structure of benzene. • Students may represent the structure of benzene as  or  in equations and mechanisms.	Candidates should be able to: (a) compare the Kekulé and delocalised models for benzene in terms of p-orbital overlap forming π bonds; (b) review the evidence for a delocalised model of benzene in terms of bond lengths, enthalpy change of hydrogenation and resistance to reaction [see also (e) below];
Electrophilic substitution of arenes • Halogen carriers include iron, iron halides and aluminium halides.	(c) describe the electrophilic substitution of arenes with (i) concentrated nitric acid in the presence of concentrated sulfuric acid,

• For nitration, candidates should include equations for formation of NO_2^+ • For halogenation, candidates should include equations for formation of X^+ or $^{\delta+}X–AlX_3^{\delta-}$.	(ii) a halogen in the presence of a halogen carrier; (d) outline the mechanism of electrophilic substitution in arenes, using the mononitration and monohalogenation of benzene as examples (see also unit F322: 2.1.1.h–j); (e) explain the relative resistance to bromination of benzene, compared with alkenes, in terms of the delocalised electron density of the π bonds in benzene compared with the localised electron density of the C=C bond in alkenes;
Phenols	(f) describe the reactions of phenol: (i) with aqueous alkalis and with sodium to form salts, (ii) with bromine to form 2,4,6-tribromophenol; (g) explain the relative ease of bromination of phenol compared with benzene, in terms of electron-pair donation to the benzene ring from an oxygen *p*-orbital in phenol; (h) state the uses of phenols in production of plastics, antiseptics, disinfectants and resins for paints.

4.1.2 Carbonyl Compounds

Context and exemplification	**Assessable learning outcomes**
Reactions of carbonyl compounds • In equations for organic redox reactions, [O] and [H] should be used. • The nucleophile can be considered as being the hydride ion, H^-, with subsequent protonation of the organic intermediate from H_2O.	Candidates should be able to: (a) describe the oxidation of alcohols (see also unit F322: 2.2.1.f) using $Cr_2O_7^{2-}/H^+$ (ie $K_2Cr_2O_7/H_2SO_4$), including: (i) the oxidation of primary alcohols to form aldehydes and carboxylic acids; the control of the oxidation product using different reaction conditions, (ii) the oxidation of secondary alcohols to form ketones; (b) describe the oxidation of aldehydes using $Cr_2O_7^{2-}/H^+$ to form carboxylic acids; (c) describe the reduction of carbonyl compounds using $NaBH_4$ to form alcohols; (d) outline the mechanism for nucleophilic addition reactions of aldehydes and ketones with hydrides, such as $NaBH_4$ (see also unit F322: 2.1.1.h–j);
Characteristic tests for carbonyl compounds	(e) describe the use of 2,4-dinitrophenylhydrazine to: (i) detect the presence of a carbonyl group in

• The equation for this reaction is not required. • Structure of derivative not required.	an organic compound, (ii) identify a carbonyl compound from the melting point of the derivative;
• In equations involving Tollens' reagent, [O] is acceptable.	(f) describe the use of Tollens' reagent (ammoniacal silver nitrate) to: (i) detect the presence of an aldehyde group, (ii) distinguish between aldehydes and ketones, explained in terms of the oxidation of aldehydes to carboxylic acids with reduction of silver ions to silver.

4.1.3 Carboxylic Acids and Esters

Context and exemplification	**Assessable learning outcomes**
Properties of carboxylic acids • Comparison of acidity of different carboxylic acids not required.	Candidates should be able to: (a) explain the water solubility of carboxylic acids in terms of hydrogen bonding and dipole–dipole interaction; (b) describe the reactions of carboxylic acids with metals, carbonates and bases;
Esters, triglycerides, unsaturated and saturated fats How Science Works 6b: • Examples: octadecanoic acid,18,0; octadec-9-enoic acid, 18,1(9); octadec-9,12-enoic acid, 18,2(9,12) • Link between unsaturated and saturated fats and current concerns about heart disease and obesity. How Science Works 7c: • Use of biodiesel as a fuel to increase contribution to energy requirements from renewable fuels.	(c) describe esterification of carboxylic acids with alcohols, in the presence of an acid catalyst (see also 2.2.1.g); of acid anhydrides with alcohols; (d) describe the hydrolysis of esters: (i) in hot aqueous acid to form carboxylic acids and alcohols, (ii) in hot aqueous alkali to form carboxylate salts and alcohols; (e) state the uses of esters in perfumes and flavourings; (f) describe a *triglyceride* as a triester of glycerol (propane-1,2,3-triol) and fatty acids; (g) compare the structures of saturated fats, unsaturated fats and fatty acids, including *cis* and *trans* isomers, from systematic names and shorthand formulae; (h) compare the link between *trans* fatty acids, the possible increase in 'bad' cholesterol and the resultant increased risk of coronary heart disease and strokes; (i) describe and explain the increased use of esters of fatty acids as biodiesel.

Context and exemplification	Assessable learning outcomes
Basicity of amines • Comparison of basicity of different amines not required.	Candidates should be able to: (a) explain the basicity of amines in terms of proton acceptance by the nitrogen lone pair; (b) describe the reactions of amines with acids to form salts;
Preparation of amines	(c) describe the preparation of: (i) aliphatic amines by substitution of halogenoalkanes with excess ethanolic ammonia, (ii) aromatic amines by reduction of nitroarenes using tin and concentrated hydrochloric acid;
Synthesis of azo dyes • Nitrous acid is generated *in situ* from $NaNO_2/HCl$.	(d) describe the synthesis of an azo dye by reaction of an aromatic amine with nitrous acid (<10 °C), with formation of a diazonium ion, followed by coupling with a phenol under alkaline conditions; (e) state the use of reactions, such as (d), in the formation of dyestuffs.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Preparation and identification of a 2,4-DNPH derivative.
- $NaBH_4$ reduction of a carbonyl compound, eg 1,2-diphenylethanedione.
- Nitration of methyl benzoate.
- Preparation of an ester, eg ethyl ethanoate and methyl 2-hydroxybenzoate.
- Synthesis of antifebrin.
- Hydrolysis of an ester, eg methyl benzoate.
- Synthesis of aspirin.

4.2 Module 2: Polymers and Synthesis

This module provides candidates with a knowledge and understanding of how amino acids are the building blocks of polypeptides and proteins, the preparation of synthetic condensation polymers and the importance of synthetic organic chemistry.

4.2.1 Amino Acids and Chirality
- amino acids, proteins and optical isomerism.

4.2.2 Polyesters and Polyamides
- polymerisation;
- hydrolysis of polymers.

4.2.3 Synthesis
- synthetic routes;
- the importance of chirality in pharmaceutical synthesis.

The material covered in this module builds on, and develops, the knowledge and understanding of functional groups encountered in AS Chemistry.

Links

AS Unit F321**:** *Atoms, Bonds and Groups*
- 1.1.3 Acids.

AS Unit F322: *Chains, Energy and Resources*
- 2.1.1 Basic Concepts.

A2 Unit F324: *Rings, Polymers and Analysis*
- 4.1.3 Carboxylic Acids and Esters;
- 4.1.4 Amines.

4.2.1 Amino Acids and Chirality

Context and exemplification	**Assessable learning outcomes**
Amino acids • In exam papers, candidates will be provided with isoelectric points.	Candidates should be able to: (a) state the general formula for an α-amino acid as $RCH(NH_2)COOH$; (b) state that an amino acid exists as a zwitterion at a pH value called the isoelectric point; (c) state that different R groups in α-amino acids may result in different isoelectric points; (d) describe the acid–base properties of α-amino acids at different pH values;
Peptide formation and hydrolysis of proteins	(e) explain the formation of a peptide (amide) linkage between α-amino acids by condensation and subsequent condensation polymerisation to form polypeptides and proteins (see also 4.2.2.a–e);

	(f) describe the acid and the alkaline hydrolysis of proteins and peptides to form α-amino acids or carboxylates (see also 4.1.3.d);
Optical isomerism	(g) describe *optical isomers* as non-superimposable mirror images about an organic chiral centre: four different groups attached to a carbon atom; (h) identify chiral centres in a molecule of given structural formula; (i) explain that optical isomerism and *E/Z* isomerism (see also unit F322: 2.1.1.f) are different types of stereoisomerism.

4.2.2 Polyesters and Polyamides

Context and exemplification	**Assessable learning outcomes**
Condensation polymers	Candidates should be able to: (a) describe *condensation polymerisation* to form
• Candidates will not be expected to recall the structures of synthetic polyesters and polyamides or their monomers.	(i) polyesters, eg Terylene from benzene-1,4-dicarboxylic acid and ethane-1,2-diol, poly(lactic acid) from 2-hydroxypropanoic acid (lactic acid) (see (h) below),
• See also polypeptides and proteins from amino acids, 4.2.1.e.	(ii) polyamides, eg nylon-6,6 from 1,6-diaminohexane and hexane-1,6-dicarboxylic acid, Kevlar from benzene-1,4-diamine and benzene-1,4-dicarboxylic acid;
• Condensation and addition polymerisation required for (c) and (d).	(b) compare condensation polymerisation with addition polymerisation (see also unit F322: 2.1.3.g–i); (c) suggest the type of polymerisation from: (i) a given monomer or pair of monomers, (ii) a given section of a polymer molecule; (d) identify the monomer(s) required to form a given section of a polymer (and *vice versa*); (e) state the use of polyesters and polyamides as fibres in clothing;
Hydrolysis and degradable polymers	(f) describe the acid and the base hydrolysis of polyesters and polyamides;
• Poly(lactic acid) is used for waste sacks, packaging, disposable eating utensils and medical applications such as internal stitches.	(g) outline the role of chemists in minimising environmental waste by development of degradable polymers, similar in structure to poly(lactic acid) [see (a) above];
How Science Works 6b: • Production of degradable polymers from renewable resources.	(h) explain that condensation polymers: (i) may be photodegradable as the C=O bond absorbs radiation, (ii) may be hydrolysed at the ester or amide group.

4.2.3 Synthesis

Context and exemplification	Assessable learning outcomes
Synthetic routes • Candidates will only be expected to identify functional groups encountered in the specification.	Candidates should be able to: (a) for an organic molecule containing several functional groups: (i) identify individual functional groups, (ii) predict properties and reactions; (b) devise multi-stage synthetic routes for preparing organic compounds;
Chirality in pharmaceutical synthesis How Science Works 6a, 6b: • Requirement for chiral drugs and medicines to minimise side effects, for economical reasons and to reduce risk to companies from litigation. • Examples of chemical chiral synthesis use cyclic strained molecules, reagents fixed to a polymer support with reactants flowing over them, and supercritical CO_2.	(c) explain that the synthesis of pharmaceuticals often requires the production of a single optical isomer; (d) explain that molecules prepared synthetically in the laboratory often contain a mixture of optical isomers, whereas molecules of the same compound produced naturally by enzymes in living systems will often be present as one optical isomer only; (e) explain that the synthesis of a pharmaceutical that is a single optical isomer: (i) increases costs due to difficulty in separating the optical isomers, (ii) reduces possible side effects and improves pharmacological activity; (f) explain that modern synthesis of a pharmaceutical with a single optical isomer is often carried out: (i) using enzymes or bacteria which promote stereoselectivity, (ii) using chemical chiral synthesis or chiral catalysts, (iii) using natural chiral molecules, such as L-amino acids or sugars, as starting materials.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Reactions of glycine.
- Nylon rope trick demonstration.

4.3 Module 3: Analysis

This module provides candidates with a deeper knowledge and understanding of modern analytical techniques for organic chemicals. In addition this module also highlights some of the analytical techniques encountered in many areas of employment and in everyday life. The material covered in this module includes the application of some of the important instrumentation techniques used in organic and forensic analysis.

4.3.1 Chromatography
  - thin-layer and gas chromatography;
  - GC-MS.

4.3.2 Spectroscopy
  - NMR spectroscopy;
  - combined techniques.

Links

AS Unit F322: *Chains, Energy and Resources*
- 2.2.3 Modern Analytical Techniques.

4.3.1 Chromatography

Context and exemplification	**Assessable learning outcomes**
Types of chromatography • Paper chromatography can be used to illustrate the separation process.	Candidates should be able to: (a) describe chromatography as an analytical technique that separates components in a mixture between a mobile phase and a stationary phase; (b) state that: (i) the mobile phase may be a liquid or a gas, (ii) the stationary phase may be a solid (as in thin-layer chromatography, TLC) or either a liquid or solid on a solid support (as in gas chromatography, GC); (c) state that: (i) a solid stationary phase separates by adsorption, (ii) a liquid stationary phase separates by relative solubility; (d) explain the term R_f *value*, and interpret one-way chromatograms in terms of R_f values; (e) explain the term *retention time*, and interpret gas chromatograms in terms of retention times and the approximate proportions of the components of a mixture; (f) explain that analysis by gas chromatography has limitations, eg:

  - (i) similar compounds often have similar retention times,
  - (ii) unknown compounds have no reference retention times for comparison;

Combining mass spectrometry with chromatography

- Mass spectrometry is used with GC as GC-MS and with high pressure liquid chromatography as HPLC-MS; separated components are directed into the mass spectrometer.
- Candidates may be expected to interpret provided gas chromatograms and mass spectra (see also unit F322: 2.2.3.f–h).

How Science Works 3, 7c:

- Use of GC-MS by society in modern analysis and the use of such evidence in courts.

(g) explain that mass spectrometry can be combined with chromatography:
  - (i) to provide a far more powerful analytical tool than from chromatography alone,
  - (ii) to generate mass spectra which can be analysed or compared with a spectral database by computer for positive identification of a component;

(h) state the use of GC-MS in analysis, eg in forensics, environmental analysis, airport security and space probes.

4.3.2 Spectroscopy

Context and exemplification

NMR Spectroscopy

- Background theory will not be tested on examination papers: the emphasis is on the interpretation of spectra. Thus, candidates will not be tested on why nuclear magnetic resonance takes place, the reasons for different chemical shift values, why spin–spin splitting occurs or why ^{13}C NMR requires proton decoupling.
- All carbon-13 NMR spectra that are assessed will be proton decoupled.
- In examinations, NMR chemical shift values will be provided on the *Data Sheet*.
- Compounds chosen will be limited to those containing any of the following atoms: C, H, N, O and halogens.
- Candidates will be expected to identify aromatic protons from chemical shift values but will not be expected to analyse their splitting patterns.

Assessable learning outcomes

Candidates should be able to:

(a) state that NMR spectroscopy involves interaction of materials with the low-energy radiowave region of the electromagnetic spectrum;

(b) analyse a carbon-13 NMR spectrum of a simple molecule to make predictions about:
  - (i) the different types of carbon present, from chemical shift values,
  - (ii) possible structures for the molecule;

(c) analyse a high resolution proton NMR spectrum of a simple molecule to make predictions about:
  - (i) the different types of proton present, from chemical shift values,
  - (ii) the relative numbers of each type of proton present from relative peak areas, using integration traces or ratio numbers, when required,
  - (iii) the number of non-equivalent protons adjacent to a given proton from the spin–spin splitting pattern, using the *n* + 1 rule,
  - (iv) possible structures for the molecule;

(d) predict the chemical shifts and splitting patterns of the protons in a given molecule;

(e) describe the use of tetramethylsilane, TMS, as the standard for chemical shift measurements;

(f) state the need for deuterated solvents, eg $CDCl_3$, when running an NMR spectrum;

(g) describe the identification of O–H and N–H protons by proton exchange using D_2O;

(h) explain that NMR spectroscopy is the same technology as that used in ‘magnetic resonance imaging’ (MRI) to obtain diagnostic information about internal structures in body scanners;

Combined techniques

- In examinations, infrared absorption values will be provided on the *Data Sheet*.
- Rearrangement reactions are not required; unipositive ions only.

(i) For organic compounds containing any of the following atoms: C, H, N and O:

  (i) analyse infrared absorptions in an infrared spectrum to identify the presence of functional groups in a molecule (see also unit F322: 2.2.3.b),

  (ii) analyse molecular ion peaks and fragmentation peaks in a mass spectrum to identify parts of structures (see also unit F322: 2.2.3.f–h),

  (iii) combine evidence from a number of spectra: NMR, IR and mass spectra, to deduce structures.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Thin-layer or paper chromatography.
- Interpretation of spectra – spectra available at: http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/cre_index.cgi?lang=eng

3.5 A2 Unit F325: *Equilibria, Energetics and Elements*

This unit builds upon the chemical concepts that have been developed during AS Chemistry.

This unit consists of **three** teaching modules:

- Module 1: **Rates, Equilibrium and pH**
  - 5.1.1 How Fast?
  - 5.1.2 How Far?
  - 5.1.3 Acids, Bases and Buffers
- Module 2: **Energy**
  - 5.2.1 Lattice Enthalpy
  - 5.2.2 Enthalpy and Entropy
  - 5.2.3 Electrode Potentials and Fuel Cells
- Module 3: **Transition Elements**
  - 5.3.1 Transition Elements

Candidates are expected to apply knowledge, understanding and other skills gained in this unit to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should

- have studied AS Chemistry and, ideally, A2 unit F324.

5.1 Module 1: Rates, Equilibrium and pH

This module provides candidates with a quantitative study of physical chemistry. The material covered in this module links many areas of chemistry and explains many chemical phenomena. For example, the qualitative treatment of reaction rates and equilibria encountered at AS is developed within a quantitative and graphical context.

5.1.1 How Fast?

- orders, rate equations, rate constants;
- continuous and initial rate methods;
- rate-determining step.

5.1.2 How Far?

- equilibrium concentrations;
- the equilibrium constant, K_c.

5.1.3 Acids, Bases and Buffers

- acid–base equilibria;
- strength of acids including K_a;
- pH determination, titration curves and buffer solutions.

Links

AS Unit F321: *Atoms, Bonds and Groups*
1.1.3 Acids;
1.3.2 Group 2 (acid reactions with metals, carbonates and bases).

AS Unit F322: *Chains, Energy and Resources*
2.3.2 Rates and Equilibrium.

5.1.1 How Fast?

Context and exemplification	Assessable learning outcomes
Rate graphs and orders	Candidates should be able to: (a) explain and use the terms: *rate of reaction*, *order*, *rate constant*, *half-life*, *rate-determining step*;
• Concentration–time can be plotted from continuous measurements taken during the course of a reaction (continuous monitoring).	(b) deduce, from a concentration–time graph, the rate of a reaction and the half-life of a first-order reaction;
	(c) state that the half-life of a first-order reaction is independent of the concentration;
	(d) deduce, from a rate–concentration graph, the order (0, 1 or 2) with respect to a reactant;
• Initial rates require separate experiments using different concentrations of one of the reactants. Clock reactions are an approximation of this method.	(e) determine, using the initial rates method, the order (0, 1 or 2) with respect to a reactant;
Rate equations; rate constants • Integrated forms of rate equations are not required.	(f) deduce, from orders, a rate equation of the form: rate = $k[A]^m[B]^n$, for which m and n are 0, 1 or 2;
	(g) calculate the rate constant, k, from a rate equation;
	(h) explain qualitatively the effect of temperature change on a rate constant and hence the rate of a reaction;
Rate-determining step	(i) for a multi-step reaction: (i) propose a rate equation that is consistent with the rate-determining step,
How Science Works 1, 7a: • Use of rate equations to predict and propose a reaction mechanism.	(ii) propose steps in a reaction mechanism from the rate equation and the balanced equation for the overall reaction.

5.1.2 How Far?

Context and exemplification	Assessable learning outcomes
Equilibrium - Candidates will not be required to solve quadratic equations.	Candidates should be able to: (a) calculate, given appropriate data, the concentration or quantities present at equilibrium; (b) deduce, for homogeneous reactions, expressions for the equilibrium constant K_c; (c) calculate the values of the equilibrium constant K_c including determination of units; (d) explain the effect of changing temperature on the value of K_c for exothermic and endothermic reactions; (e) state that the value of K_c is unaffected by changes in concentration or pressure or by the presence of a catalyst.

5.1.3 Acids, Bases and Buffers

Context and exemplification	Assessable learning outcomes
Brønsted–Lowry acids and bases	Candidates should be able to: (a) describe an acid as a species that can donate a proton and a base as a species that can accept a proton (see also unit F321: 1.1.3.a,h); (b) illustrate, using ionic equations, the role of H^+ in the reactions of acids with metals, carbonates, bases and alkalis (see also unit F321: 1.1.3.g; 1.1.4.f); (c) describe and use the term *conjugate acid–base pairs*;
Strong and weak acids	(d) explain qualitatively, in terms of dissociation, the differences between *strong* and *weak* acids; (e) explain that the *acid dissociation constant,* K_a, shows the extent of acid dissociation; (f) deduce, for weak acids, expressions for K_a and pK_a;
pH and $[H^+(aq)]$ - For a weak acid HA, assume: $[H^+(aq)] = [A^-(aq)]$; equilibrium [HA] = undissociated [HA].	(g) define *pH* as $pH = -\log[H^+]$; $[H^+] = 10^{-pH}$; (h) state and use the expression for the *ionic product of water*, K_w;

(i) calculate pH from [$H^+(aq)$] and [$H^+(aq)$] from pH for:

  (i) strong monobasic acids,

  (ii) weak monobasic acids,

  (iii) strong bases, using K_w;

(j) calculate K_a for a weak acid, given appropriate data;

Buffers: action, uses and calculations

- The details of a basic buffer system are not required.

(k) describe a *buffer solution* as a system that minimises pH changes on addition of small amounts of an acid or a base;

(l) state that a buffer solution can be made from a weak acid and a salt of the weak acid, eg CH_3COOH/CH_3COONa;

(m) explain the role of the conjugate acid–base pair in an acid buffer solution, eg CH_3COOH/CH_3COO^-, in the control of pH;

(n) calculate the pH of a buffer solution, from the K_a value of a weak acid and the equilibrium concentrations of the conjugate acid–base pair;

- The H_2CO_3/HCO_3^- buffer is present in blood plasma, maintaining a pH between 7.35 and 7.45.

(o) explain the role of carbonic acid–hydrogencarbonate as a buffer in the control of blood pH;

Neutralisation

(p) for acid–base titration pH curves for strong and weak acids and bases:

  (i) interpret, or sketch, their shapes,

  (ii) explain the choice of suitable indicators for acid–base titrations, given the pH range of the indicator;

(q) define and use the term *enthalpy change of neutralisation* and calculate enthalpy changes from appropriate experimental results (see also unit F322: 2.3.1.f,g).

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Continuous monitoring of a reaction for ‘quantity’ against time graph:
  $CaCO_3/HCl$: monitoring gas or mass loss; $H^+/I_2/(CH_3)_2CO$: monitoring [I_2] using a colorimeter.
- Clock reactions for determination of orders and rate constants by initial rates and rate concentration graphs:
  Iodine clocks: $I_2/S_2O_8^{2-}$ or $H^+/H_2O_2/I_2$ with $S_2O_3^{2-}$ (or vitamin C); Thiosulfate clock: $HCl/S_2O_3^{2-}$.
- The effect of temperature on reaction rates (clock reactions above are suitable).
- Determination of K_c for ethanoic acid/ethyl ethanoate equilibrium.
- Use of pH meters to: measure pHs of strong and weak acids; investigate buffer solutions.
- Generating an acid–base titration curve with a data logger, www.chemit.co.uk/uploads/java/ .

5.2 Module 2: Energy

This module extends the study of energy encountered within unit F322: Chains, Energy and Resources. This module provides candidates with a deeper knowledge and understanding of chemical energy and also considers ways in which scientists are working to provide cleaner and more efficient energy.

The main areas of energy studied include:

5.2.1 Lattice Enthalpy

- lattice enthalpy and Born–Haber cycles.

5.2.2 Enthalpy and Entropy

- enthalpy *versus* entropy;
- free energy.

5.2.3 Electrode Potentials and Fuel Cells

- redox chemistry and electrochemical cells;
- fuel cells for the future.

Links

AS Unit F321: *Atoms, Bonds and Groups*

- 1.1.4 Redox.

AS Unit F322: *Chains, Energy and Resources*

- 2.3.1 Enthalpy Changes;
- 2.4.1 Chemistry of the Air.

5.2.1 Lattice Enthalpy

Context and exemplification	Assessable learning outcomes
Lattice enthalpy	Candidates should be able to: (a) explain and use the term *lattice enthalpy* (ΔH negative, ie gaseous ions to the solid lattice) as a measure of ionic bond strength;
Born–Haber and related enthalpy cycles Relevant Energy Terms: *enthalpy change of formation, ionisation energy, enthalpy change of atomisation and electron affinity.* How Science Works 1, 7a: • Born–Haber cycle as a model for determination of lattice enthalpies and in testing the ionic model of bonding.	(b) use the lattice enthalpy of a simple ionic solid (ie NaCl, $MgCl_2$) and relevant energy terms to: (i) construct Born–Haber cycles, (ii) carry out related calculations; (c) explain and use the terms *enthalpy change of solution* and *enthalpy change of hydration*; (d) use the enthalpy change of solution of a simple ionic solid (ie NaCl, $MgCl_2$) and

relevant energy terms (*enthalpy change of hydration,* and *lattice enthalpy*), to:

(i) construct Born–Haber cycles,

(ii) carry out related calculations;

(e) explain, in qualitative terms, the effect of ionic charge and ionic radius on the exothermic value of a lattice enthalpy and enthalpy change of hydration.

5.2.2 Enthalpy and Entropy

Context and exemplification	Assessable learning outcomes
Entropy	Candidates should be able to: (a) explain that entropy is a measure of the 'disorder' of a system, and that a system becomes energetically more stable when it becomes more disordered; (b) explain the difference in magnitude of entropy: (i) of a solid and a gas, (ii) when a solid lattice dissolves, (iii) for a reaction in which there is a change in the number of gaseous molecules; (c) calculate the entropy change for a reaction given the entropies of the reactants and products;
Balance between entropy and enthalpy changes	(d) explain that the tendency of a process to take place depends on temperature, T, the entropy change in the system, ΔS, and the enthalpy change, ΔH, with the surroundings; (e) explain that the balance between entropy and enthalpy changes is the *free energy change*, ΔG, which determines the feasibility of a reaction; (f) state and use the relationship $\Delta G = \Delta H - T\Delta S$; (g) explain, in terms of enthalpy and entropy, how endothermic reactions are able to take place spontaneously.

5.2.3 Electrode Potentials and Fuel Cells

Context and exemplification	**Assessable learning outcomes**
Redox	Candidates should be able to: (a) explain, for simple redox reactions, the terms *redox, oxidation number, half-reaction, oxidising agent* and *reducing agent* (see also unit F321: 1.1.4); (b) construct redox equations using relevant half-equations or oxidation numbers; (c) interpret and make predictions for reactions involving electron transfer.
Electrode potentials - $E^{\ominus}$ data will be provided on examination papers. - For $E^{\ominus}$ measurements, ions of the same element can have concentrations of 1 mol dm^{-3} or be equimolar.	(d) define the term *standard electrode (redox) potential*, $E^{\ominus}$; (e) describe how to measure, using a hydrogen electrode, standard electrode potentials of: (i) metals or non-metals in contact with their ions in aqueous solution, (ii) ions of the same element in different oxidation states; (f) calculate a standard cell potential by combining two standard electrode potentials;
Feasibility of reactions	(g) predict, using standard cell potentials, the feasibility of a reaction; (h) consider the limitations of predictions made using standard cell potentials, in terms of kinetics and concentration;
Storage and fuel cells - Recall of a specific storage cell will not be required. - Candidates will be expected to make predictions on supplied storage cells. All relevant electrode potentials and other data will be supplied. - Hydrogen-rich fuels include methanol, natural gas, or petrol, which are converted into hydrogen gas by an onboard 'reformer'. How Science Works 6a: - Development of fuel cells as an alternative to direct use of finite oil-based fuels in cars compared with logistical problems of their development and use. - Pure hydrogen emits only water whilst hydrogen-rich fuels produce only small amounts of air pollutants and CO_2.	(i) apply principles of electrode potentials to modern storage cells; (j) explain that a fuel cell uses the energy from the reaction of a fuel with oxygen to create a voltage; (k) explain the changes that take place at each electrode in a hydrogen–oxygen fuel cell; (l) outline that scientists in the car industry are developing fuel cell vehicles (FCVs), fuelled by: (i) hydrogen gas, (ii) hydrogen-rich fuels; (m) state advantages of FCVs over conventional petrol or diesel-powered vehicles, in terms of: (i) less pollution and less CO_2, (ii) greater efficiency;

- Efficiency can be more than twice that of similarly sized conventional vehicles; other advanced technologies can further increase efficiency.

How Science Works 7a, 7b:

- Political and social desire to move to a hydrogen economy has many obstacles including ignorance that energy is needed to produce hydrogen and that fuel cells have a finite life.
- Hydrogen is an energy carrier and not a source.

(n) understand how hydrogen might be stored in FCVs:
    (i) as a liquid under pressure,
    (ii) adsorbed on the surface of a solid material,
    (iii) absorbed within a solid material;

(o) consider limitations of hydrogen fuel cells, for example:
    (i) storing and transporting hydrogen, in terms of safety, feasibility of a pressurised liquid and a limited life cycle of a solid 'adsorber' or 'absorber',
    (ii) limited lifetime (requiring regular replacement and disposal) and high production costs,
    (iii) use of toxic chemicals in their production (see also unit F322: 2.4.2);

(p) comment that a 'hydrogen economy' may contribute largely to future energy needs but limitations include:
    (i) public and political acceptance of hydrogen as a fuel,
    (ii) handling and maintenance of hydrogen systems,
    (iii) initial manufacture of hydrogen, requiring energy.

Practical Skills are assessed using OCR set tasks. The practical work suggested below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Measuring enthalpy changes of solution.
- Measuring an enthalpy change of neutralisation by a thermometric titration.
- Redox reactions (test-tube scale):
    metal displacements;
    reactions involving colour changes.
- Constructing electrochemical cells and measuring electrode potentials.
- Making a fuel cell.

5.3 Module 3: Transition Elements

This module extends the study of periodicity encountered within unit F321: Atoms, Bonds and Groups. By studying the transition elements, this module provides candidates with a deeper knowledge and understanding of inorganic chemistry and the Periodic Table. The module also links with many other areas of chemistry and provides many opportunities to consider chemistry synoptically.

5.3.1 Transition Elements

- general properties;
- precipitation reactions;
- ligands and complex ions;
- ligand substitution;
- redox reactions and titrations.

Links

AS Unit F321: *Atoms, Bonds and Groups*

- 1.1.4 Redox
- 1.3.2 Group 2

A2 Unit F325: *Equilibria, Energetics and Elements*

- 5.1.2 How Far?
- 5.2.3 Electrode Potentials and Fuel Cells

5.3.1 Transition Elements

Context and exemplification	Assessable learning outcomes
Properties • Candidates should use sub-shell notation, eg for Fe: $1s^22s^22p^63s^23p^63d^64s^2$. • No detail of how colour arises is required. • No detail of catalytic processes required.	Candidates should be able to: (a) deduce the electron configurations of atoms and ions of the d-block elements of Period 4 (Sc–Zn) , given the atomic number and charge; (b) describe the elements Ti–Cu as *transition elements*, ie d-block elements that have an ion with an incomplete d sub-shell; (c) illustrate: (i) the existence of more than one oxidation state for each element in its compounds, (ii) the formation of coloured ions, (iii) the catalytic behaviour of the elements and/or their compounds;

Precipitation reactions

- Non-complexed formulae such as $Cu(OH)_2$ and $Fe(OH)_3$ are acceptable.
- Oxidation of alkaline Fe(II) and Co(II) not required.

(d) describe, including ionic equations, the simple precipitation reactions and the accompanying colour changes of $Cu^{2+}(aq)$, $Co^{2+}(aq)$, $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ with aqueous sodium hydroxide;

Ligands and complex Ions

- Examples should use H_2O, Cl^-, NH_3 as simple monodentate ligands. In examinations, other ligands might be introduced.

(e) explain the term *ligand* in terms of coordinate bonding;

(f) state and use the terms *complex ion* and *coordination number*;

(g) state and give examples of complexes with sixfold coordination with an octahedral shape;

(h) explain and use the term *bidentate ligand* (eg $NH_2CH_2CH_2NH_2$, ‘en’);

(i) describe the types of stereoisomerism shown by complexes, including those associated with bidentate and multidentate ligands:

   (i) *cis-trans* isomerism, eg $Ni(NH_3)_2Cl_2$,

   (ii) optical isomerism, eg $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$;

(j) describe the use of *cis*-platin as an anti-cancer drug and its action by binding to DNA in cancer cells, preventing division;

Ligand substitution

(k) describe the process of ligand substitution and the accompanying colour changes in the formation of:

   (i) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[CuCl_4]^{2-}$ from $[Cu(H_2O)_6]^{2+}$,

   (ii) $[CoCl_4]^{2-}$ from $[Co(H_2O)_6]^{2+}$;

(l) explain the biochemical importance of iron in haemoglobin, including ligand substitution involving O_2 and CO;

(m) state that the stability constant, $K_{stab,}$, of a complex ion is the equilibrium constant for the formation of the complex ion in a solvent from its constituent ions;

(n) deduce expressions for the stability constant, K_{stab}, of a ligand substitution, eg

$M^{2+}(aq) + 6X^-(aq) \rightleftharpoons MX_6^{4-}(aq)$
$K_{stab} = [MX_6^{4-}(aq)]/[M^{2+}(aq)][X^-(aq)]^6$
(see also 5.1.2.b);

(o) relate ligand substitution reactions of complexes to stability constants and understand that a large K_{stab} results in formation of a stable complex ion;

Redox reactions and titrations

- Non-structured titration calculations could be examined in the context of both acid–base and redox titrations.

(p) describe, using suitable examples, redox behaviour in transition elements;

(q) carry out redox titrations, and carry out structured calculations, involving MnO_4^- and $I_2/S_2O_3^{2-}$;

(r) perform non-structured titration calculations, based on experimental results.

Practical Skills are assessed using specified OCR set tasks. The practical work outlined below may be carried out as part of skill development. Centres are not required to carry out all of these experiments:

- Precipitation of transition metal hydroxides (test-tube scale).
- Ligand substitution reaction of complex ions (test-tube scale).
- Redox titrations:
  the estimation of iron in iron tablets titration with MnO_4^- in acid conditions;
  the estimation of copper in alloys such as brass by titration using $I_2/S_2O_3^{2-}$.

3.6 A2 Unit F326: *Practical Skills in Chemistry 2*

This unit assesses practical and investigative skills developed within contexts encountered during A Level Chemistry. Further information on the assessment of the tasks is provided as Appendix D.

Candidates are required to carry out **three** tasks:

1. Qualitative task [10 marks];
2. Quantitative task [15 marks];
3. Evaluative task [15 marks].

Tasks will be chosen from a selection provided by OCR.

The Qualitative and Quantitative tasks will test skills of observation and measurement.

Candidates will carry out these tasks under controlled conditions.

Each task will be internally assessed using a mark scheme provided by OCR.

Candidates may attempt more than one task from each category with the best mark from each category being used to make up the overall mark.

Centres will supply OCR with a single mark out of 40.

How Science Works

5a Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.

5b Analyse and interpret data to provide evidence, recognising correlations and causal relationships.

5c Evaluate methodology, evidence and data, and resolve conflicting evidence.

The mark schemes supplied by OCR will be based on the following generic criteria:

	Assessable learning outcomes
1. Qualitative task • Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate skilful and safe practical techniques using suitable qualitative methods; (b) make and record valid observations; organise results suitably.
2. Quantitative task • Candidates carry out a practical task using instructions supplied by OCR.	Candidates should be able to: (a) demonstrate skilful and safe practical techniques using suitable quantitative methods; (b) make and record accurate measurements to an appropriate precision; (c) analyse, interpret and evaluate experimentally derived results quantitatively to reach valid conclusions.
3. Evaluative task • This task may extend one of the qualitative or quantitative tasks. • Candidates will evaluate the quality of the data and procedures. • Evaluative tasks will not require additional data collection.	Candidates should be able to: (a) analyse and interpret data; identify anomalies and reach valid conclusions; (b) assess the reliability and accuracy of an experimental task, identify significant weaknesses in experimental procedures and measurements; (c) understand and select simple improvements to experimental procedures and measurements.

The Tasks

Tasks, mark schemes and guidance for teachers and technicians can be downloaded from the OCR Interchange site.

Further advice and guidance on the use and marking of the tasks can be found in the Practical Skills Handbook.

4 Schemes of Assessment

4.1 AS GCE Scheme of Assessment

AS GCE Chemistry A (H034)	
AS Unit F321: *Atoms, Bonds and Groups*	
30% of the total AS GCE marks 1 h written paper 60 marks	Candidates answer **all** questions.
AS Unit F322: *Chains, Energy and Resources*	
50% of the total AS GCE marks 1.75 h written paper 100 marks	Candidates answer **all** questions.
AS Unit F323: *Practical Skills in Chemistry 1*	
20% of the total AS GCE marks Coursework 40 marks	Candidates complete three tasks set by OCR. Tasks are marked by the centre using a mark scheme written by OCR. Work is moderated by OCR.
	Assessment criteria: please refer to Section 3.3.

4.2 Advanced GCE Scheme of Assessment

Advanced GCE Chemistry A (H434)	
AS Units as above, Unit F321 being 15% of the total Advanced GCE marks, Unit F322 being 25% of the Advanced GCE marks and Unit F323 being 10% of the Advanced GCE marks.	
A2 Unit F324: *Rings, Polymers and Analysis*	
15% of the total Advanced GCE marks 1 h written paper 60 marks	Candidates answer **all** questions. This unit contains some synoptic assessment and Stretch and Challenge questions.
A2 Unit F325: *Equilibria, Energetics and Elements*	
25% of the total Advanced GCE marks 1.75 h written paper 100 marks	Candidates answer **all** questions. This unit contains some synoptic assessment and Stretch and Challenge questions.
A2 Unit F326: *Practical Skills in Chemistry 2*	
10% of the total Advanced GCE marks Coursework 40 marks	Candidates complete three tasks set by OCR. Tasks are marked by the centre using a mark scheme written by OCR. Work is moderated by OCR.
	Assessment criteria: please refer to Section 3.6.

4.3 Unit Order

The normal order in which the unit assessments could be taken is AS Units F321, F322 and F323 in the first year of study, leading to an AS GCE award, then A2 Units F324, F325 and F326 leading to the Advanced GCE award.

Alternatively, candidates may take a valid combination of unit assessments at the end of their AS GCE or Advanced GCE course in a 'linear' fashion.

4.4 Unit Options (at AS/A2)

There are no optional units in the AS GCE specification; for AS GCE Chemistry A, candidates must take AS Units F321, F322 and F323.

There are no optional units in the Advanced GCE specification; for Advanced GCE Chemistry A, candidates take AS Units F321, F322 and F323, *and* A2 Units F324, F325 and F326.

4.5 Synoptic Assessment (A Level GCE)

Synoptic assessment tests the candidates' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. All A2 units, whether internally or externally assessed, contain synoptic assessment.

Synoptic assessment requires candidates to make and use connections within and between different areas of chemistry at AS and A2, for example, by:

- applying knowledge and understanding of more than one area to a particular situation or context;
- using knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data;
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

All A2 units, F324–F326, contain some synoptic assessment.

4.6 Assessment Availability

There are two examination series each year, in January and June.

The availability of units is shown below.

Level	Unit	January 2009	June 2009	January 2010	June 2010	January 2011	June 2011
AS	F321	✓	✓	✓	✓	✓	✓
AS	F322		✓	✓	✓	✓	✓
AS	F323		✓		✓		✓
A2	F324			✓	✓	✓	✓
A2	F325				✓	✓	✓
A2	F326				✓		✓

The availability shown for 2011 will apply for subsequent years.

4.7 Assessment Objectives

Candidates are expected to demonstrate the following in the context of the content described:

AO1 Knowledge and Understanding

- recognise, recall and show understanding of scientific knowledge;
- select, organise and communicate relevant information in a variety of forms.

AO2 Application of Knowledge and Understanding

- analyse and evaluate scientific knowledge and processes;
- apply scientific knowledge and processes to unfamiliar situations including those related to issues;
- assess the validity, reliability and credibility of scientific information.

AO3 How Science Works

- demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods.

- make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy.

- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

AO Weightings in AS GCE

Unit	% of AS GCE			
	AO1	AO2	AO3	Total
AS Unit F321: *Atoms, Bonds and Groups*	14	14	2	30%
AS Unit F322: *Chains, Energy and Resources*	21	24	5	50%
AS Unit F323: *Practical Skills in Chemistry 1*	3	2	15	20%
	38%	40%	22%	100%

AO Weightings in Advanced GCE

Unit	% of Advanced GCE			
	AO1	AO2	AO3	Total
AS Unit F321: *Atoms, Bonds and Groups*	7	7	1	15%
AS Unit F322: *Chains, Energy and Resources*	10.5	12	2.5	25%
AS Unit F323: *Practical Skills in Chemistry 1*	1.5	1	7.5	10%
A2 Unit F324: *Rings, Polymers and Analysis*	5	9	1	15%
A2 Unit F325: *Equilibria, Energetics and Elements*	9	13.5	2.5	25%
A2 Unit F326: *Practical Skills in Chemistry 2*	1	1.5	7.5	10%
	34%	44.%	22%	100%

4.8 Quality of Written Communication

Quality of Written Communication is assessed in all units and credit may be restricted if communication is unclear.

Candidates will:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;

- select and use a form and style of writing appropriate to purpose and to complex subject matter;

- organise information clearly and coherently, using specialist vocabulary when appropriate.

5 Technical Information

5.1 Making Unit Entries

Please note that centres must be registered with OCR in order to make any entries, including estimated entries. It is recommended that centres apply to OCR to become a registered centre well in advance of making their first entries. Centres must have made an entry for a unit in order for OCR to supply the appropriate forms or moderator details for internal assessment.

It is essential that unit entry codes are quoted in all correspondence with OCR. See Sections 4.1 and 4.2 for these unit entry codes.

5.2 Making Qualification Entries

Candidates must enter for qualification certification separately from unit assessment(s). If a certification entry is **not** made, no overall grade can be awarded.

Candidates may enter for:

- AS GCE certification (entry code H034).
- Advanced GCE certification (entry code H434).

A candidate who has completed all the units required for the qualification may enter for certification either in the same examination series (within a specified period after publication of results) or in a later series.

AS GCE certification is available from June 2009.
Advanced GCE certification is available from June 2010.

5.3 Grading

All GCE units are awarded a–e. The AS GCE is awarded on the scale A–E. The Advanced GCE is awarded on the scale A–E with access to an A*. To be awarded an A*, candidates will need to achieve a grade A on their full A Level qualification and an A* on the aggregate of their A2 units. Grades are reported on certificates. Results for candidates who fail to achieve the minimum grade (E or e) will be recorded as *unclassified* (U or u) and this is **not** certificated.

A Uniform Mark Scale (UMS) enables comparison of candidates' performance across units and across series and enables candidates' scores to be put on a common scale for aggregation purposes. The three-unit AS GCE has a total of 300 *uniform* marks and the six-unit Advanced GCE has a total of 600 *uniform* marks.

OCR converts the candidate's raw mark for each unit to a *uniform* mark. The maximum *uniform* mark for any unit depends on that unit's weighting in the specification. In these Chemistry A specifications, the six units of the Advanced GCE specification have UMS weightings of 15%/25%/10%/15%/25%/10% (and the three units of the AS GCE specification have UMS weightings of 30%/50%/20%). The *uniform* mark totals are 90/150/60/90/150/60, respectively. Each unit's *raw* mark grade boundary equates to the *uniform* mark boundary at the same grade. Intermediate marks are converted on a *pro-rata* basis.

Uniform marks correspond to *unit* grades as follows:

(Advanced GCE) Unit Weighting	Maximum Unit Uniform Mark	Unit Grade					
		a	b	c	d	e	u
25%	150	150–120	119–105	104–90	89–75	74–60	59–0
15%	90	90–72	71–63	62–54	53–45	44–36	35–0
10%	60	60–48	47–42	41–36	35–30	29–24	23–0

OCR adds together the unit *uniform* marks and compares these to pre-set boundaries (see the table below) to arrive at *qualification* grades (A–E).

Qualification	Qualification Grade					
	A	B	C	D	E	U
AS GCE	300–240	239–210	209–180	179–150	149–120	119–0
Advanced GCE	600–480	479–420	419–360	359–300	299–240	239–0

Candidates achieving at least 480 *uniform* marks in their Advanced GCE, ie grade A, and who also gain at least 270 *uniform* marks in their three A2 units will receive an A* grade.

5.4 Result Enquiries and Appeals

Under certain circumstances, a centre may wish to query the grade available to one or more candidates or to submit an appeal against an outcome of such an enquiry. Enquiries about unit results must be made immediately following the series in which the relevant unit was taken.

For procedures relating to enquires on results and appeals, centres should consult the OCR *Administration Guide for General Qualifications* and the document *Enquiries about Results and Appeals – Information and Guidance for Centres* produced by the Joint Council. Copies of the most recent editions of these papers can be obtained from OCR.

5.5 Shelf-life of Units

Individual unit results, prior to certification of the qualification, have a shelf-life limited only by that of the qualification.

5.6 Unit and Qualification Re-sits

There is no restriction on the number of times a candidate may re-sit each unit before entering for certification for an AS GCE or Advanced GCE.

Candidates may enter for the full qualifications an unlimited number of times.

5.7 Guided Learning Hours

AS GCE Chemistry A requires **180** guided learning hours in total.
Advanced GCE Chemistry A requires **360** guided learning hours in total.

5.8 Code of Practice/Subject Criteria/Common Criteria Requirements

These specifications comply in all respects with current *GCSE, GCE, GNVQ and AEA Code of Practice* as available on the QCA website, the subject criteria for GCE Chemistry and *The Statutory Regulation of External Qualifications 2004*.

5.9 Arrangements for Candidates with Particular Requirements

For candidates who are unable to complete the full assessment or whose performance may be adversely affected through no fault of their own, teachers should consult the *Access Arrangements and Special Consideration: Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations* produced by the Joint Council. In such cases advice should be sought from OCR as early as possible during the course.

5.10 Prohibited Qualifications and Classification Code

Candidates who enter for the OCR GCE specifications may not also enter for any other GCE specification with the certification title *Chemistry* in the same examination series.

Every specification is assigned to a national classification code indicating the subject area to which it belongs.

Centres should be aware that candidates who enter for more than one GCE qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Achievement and Attainment Tables.

The classification code for these specifications is 1110.

5.11 Coursework Administration/Regulations

Supervision and Authentication

As with all coursework, teachers must be able to verify that the work submitted for assessment is the candidate's own work. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the coursework marks with confidence.

Submitting marks to OCR

Centres must have made an entry for a unit in order for OCR to supply the appropriate forms or moderator details for coursework. Coursework administration documents are sent to centres on the basis of estimated entries. Marks may be submitted to OCR either *via* Interchange, on the computer-printed Coursework Mark Sheets (MS1) provided by OCR (sending the top copy to OCR and the second copy to their allocated moderator) or by EDI (centres using EDI are asked to print a copy of their file and sign it before sending to their allocated moderator).

Deadline for the receipt of coursework marks is:
15 May for the June series.

The awarding body requires centres to obtain from each candidate a signed declaration that authenticates the work they produce as their own. For regulations governing internally assessed work, centres should consult the OCR *Administration Guide for General Qualifications.* Further copies of the coursework administration documents are available on the OCR website (www.ocr.org.uk).

Standardisation and Moderation

All internally-assessed coursework is marked by the teacher and internally standardised by the centre. Marks must be submitted to OCR by the agreed date, after which postal moderation takes place in accordance with OCR procedures.

The purpose of moderation is to ensure that the standard for the award of marks in internally-assessed coursework is the same for each centre, and that each teacher has applied the standards appropriately across the range of candidates within the centre.

The sample of work which is submitted to the moderator for moderation must show how the marks have been awarded in relation to the marking criteria.

Minimum Coursework Required

If a candidate submits no work for a unit, then the candidate should be indicated as being absent from that unit on the Coursework Mark Sheets (MS1) submitted to OCR. If a candidate completes any work at all for that unit then the work should be assessed according to the criteria and marking instructions and the appropriate mark awarded, which may be zero.

6 Other Specification Issues

6.1 Overlap with other Qualifications

Links with other AS and Advanced GCE specifications.

Chemistry sits centrally within the sciences and this course provides overlap with other A Level science specifications. The specification in science emphasises links between Chemistry and related subjects such as Biology, Geology, Physics and Science.

Examples of overlap include:

Biology

- Unit F322: *Chains, Energy and Resources*. Climate change.
- Unit F324: *Rings, Polymers and Analysis*. Amino acids, proteins, chromatography.

Geology

- Unit F322: *Chains, Energy and Resources*. Climate change, the atmosphere.

Physics

- Unit F321: *Atoms, Bonds and Groups*. Atomic structure.

Science

- Unit F321: *Atoms, Bonds and Groups*. Atomic structure.
- Unit F322: *Chains, Energy and Resources*. Climate change, the atmosphere, the development of renewable alternatives to finite energy resources, enthalpy changes, rates of reaction, catalysis.
- Unit F324: *Rings, Polymers and Analysis*. Amino acids, proteins, infrared spectroscopy, chromatography.

6.2 Progression from these Qualifications

Throughout the course, candidates are introduced to the ideas of chemistry and their application to a variety of contexts, both everyday and more specialised. Their understanding of How Science Works in chemistry is deepened.

The specification thus provides a valuable education for candidates who take chemistry or related subjects no further. It is also an excellent foundation for further study of chemistry, medicine (and related subjects such as pharmacy and pharmacology) or other sciences.

6.3 Key Skills Mapping

These specifications provide opportunities for the development of the Key Skills of *Communication*, *Application of Number*, *Information Technology*, *Working with Others*, *Improving Own Learning and Performance* and *Problem Solving* at Levels 2 and/or 3. However, the extent to which this evidence fulfils the Key Skills criteria at these levels will be totally dependent on the style of teaching and learning adopted for each unit.

The following table indicates where opportunities *may* exist for at least some coverage of the various Key Skills criteria at Levels 2 and/or 3 for each unit.

Unit	C				AoN			IT			WwO			IOLP			PS		
	.1a	.1b	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3
F321	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F322	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F323				✓	✓	✓	✓	✓	✓	✓									
F324	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F325	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F326		✓	✓	✓	✓	✓	✓	✓	✓	✓									

6.4 Spiritual, Moral, Ethical, Social, Legislative, Economic and Cultural Issues

These specifications offer opportunities which can contribute to an understanding of these issues in the following topics:

- a sense of awe and wonder at the atomic and molecular workings of the material world;
- the endeavour of chemists and other scientists in the development of knowledge and understanding of the material world;

- ethical and moral implications of some of the applications of chemistry;
- cultural issues, driven by society, are often perceived as ‘chemical’, eg drug dependency or pollution;
- economic issues, such as how the chemical industry is important to the economy of the UK.

However, there are no legislative issues in these specifications.

6.5 Sustainable Development, Health and Safety Considerations and European Developments

These specifications support these issues, consistent with current EU agreements, in the following topics:

- sufficient food is provided by using artificial fertilisers;
- chlorine is used in potable water to prevent disease;
- ethanol is the drug in alcoholic drinks;
- design and synthesis of medicines have played a major role in improving health and standard of life;
- chemical companies are frequently multinational and many UK companies have sites in Europe;
- chemical pollution does not recognise national boundaries, for example: Scandinavia experiences acid rain which originates from the UK and other European countries; the ozone layer is depleted by emissions of CFCs.

6.6 Avoidance of Bias

OCR has taken great care in the preparation of these specifications and assessment materials to avoid bias of any kind.

6.7 Language

These specifications and associated assessment materials are in English only.

6.8 Disability Discrimination Act Information Relating to these Specifications

AS/A Levels often require assessment of a broad range of competences. This is because they are general qualifications and, as such, prepare candidates for a wide range of occupations and higher level courses.

The revised AS/A Level qualification and subject criteria were reviewed to identify whether any of the competences required by the subject presented a potential barrier to any disabled candidates. If this was the case, the situation was reviewed again to ensure that such competences were included only where essential to the subject. The findings of this process were discussed with disability groups and with disabled people.

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments. For this reason, very few candidates will have a complete barrier to any part of the assessment. Information on reasonable adjustments is found in *Access Arrangements and Special Consideration Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations* produced by the Joint Council (refer to Section 5.9 of this specification).

Candidates who are still unable to access a significant part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award. They would be given a grade on the parts of the assessment they have taken and there would be an indication on their certificate that not all of the competences have been addressed. This will be kept under review and may be amended in the future.

Practical assistants may be used for manipulating equipment and making observations. Technology may help visually impaired students to take readings and make observations.

Appendix A: Performance Descriptions

Performance descriptions have been created for all GCE subjects. They describe the learning outcomes and levels of attainment likely to be demonstrated by a representative candidate performing at the A/B and E/U boundaries for AS and A2.

In practice most candidates will show uneven profiles across the attainments listed, with strengths in some areas compensating in the award process for weaknesses or omissions elsewhere. Performance descriptions illustrate expectations at the A/B and E/U boundaries of the AS and A2 as a whole; they have not been written at unit level.

Grade A/B and E/U boundaries should be set using professional judgement. The judgement should reflect the quality of candidates' work, informed by the available technical and statistical evidence. Performance descriptions are designed to assist examiners in exercising their professional j0075dgement. They should be interpreted and applied in the context of individual specifications and their associated units. However, performance descriptions are not designed to define the content of specifications and units.

The requirement for all AS and A Level specifications to assess candidates' quality of written communication will be met through one or more of the assessment objectives.

The performance descriptions have been produced by the regulatory authorities in collaboration with the awarding bodies.

AS performance descriptions for chemistry

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**Knowledge and understanding of science and of How Science Works** Candidates should be able to: • recognise, recall and show understanding of scientific knowledge; • select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of How Science Works** Candidates should be able to: • analyse and evaluate scientific knowledge and processes; • apply scientific knowledge and processes to unfamiliar situations including those related to issues; • assess the validity, reliability and credibility of scientific information.	**How Science Works** Candidates should be able to: • demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods; • make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy; • analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary Performance Descriptions	Candidates characteristically: a) demonstrate knowledge and understanding of most principles, concepts and facts and from the AS specification; b) select relevant information from the AS specification; c) organise and present information clearly in appropriate forms; d) write equations for most straightforward reactions using scientific terminology.	Candidates characteristically: a) apply principles and concepts in familiar and new contexts involving only a few steps in the argument; b) describe significant trends and patterns shown by data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly; c) comment critically on statements, conclusions or data; d) carry out accurately most structured calculations specified for AS; e) use a range of chemical equations; f) translate successfully data presented as prose, diagrams, drawings, tables or graphs from one form to another.	Candidates characteristically: a) devise and plan experimental and investigative activities, selecting appropriate techniques; b) demonstrate safe and skilful practical techniques; c) make observations and measurements with appropriate precision and record these methodically; d) interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

E/U boundary Performance Descriptions	Candidates characteristically: a) demonstrate knowledge and understanding of some principles and facts from the AS specification; b) select some relevant information from the AS specification; c) present information using basic terminology from the AS specification; d) write equations for some straightforward reactions.	Candidates characteristically: a) apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument; b) describe some trends or patterns shown by data presented in tabular or graphical form; c) identify, when directed, inconsistencies in conclusions or data; d) carry out some steps within calculations; e) use simple chemical equations; f) translate data successfully from one form to another, in some contexts.	Candidates characteristically: a) devise and plan some aspects of experimental and investigative activities; b) demonstrate safe practical techniques; c) make observations and measurements and record them; d) interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for chemistry

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**Knowledge and understanding of science and of How Science Works** Candidates should be able to: • recognise, recall and show understanding of scientific knowledge; • select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of How Science Works** Candidates should be able to: • analyse and evaluate scientific knowledge and processes; • apply scientific knowledge and processes to unfamiliar situations including those related to issues; • assess the validity, reliability and credibility of scientific information.	**How Science Works** Candidates should be able to: • demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods; • make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy; • analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

A/B boundary Performance Descriptions	Candidates characteristically: a) demonstrate detailed knowledge and understanding of most principles, concepts and facts from the A2 specification; b) select relevant information from the A2 specification; c) organise and present information clearly in appropriate forms using scientific terminology; d) write equations for most chemical reactions.	Candidates characteristically: a) apply principles and concepts in familiar and new contexts involving several steps in the argument; b) describe significant trends and patterns shown by complex data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly; c) evaluate critically the statements, conclusions or data; d) carry out accurately complex calculations specified for A Level; e) use chemical equations in a range of contexts; f) translate successfully data presented as prose, diagrams, drawings, tables or graphs, from one form to another; g) select a wide range of facts, principles and concepts from both AS and A2 specifications; h) link together appropriate facts principles and concepts from different areas of the specification.	Candidates characteristically: a) devise and plan experimental and investigative activities, selecting appropriate techniques; b) demonstrate safe and skilful practical techniques; c) make observations and measurements with appropriate precision and record these methodically; d) interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.
E/U boundary Performance Descriptions	Candidates characteristically: a) demonstrate knowledge and understanding of some principles and facts from the A2 specification; b) select some relevant information from the A2 specification; c) present information using basic terminology from the A2 specification; d) write equations for some chemical reactions.	Candidates characteristically: a) apply given principles or concepts in familiar and new contexts involving a few steps in the argument; b) describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; c) identify, when directed, inconsistencies in conclusions or data; d) carry out some steps within calculations e) use some chemical equations; f) translate data successfully from one form to another, in some contexts; g) select some facts, principles and concepts from both AS and A2 specifications; h) put together some facts, principles and concepts from different areas of the specification.	Candidates characteristically: a) devise and plan some aspects of experimental and investigative activities; b) demonstrate safe practical techniques; c) make observations and measurements and record them; d) interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

Appendix B: Chemistry A Data Sheet

RECOGNISING ACHIEVEMENT

Data Sheet for Chemistry A

(version 2.0)

GCE Advanced Level and Advanced Subsidiary

Chemistry A (H034, H434)

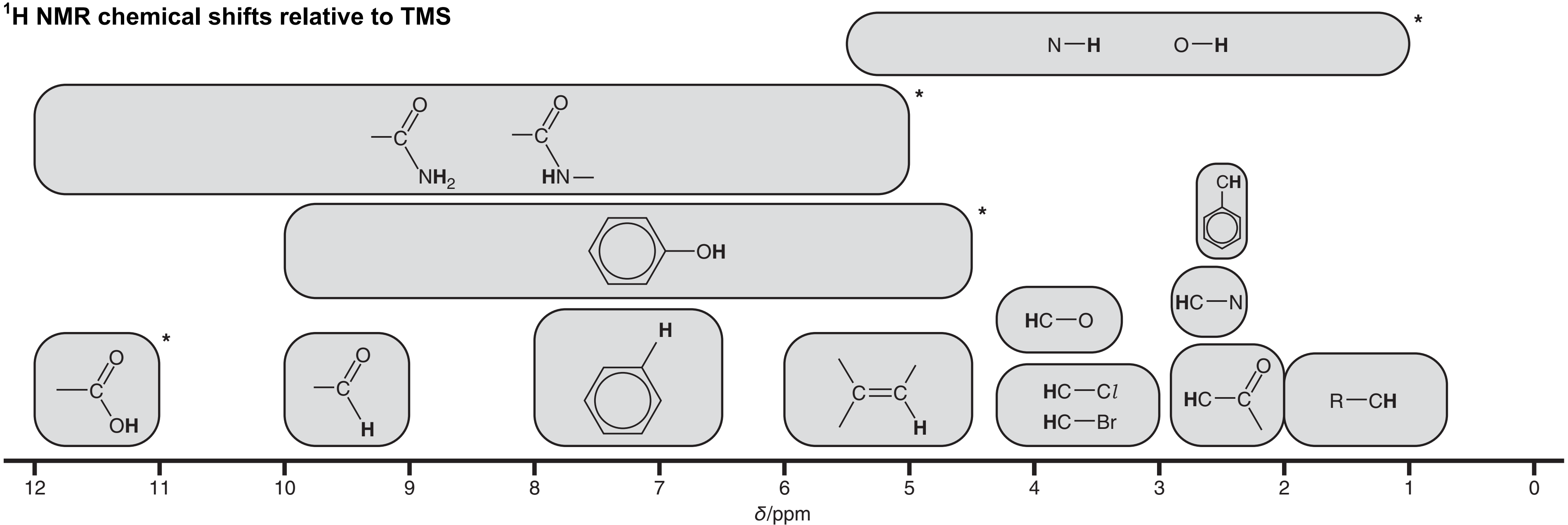
Chemistry A units F321–F326

The information in this sheet is for the use of candidates following Chemistry A (H034 and H434).

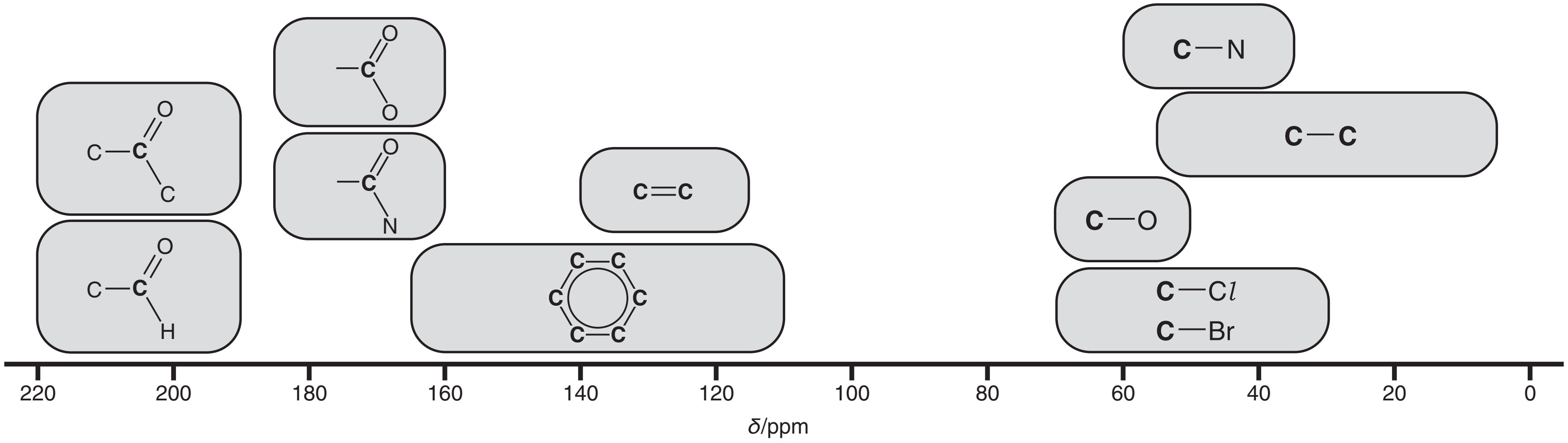
Clean copies of this sheet must be issued to candidates in the examination room, and must be given up to the invigilator at the end of the examination.

Copies of this sheet may be used for teaching.

^{1}H NMR chemical shifts relative to TMS



^{13}C NMR chemical shifts relative to TMS



Chemical shifts are typical values and can vary slightly depending on the solvent, concentration and substituents.
* OH and NH chemical shifts are very variable (sometimes outside these limits) and are often broad. Signals are not usually see as split peaks

The Periodic Table of the Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112–116 have been reported but not fully authenticated						

140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	144.9 **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.2 **Gd** gadolinium 64	158.9 **Tb** terbium 65	162.5 **Dy** dysprosium 66	164.9 **Ho** holmium 67	167.3 **Er** erbium 68	168.9 **Tm** thulium 69	173.0 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
232.0 **Th** thorium 90	[231] **Pa** protactinium 91	238.1 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

General Information

- 1 mol of gas molecules occupies 24.0 dm^3 at room temperature and pressure, RTP.

- Avogadro constant, $N_A = 6.02 \times 10^{23}$ $mol^{-1.}$

- Ionic product of water, $K_w = 1.00 \times 10^{-14}$ $mol^2\,dm^{-6}$.

Characteristic infrared absorptions in organic molecules

bond	**location**	**wavenumber/cm^{-1}**
C——O	alcohols, esters, carboxylic acids	1000–1300
C══O	aldehydes, ketones, carboxylic acids, esters, amides	1640–1750
C——H	organic compound with a C H bond	2850–3100
O——H	carboxylic acids	2500–3300 (very broad)
N——H	amines, amides	3200–3500
O——H	alcohols, phenols	(broad)

Appendix C: How Science Works

Incorporating Section 3.6 (the skills, knowledge and understanding of *How Science Works*) of the QCA criteria into the specification.

References in this specification to *How Science Works* (HSW) are to the following statements. These have been written by rearranging the statements in Section 3.6 of the QCA Subject Criteria.

1. Use theories, models and ideas to develop and modify scientific explanations.

2. Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas.

3. Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems.

4. Communicate information and ideas in appropriate ways using appropriate terminology.

5. Obtaining, analysing and evaluating data:

- **a.** carry out experimental and investigative activities, including appropriate risk management, in a range of contexts;
- **b.** analyse and interpret data to provide evidence, recognising correlations and causal relationships;
- **c.** evaluate methodology, evidence and data, and resolve conflicting evidence.

6. Applications, implications and ethical considerations:

- **a.** consider applications and implications of science and appreciate their associated benefits and risks;
- **b.** consider ethical issues in the treatment of humans, other organisms and the environment.

7. Scientific knowledge in its social context:

- **a.** appreciate the tentative nature of scientific knowledge;
- **b.** appreciate the role of the scientific community in validating new knowledge and ensuring integrity;
- **c.** appreciate the ways in which society uses science to inform decision-making.

The skills, knowledge and understanding of *How Science Works* are summarised in the left-hand column below. These will underpin the teaching and assessment contexts of the course. The examples below are not exhaustive but help to show the coverage of ‘How Science Works’ throughout the course.

	Examples of coverage	
How Science Works statement	**AS**	**A2**
1 Use theories, models and ideas to develop and modify scientific explanations.	**1.1.1.a–e** Modern development of the structure of the atom **1.2.1.b** Orbitals as mathematical models for the behaviour of electrons **1.2.1.c** Successive ionisation energies and development of electron structure **1.3.1.a–c** Periodicity and development of the Periodic Table **2.3.2.f–h** The Boltzmann distribution as a theoretical model arising from kinetic theory	**4.1.1.a,b** The development and acceptance of models for the structure of benzene **5.1.1.i** Reaction mechanisms and rate equations **5.2.1.b–e** Born–Haber cycle as a model for determination of lattice enthalpies and in testing the ionic model of bonding
2 Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas.	Many examples of this wide-ranging statement, are embedded within the learning outcomes.	Many examples of this wide-ranging statement, are embedded within the learning outcomes.
3 Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems.	**1.1.1.i** Use of spreadsheets in calculating relative atomic mass from data **1.2.2.i,j** Three-dimensional molecular shapes **2.2.3.d–i** Mass spectrometry	**4.2.2.a** Analysis of pharmaceuticals **4.3.1.h,i** Use of GC-MS by society in modern analysis and the use of such evidence in courts **5.1.3.i** Titration curves
4 Communicate information and ideas in appropriate ways using appropriate terminology.	**1.1.1.i** Use of spreadsheets in calculating relative atomic mass from data **1.2.2.i,j** Three-dimensional molecular shapes **2.2.3.d–i** Mass spectrometry	**4.2.1.g–i** Stereoisomerism, including *E*/*Z* and optical isomerism **4.3.1.g,h** Combining mass spectrometry with gas chromatography **4.3.2.a–i** NMR spectroscopy
5a Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.	**Unit F323** AS Practical	**Unit F326** A2 Practical
5b Analyse and interpret data to provide evidence, recognising correlations and causal relationships.	**Unit F323** AS Practical	**Unit F326** A2 Practical
5c Evaluate methodology, evidence and data, and resolve conflicting evidence.	**Unit F323** AS Practical	**Unit F326** A2 Practical
6a Consider applications and implications of science and appreciate their associated benefits and risks.	**1.3.3.f** Risks and benefits of chlorine use in water treatment **2.1.1.l–p** Atom economy **2.1.2.j** Non-renewable fuels **2.1.3.j** Industrial importance of alkenes **2.2.2.f,g** Use of CFCs	**4.2.3.c–e** Requirement for chiral drugs and medicines to minimise side effects, for economical reasons and to reduce risk to companies from litigation **4.3.1.g,h** Uses of GC-MS **5.2.3.i–p** Political and social desire to move to a hydrogen economy has many obstacles including

	2.3.2.d Catalysts **2.3.2.l** Compromise in industrial processes **2.4.1.e,f** Breakdown of ozone **2.4.1.j** Use of IR for monitoring pollution in MOT gas analysers **2.4.2** Green chemistry	ignorance that energy is needed to produce hydrogen and that fuel cells have a finite life **5.3.1.j** *cis*-Platin
6b Consider ethical issues in the treatment of humans, other organisms and the environment.	**2.1.2g** Toxicity from CO production during incomplete combustion of fuels **2.1.2.j** Non-renewable fuels **2.1.3.l** Minimising damage to the environment **2.2.2.f,g** Use of CFCs **2.4.1.e,f** Breakdown of ozone **2.4.2** Green chemistry	**4.1.3.h** Link between unsaturated and saturated fats and current concerns about heart disease and obesity **4.2.2.g,h** Production of degradable polymers from renewable resources **4.2.3.c–f** Requirement for chiral drugs and medicines to minimise side effects, for economical reasons and to reduce risk to companies from litigation
7a Appreciate the tentative nature of scientific knowledge.	**1.1.1.a–e** The changing accepted view of the structure of the atom **1.3.1.a–c** Changing view of organising elements	**4.3.1.f** Limitations of gas chromatography **5.2.1.b–e** Born–Haber cycle as a model for determination of lattice enthalpies and in testing the ionic model of bonding
7b Appreciate the role of the scientific community in validating new knowledge and ensuring integrity.	**1.1.1.a–e** Acceptance (and rejection) of different theories for the structure of the atom from Greeks, Dalton, Thompson and Rutherford **1.3.1.a–c** Acceptance (and rejection) of different theories for organising the elements from Newlands to Mendeleev	**5.2.3.o–p** Political and social desire to move to a hydrogen economy has many obstacles including ignorance that energy is needed to produce hydrogen and that fuel cells have a finite life
7c Appreciate the ways in which society uses science to inform decision-making.	**2.1.3.k** Using waste polymers **2.1.3.l** Minimising damage to the environment **2.2.3.c** Breathalysers **2.4.1.d** Scientists influencing decision making to combat global warming **2.4.2** Green chemistry	**4.1.3.i** Use of biodiesel as a fuel to increase contribution to energy requirements from renewable fuels **4.3.1.h** Use of GC-MS by society in modern analysis and the use of such evidence in courts **5.2.3.o–p** Political and social desire to move to a hydrogen economy has many obstacles including ignorance that energy is needed to produce hydrogen and that fuel cells have a finite life

Appendix D: Practical Skills in Chemistry A (Strands and Qualities)

Practical Skills are assessed using several skill qualities split into three strands.
The strands and qualities are shown below.

	Quality A1	**Quality A2**
Strand A	Demonstrate skilful and safe practical techniques using suitable qualitative methods.	Demonstrate skilful and safe practical techniques using suitable quantitative methods.

	Quality B1	**Quality B2**
Strand B	Make and record valid observations; organise results suitably.	Make and record accurate measurements to an appropriate precision.

	Quality C1	**Quality C2**
Strand C	Recognise and interpret data, identify anomalies and reach valid conclusions.	Analyse, interpret and evaluate experimentally derived results quantitatively to reach valid conclusions.
	Quality C3	**Quality C4**
	Assess the reliability and accuracy of an experimental task; Identify significant weaknesses in experimental procedures and measurements.	Understand and select simple improvements to the experimental procedures and measurements.

The different strands and qualities are assessed using three task types at AS and at A2:

- a qualitative task;
- a quantitative task;
- an evaluative task.

The qualities assessed by each task type are shown below.

F323: AS Task Types

Task type	**Quality**								**Assessment outcome**			**Total**
	A1	**A2**	**B1**	**B2**	**C1**	**C2**	**C3**	**C4**	**AO1**	**AO2**	**AO3**	
Qualitative	✓		✓								10	10
Quantitative		✓		✓		✓			3	2	10	15
Evaluative					✓		✓	✓	3	2	10	15
TOTAL												**40**

F326: A2 Task Types

Task type	**Quality**								**Assessment outcome**			**Total**
	A1	**A2**	**B1**	**B2**	**C1**	**C2**	**C3**	**C4**	**AO1**	**AO2**	**AO3**	
Qualitative	✓		✓								10	10
Quantitative		✓		✓		✓			2	3	10	15
Evaluative					✓		✓	✓	2	3	10	15
TOTAL												**40**

Appendix E: Using OCR Interchange to download Practical Skills tasks

All materials for the assessment of GCE Chemistry A Practical Skills can be obtained from OCR Interchange.

How to use OCR Interchange
OCR Interchange is a secure extranet enabling registered users to administer qualifications on-line. Your Examinations Officer is probably using OCR Interchange to administer qualifications already. If this is not the case, then your centre will need to register.

Your Examinations Officer will be able to:*

- download the relevant documents for you by adding the role of 'Science Coordinator' to their other roles or
- create a new user account for you (adding the Science Coordinator role) so that you can access the GCE Chemistry A pages and download documents when you need them.*

*Note that in order to assign the role of Science Coordinator to others, the Examinations Officer will need to hold the role of Centre Administrator.

The website address for Interchange is:

https://interchange.ocr.org.uk

The teacher who has downloaded these materials is responsible for ensuring that any pages labelled **confidential** are stored securely so that students do not have the opportunity to access them.

It is intended that the circulation of the Practical Tasks is limited to those students who are currently undertaking that task. These materials should be photocopied and issued to students at the start of the task. Numbering the documents may help to keep track of them.

Registering for Interchange

If your Examinations Officer is not already a registered user of Interchange then he/she will need to register before the Chemistry A Tasks can be downloaded.

This is a straightforward process:

- Go to the website – https://interchange.ocr.org.uk
- The first page has a New User section
- Click on Sign Up to access the OCR Interchange Agreement Form 1
- Download this document and fill in your details
- Return form by post to OCR Customer Contact Centre, Westwood Way, Coventry, CV4 8JQ or fax the form back to 024 76 851633
- OCR will then contact the Head of Centre with the details needed for the Examinations Officer to access OCR Interchange.

Appendix F: Mathematical Requirements

In order to be able to develop their skills, knowledge and understanding in chemistry, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated below.

1 Arithmetic and numerical computation:

  - (a) recognise and use expressions in decimal and standard form;
  - (b) use ratios, fractions and percentages;
  - (c) make estimates of the results of calculations (without using a calculator);
  - (d) use calculators to find and use power, exponential and logarithmic functions.

2 Handling data:

  - (a) use an appropriate number of significant figures;
  - (b) find arithmetic means.

3 Algebra:

  - (a) understand and use the symbols: $=$, $<$, $\ll$, $\gg$,$>$, $\propto$, $\sim$;
  - (b) change the subject of an equation;
  - (c) substitute numerical values into algebraic equations using appropriate units for physical quantities;
  - (d) solve simple algebraic equations;
  - (e) use logarithms in relation to quantities which range over several orders of magnitude.

4 Graphs:

  - (a) translate information between graphical, numerical and algebraic forms;
  - (b) plot two variables from experimental or other data;
  - (c) understand that $y = mx + c$ represents a linear relationship;
  - (d) determine the slope and intercept of a linear graph;
  - (e) calculate rate of change from a graph showing a linear relationship;
  - (f) draw and use the slope of a tangent to a curve as a measure of rate of change.

5 Geometry and trigonometry:

  - a) appreciate angles and shapes in regular 2-D and 3-D structures;
  - b) visualise and represent 2-D and 3-D forms including two-dimensional representations of 3-D objects;
  - c) understand the symmetry of 2-D and 3-D shapes.

Appendix G: Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for AS and Advanced GCE, this is likely to be the local education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at www.ase.org.uk/htm/teacher_zone/safety_in_science_education.php.

For members, the CLEAPSS® guide, *Managing Risk Assessment in Science** offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- *Safety in Science Education*, DfEE, 1996, HMSO, ISBN 0 11 270915 X.

  Now out of print but sections are available at:
  www.ase.org.uk/htm/teacher_zone/safety_in_science_education.php;

- *Topics in Safety*, 3rd edition, 2001, ASE ISBN 0 86357 316 9;

- *Safeguards in the School Laboratory*, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;

- CLEAPSS® *Hazcards*, 2007 edition and later updates*;

- CLEAPSS® *Laboratory Handbook**;

- *Hazardous Chemicals*, A Manual for Science Education, 1997, SSERC Limited

  ISBN 0 9531776 0 2 (see www.sserc.org.uk/public/hazcd/whats_new.htm).

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer’s model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS® (or, in Scotland, SSERC).

*****These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications CD-ROM issued annually to members. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk. In Scotland, SSERC (www.sserc.org.uk) has a similar role to CLEAPSS® and there are some reciprocal arrangements.