GCE

AS and A Level Specification

Chemistry

AS exams 2009 onwards
A2 exams 2010 onwards

Contents

Vertical black lines indicate a significant change or addition to the previous version of this specification.

1 Introduction

1.1 Why choose AQA?

It's a fact that AQA is the UK's favourite exam board and more students receive their academic qualifications from AQA than from any other board. But why does AQA continue to be so popular?

- **Specifications**
  Ours are designed to the highest standards, so teachers, students and their parents can be confident that an AQA award provides an accurate measure of a student's achievements. And the assessment structures have been designed to achieve a balance between rigour, reliability and demands on candidates.

- **Support**
  AQA runs the most extensive programme of support meetings; free of charge in the first years of a new specification and at a very reasonable cost thereafter. These support meetings explain the specification and suggest practical teaching strategies and approaches that really work.

- **Service**
  We are committed to providing an efficient and effective service and we are at the end of the phone when you need to speak to a person about an important issue. We will always try to resolve issues the first time you contact us but, should that not be possible, we will always come back to you (by telephone, email or letter) and keep working with you to find the solution.

- **Ethics**
  AQA is a registered charity. We have no shareholders to pay. We exist solely for the good of education in the UK. Any surplus income is ploughed back into educational research and our service to you, our customers. We don't profit from education, you do.

If you are an existing customer then we thank you for your support. If you are thinking of moving to AQA then we look forward to welcoming you.

1.2 Why choose Chemistry?

- Our objective is to ensure that learning is enjoyable, and enhances a candidate's enthusiasm for chemistry.
- The AQA Specification has been tailored to follow on from Additional Science at GCSE, and will develop a candidate's knowledge and understanding to provide a pathway to further study.
- To promote this practice, we have built on the concepts of *How Science Works* that were introduced at GCSE. This ensures relevance to contemporary issues.
- This new model follows the key themes of the highly popular former AQA specification, updated in-line with the new QCA Science criteria.
- There are two routes for internal assessment: centre-marked or AQA-marked. This provides flexibility to meet the needs of centres and candidates.
- The assessment time is reduced to three hours at AS and three and a half hours at A2.
- This is long enough to test synoptic understanding and thus ensuring rigour, knowledge of *How Science Works* and stretch and challenge, whilst still allowing for a fair and balanced question paper, without overburdening candidates.
- Unit size is crafted to allow greater use of January examinations, allowing the course to become truly modular.
- We are working with Nelson Thornes to provide a blend of print and electronic resources for teaching and learning.

1.3 How do I start using this specification?

Already using the existing AQA Chemistry specification?

- Register to receive further information, such as mark schemes, past question papers, details of teacher support meetings, etc, at **http://www.aqa.org.uk/rn/askaqa.php** Information will be available electronically or in print, for your convenience.
- Tell us that you intend to enter candidates. Then we can make sure that you receive all the material you need for the examinations. This is particularly important where examination material is issued before the final entry deadline. You can let us know by completing the appropriate Intention to Enter and Estimated Entry forms. We will send copies to your Exams Officer and they are also available on our website **http://www.aqa.org.uk/admin/p_entries.html**.

Not using the AQA specification currently?

- Almost all centres in England and Wales use AQA or have used AQA in the past and are approved AQA centres. A small minority are not. If your centre is new to AQA, please contact our centre approval team at **centreapproval@aqa.org.uk**

1.4 How can I find out more?

Ask AQA

You have 24-hour access to useful information and answers to the most commonly asked questions at **http://www.aqa.org.uk/rn/askaqa.php**

If the answer to your question is not available, you can submit a query for our team. Our target response time is one day.

Teacher Support

Details of the full range of current Teacher Support meetings are available on our website at **http://www.aqa.org.uk/support/teachers.html**

There is also a link to our fast and convenient online booking system for Teacher Support meetings at **http://events.aqa.org.uk/ebooking**

If you need to contact the Teacher Support team, you can call us on 01483 477860 or email us at **teachersupport@aqa.org.uk**

2 Specification at a Glance: Chemistry

2

AS Examinations

Unit 1 – CHEM1 **Foundation Chemistry**

Examination paper (70 raw marks/100 UMS). 4 – 6 short answer questions plus 1 – 2 longer structured question(s).

1 hour 15 minutes
33 1/3% of the total AS marks
16 2/3% of the total A Level marks
Available January and June

Unit 2 – CHEM2 **Chemistry In Action**

Examination paper (100 raw marks/140 UMS). 6 – 8 short answer questions plus 2 longer structured questions

1 hour 45 minutes
46 2/3% of the total AS marks
23 1/3% of the total A Level marks
Available January and June

Unit 3 – Internal Assessment **Investigative and practical skills in AS Chemistry**

EITHER **CHM3T,** Centre Marked Route T (50 raw marks/60 UMS)
Practical Skills Assessment (PSA – 12 raw marks)
Investigative Skills Assignment (ISA – 38 raw marks)

OR **CHM3X,** Externally Marked Route X (50 raw marks/60 UMS)
Practical Skills Verification (PSV – teacher verification)
Externally Marked Practical Assignment (EMPA – 50 raw marks)

20% of the total AS marks
10% of the total A Level marks
Available in June only

AS Award 1421

A2 Examinations

Unit 4 – CHEM4 **Kinetics, Equilibria and Organic Chemistry**

Examination paper (100 raw marks/120 UMS). 6 – 8 short answer questions plus 2 – 3 structured questions. Some of the questions will have synoptic elements.

1 hour 45 minutes
20% of the total A Level marks
Available January and June

Unit 5 – CHEM5 **Energetics, Redox and Inorganic Chemistry**

Examination paper (100 raw marks/120 UMS). 6 – 8 short answer questions plus 2 – 3 longer structured questions. Some of the questions will have synoptic elements.

1 hour 45 minutes
20% of the total A Level marks
Available January and June

Unit 6 – Internal Assessment **Investigative and practical skills in A2 Chemistry**

EITHER **CHM6T,** Centre Marked Route T (50 raw marks/60 UMS)
Practical Skills Assessment (PSA – 12 raw marks)
Investigative Skills Assignment (ISA – 38 raw marks)

OR **CHM6X,** Externally Marked Route X (50 raw marks/60 UMS)
Practical Skills Verification (PSV – teacher verification)
Externally Marked Practical Assignment (EMPA – 50 raw marks)

10% of the total A Level marks
Available in June only

A Level Award 2421

AS + A2 = A Level

3 Subject Content

3.1 Unit 1 CHEM1 Foundation Chemistry

Introduction

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

Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this unit. The development of these skills is associated with the Investigative and Practical Skills detailed in Unit 3.

Candidates should

3.1.1	**Atomic Structure**	
	Fundamental particles	be able to describe the properties of protons, neutrons and electrons in terms of relative charge and relative mass
		know that early models of atomic structure predicted that atoms and ions with noble gas electron arrangements should be stable
	Protons, neutrons and electrons	understand the importance of these particles in the structure of the atom and appreciate that there are various models to illustrate atomic structure
	Mass number and isotopes	be able to recall the meaning of mass number (A) and atomic (proton) number (Z)
		be able to explain the existence of isotopes
		understand the principles of a simple mass spectrometer, limited to ionisation, acceleration, deflection and detection
		know that the mass spectrometer gives accurate information about relative isotopic mass and also about the relative abundance of isotopes
		be able to interpret simple mass spectra of elements and calculate relative atomic mass from isotopic abundance, limited to mononuclear ions
		know that mass spectrometry can be used to identify elements (as used for example in planetary space probes)
		know that mass spectrometry can be used to determine relative molecular mass
	Electron arrangement	know the electron configurations of atoms and ions up to Z = 36 in terms of levels and sub-levels (orbitals) s, p and d
		know the meaning of the term *ionisation energy*.
		understand how ionisation energies in Period 3 (Na – Ar) and in Group 2 (Be – Ba) give evidence for electron arrangement in sub-levels and in levels

3

3.1.2	**Amount of Substance**	
	Relative atomic mass and relative molecular mass	be able to define relative atomic mass (A_r) and relative molecular mass (M_r) in terms of ^{12}C. (The term relative formula mass will be used for ionic compounds)
	The mole and the Avogadro constant (L)	understand the concept of a mole as applied to electrons, atoms, molecules, ions, formulae and equations
		understand the concept of the Avogadro constant. (Calculation not required)
	The ideal gas equation	be able to recall the ideal gas equation $pV = nRT$ and be able to apply it to simple calculations in S.I. units, for ideal gases
	Empirical and molecular formulae	understand the concept of, and the relationship between, empirical and molecular formulae
		be able to calculate empirical formulae from data giving percentage composition by mass
	Balanced equations and associated calculations	be able to write balanced equations (full and ionic) for reactions studied
		be able to balance equations for unfamiliar reactions when reactants and products are specified. (This is an important skill that applies in all units.)
		be able to calculate reacting volumes of gases
		be able to calculate concentrations and volumes for reactions in solutions, limited to titrations of monoprotic acids and bases and examples for which the equations are given
		know that $\%\text{ atom economy} = \frac{\text{mass of desired product}}{\text{total mass of reactants}} \times 100$
		be able to calculate reacting masses, % yields and % atom economies from balanced equations
3.1.3	**Bonding**	
	Nature of ionic, covalent and metallic bonds	understand that ionic bonding involves attraction between oppositely charged ions in a lattice
		know that a covalent bond involves a shared pair of electrons
		know that co-ordinate bonding is dative covalency
		understand that metallic bonding involves a lattice of positive ions surrounded by delocalised electrons
	Bond polarity	understand that electronegativity is the power of an atom to withdraw electron density from a covalent bond
		understand that the electron distribution in a covalent bond may not be symmetrical
		know that covalent bonds between different elements will be polar to different extents
	Forces acting between molecules	understand qualitatively how molecules may interact by permanent dipole–dipole, induced dipole–dipole (van der Waals') forces and hydrogen bonding
		understand the importance of hydrogen bonding in determining the boiling points of compounds and the structures of some solids (e.g. ice)

	States of matter	be able to explain the energy changes associated with changes of state
		recognise the four types of crystal: ionic, metallic, giant covalent (macromolecular) and molecular
		know the structures of the following crystals: sodium chloride, magnesium, diamond, graphite, iodine and ice
		be able to relate the physical properties of materials to the type of structure and bonding present
	Shapes of simple molecules and ions	understand the concept of bonding and lone (non bonding) pairs of electrons as charge clouds.
		be able, in terms of electron pair repulsion, to predict the shapes of, and bond angles in, simple molecules and ions, limited to 2, 3, 4, 5 and 6 co-ordination
		know that lone pair/lone pair repulsion is greater than lone pair/bonding pair repulsion, which is greater than bonding pair/bonding pair repulsion, and understand the resulting effect on bond angles
3.1.4	**Periodicity**	
	Classification of elements in s, p and d blocks	be able to classify an element as s, p or d block according to its position in the Periodic Table
	Properties of the elements of Period 3 to illustrate periodic trends	be able to describe the trends in atomic radius, first ionisation energy, melting and boiling points of the elements Na – Ar
		understand the reasons for the trends in these properties
3.1.5	**Introduction to Organic Chemistry**	
	Nomenclature	know and understand the terms *empirical formula*, *molecular formula*, *structural formula*, *displayed formula*, *homologous series* and *functional group*
		be able to apply IUPAC rules for nomenclature to simple organic compounds, limited to chains with up to 6 carbon atoms limited in this module to alkanes, alkenes and haloalkanes
	Isomerism	know and understand the meaning of the term *structural isomerism*
		be able to draw the structures of chain, position and functional group isomers

3.1.6	**Alkanes**	
	Fractional distillation of crude oil	know that alkanes are saturated hydrocarbons
		know that petroleum is a mixture consisting mainly of alkane hydrocarbons
		understand that different components (fractions) of this mixture can be drawn off at different levels in a fractionating column because of the temperature gradient
	Modification of alkanes by cracking	understand that cracking involves the breaking of C–C bonds in alkanes
		know that thermal cracking takes place at high pressure and high temperature and produces a high percentage of alkenes (mechanism not required)
		know that catalytic cracking takes place at a slight pressure, high temperature and in the presence of a zeolite catalyst and is used mainly to produce motor fuels and aromatic hydrocarbons (mechanism not required)
		understand the economic reasons for the cracking of alkanes (e.g. ethene used for poly(ethene); conversion of heavy fractions into higher value products)
	Combustion of alkanes	know that alkanes are used as fuels and understand that their combustion can be complete or incomplete and that the internal combustion engine produces a number of pollutants (e.g. NO_x, CO and unburned hydrocarbons)
		know that these pollutants can be removed using catalytic converters
		know that combustion of hydrocarbons containing sulfur leads to sulfur dioxide that causes air pollution and understand how sulfur dioxide can be removed from flue gases using calcium oxide
		know that the combustion of fossil fuels (including alkanes) results in the release of carbon dioxide into the atmosphere
		know that carbon dioxide, methane and water vapour are referred to as greenhouse gases and that these gases may contribute to global warming

3

3.2 Unit 2 CHEM2 Chemistry in Action

Introduction

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

Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this unit.

A knowledge of the Chemistry in Unit 1 is assumed in this unit.

Candidates should

3.2.1	**Energetics**	
	Enthalpy change (ΔH)	know that reactions can be endothermic or exothermic
		understand that enthalpy change (ΔH) is the heat energy change measured under conditions of constant pressure
		know that standard enthalpy changes refer to standard conditions, i.e. 100 kPa and a stated temperature (e.g. ΔH_{298})
		be able to recall the definition of standard enthalpies of combustion ($\Delta H_c^\ominus$) and formation ($\Delta H_f^\ominus$)
	Calorimetry	be able to calculate the enthalpy change from the heat change in a reaction using the equation $q = mc\,\Delta T$
	Simple applications of Hess's Law	know Hess's Law and be able to use it to perform simple calculations, for example calculating enthalpy changes for reactions from enthalpies of combustion or enthalpies of formation
	Bond enthalpies	be able to determine mean bond enthalpies from given data
		be able to use mean bond enthalpies to calculate a value of ΔH for simple reactions
3.2.2	**Kinetics**	
	Collision theory	understand that reactions can only occur when collisions take place between particles having sufficient energy
		be able to define the term *activation energy* and understand its significance
		understand that most collisions do not lead to reaction
	Maxwell–Boltzmann distribution	have a qualitative understanding of the Maxwell–Boltzmann distribution of molecular energies in gases
		be able to draw and interpret distribution curves for different temperatures
	Effect of temperature on reaction rate	understand the qualitative effect of temperature changes on the rate of reaction
		understand how small temperature increases can lead to a large increase in rate
	Effect of concentration	understand the qualitative effect of changes in concentration on rate of reaction
	Catalysts	know the meaning of the term *catalyst*
		understand that catalysts work by providing an alternative reaction route of lower activation energy

3.2.3	**Equilibria**	
	The dynamic nature of equilibria	know that many chemical reactions are reversible
		understand that for a reaction in equilibrium, although the concentrations of reactants and products remain constant, both forward and reverse reactions are still proceeding at equal rates
	Qualitative effects of changes of pressure, temperature and concentration on a system in equilibrium	be able to use Le Chatelier's principle to predict the effects of changes in temperature, pressure and concentration on the position of equilibrium in homogeneous reactions
		know that a catalyst does not affect the position of equilibrium
	Importance of equilibria in industrial processes	be able to apply these concepts to given chemical processes
		be able to predict qualitatively the effect of temperature on the position of equilibrium from the sign of ΔH for the forward reaction
		understand why a compromise temperature and pressure may be used
		know about the hydration of ethene to form ethanol and the reaction of carbon monoxide with hydrogen to form methanol as important industrial examples where these principles can be applied
		know the importance of these alcohols as liquid fuels
3.2.4	**Redox Reactions**	
	Oxidation and reduction	know that oxidation is the process of electron loss know that oxidising agents are electron acceptors
		know that reduction is the process of electron gain know that reducing agents are electron donors
	Oxidation states	know and be able to apply the rules for assigning oxidation states in order to work out the oxidation state of an element in a compound from its formula
		understand oxidation and reduction reactions of s and p block elements
	Redox equations	be able to write half-equations identifying the oxidation and reduction processes in redox reactions when the reactants and products are specified
		be able to combine half-equations to give an overall redox equation

3.2.5	**Group 7(*17*), the Halogens**	
	Trends in physical properties	understand the trends in electronegativity and boiling point of the halogens
	Trends in the oxidising abilities of the halogens	understand that the ability of the halogens (from fluorine to iodine) to oxidise decreases down the group (e.g. the displacement reactions with halide ions in aqueous solution)
	Trends in the reducing abilities of the halide ions	understand the trend in reducing ability of the halide ions
		know the different products formed by reaction of NaX and H_2SO_4
	Identification of halide ions using silver nitrate	understand why acidified silver nitrate solution is used as a reagent to identify and distinguish between F^-, Cl^-, Br^- and I^-
		know the trend in solubility of the silver halides in ammonia
	Uses of chlorine and chlorate(I)	know the reactions of chlorine with water and the use of chlorine in water treatment
		appreciate that the benefits to health of water treatment by chlorine outweigh its toxic effects
		know the reaction of chlorine with cold, dilute, aqueous NaOH and the uses of the solutions formed
3.2.6	**Group 2, the Alkaline Earth Metals**	
	Trends in physical properties	understand the trends in atomic radius, first ionisation energy and melting point of the elements Mg – Ba
	Trends in chemical properties	know the reactions of the elements Mg – Ba with water and recognise the trend
		know the relative solubilities of the hydroxides of the elements Mg – Ba and that $Mg(OH)_2$ is sparingly soluble
		know the use of $Mg(OH)_2$ in medicine and of $Ca(OH)_2$ in agriculture
		know the relative solubilities of the sulfates of the elements Mg – Ba
		understand why acidified $BaCl_2$ solution is used as a reagent to test for sulfate ions
		know the use of $BaSO_4$ in medicine

3

3.2.7	**Extraction of Metals**	
	Principles of metal extraction	know that metals are found in ores, usually as oxides or sulfides and that sulfide ores are usually converted into oxides by roasting in air
		understand the environmental problems associated with the conversion of sulfides into oxides and also that the sulfur dioxide produced can be used to manufacture sulfuric acid
		understand that extraction of metals involves reduction
		understand that carbon and carbon monoxide are cheap and effective reducing agents that are used in the extraction of iron, manganese and copper (reduction equations and conditions only)
		know why carbon reduction is not used for extraction of titanium, aluminium and tungsten
		understand how aluminium is manufactured from purified bauxite (energy considerations, electrode equations and conditions only)
		understand how titanium is extracted from TiO_2 via $TiCl_4$ (equations and conditions only: either Na or Mg as a reducing agent)
		understand how tungsten is extracted from WO_3 by reduction with hydrogen (equation, conditions and risks only)
	Environmental aspects of metal extraction	understand the environmental and economic advantages and disadvantages of recycling scrap metals compared with the extraction of metals
		understand the environmental advantages of using scrap iron to extract copper from aqueous solutions compared with the high-temperature carbon reduction of copper oxide
		know that the usual source of such aqueous solutions is low grade ore
3.2.8	**Haloalkanes**	
	Synthesis of chloroalkanes	understand the reaction mechanism of methane with chlorine as a free-radical substitution reaction in terms of initiation, propagation and termination steps
		know that chloroalkanes and chlorofluoroalkanes can be used as solvents
		understand that ozone, formed naturally in the upper atmosphere is beneficial
		be able to use equations such as the following to explain why chlorine atoms catalyse the decomposition of ozone and contribute to the formation of a hole in the ozone layer $Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$ and $ClO^{\bullet} + O_3 \rightarrow 2O_2 + Cl^{\bullet}$
		know that chlorine atoms are formed in the upper atmosphere when energy from ultra-violet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break
		appreciate that legislation to ban the use of CFCs was supported by chemists and that they have now developed alternative chlorine-free compounds

3

	Nucleophilic substitution	understand that haloalkanes contain polar bonds
		understand that haloalkanes are susceptible to nucleophilic attack, limited to OH^-, CN^- and NH_3
		understand the mechanism of nucleophilic substitution in primary haloalkanes
		understand that the carbon–halogen bond enthalpy influences the rate of hydrolysis
		appreciate the usefulness of these reactions in organic synthesis
	Elimination	understand concurrent substitution and elimination (including mechanisms) in the reaction of a haloalkane (e.g. 2- bromopropane with potassium hydroxide) and the role of the reagent as both nucleophile and base
		appreciate the usefulness of this reaction in organic synthesis
3.2.9	**Alkenes**	
	Alkenes: structure, bonding and reactivity	know that alkenes are unsaturated hydrocarbons
		know that bonding in alkenes involves a double covalent bond
		know that the arrangement >C=C< is planar
		know that the alkenes can exhibit E-Z stereoisomerism
		be able to draw the structures of E and Z isomers
		understand that E-Z isomers exist due to restricted rotation about the C=C bond
		understand that the double bond in an alkene is a centre of high electron density
	Addition reactions of alkenes	understand the mechanism of electrophilic addition of alkenes with HBr, H_2SO_4 and Br_2
		know that bromine can be used to test for unsaturation
		be able to predict the products of addition to unsymmetrical alkenes by reference to the relative stabilities of primary, secondary and tertiary carbocation intermediates
		understand that alcohols are produced industrially by hydration of alkenes in the presence of an acid catalyst.
		know the typical conditions for the industrial production of ethanol from ethene
	Polymerisation of alkenes	know how addition polymers are formed from alkenes
		recognise that poly(alkenes) like alkanes are unreactive
		be able to recognise the repeating unit in a poly(alkene)
		know some typical uses of poly(ethene) and poly(propene) and know that poly(propene) is recycled

3

3.2.10	**Alcohols**	
	Nomenclature	be able to apply IUPAC rules for nomenclature to alcohols, aldehydes, ketones and carboxylic acids limited to chains with up to 6 carbon atoms
	Ethanol production	know how ethanol is produced industrially by fermentation
		know the conditions for this reaction and understand the economic and environmental advantages and disadvantages of this process compared with the industrial production from ethene
		understand the meaning of the term biofuel
		know that the term carbon neutral refers to 'an activity that has no net annual carbon (greenhouse gas) emissions to the atmosphere'
		appreciate the extent to which ethanol, produced by fermentation, can be considered to be a carbon-neutral biofuel
	Classification and reactions	understand that alcohols can be classified as primary, secondary or tertiary
		understand that tertiary alcohols are not easily oxidised
		understand that primary alcohols can be oxidised to aldehydes and carboxylic acids and that secondary alcohols can be oxidised to ketones by a suitable oxidising agent such as acidified potassium dichromate(VI) (equations showing [O] as oxidant are acceptable)
		be able to use a simple chemical test to distinguish between aldehydes and ketones (e.g. Fehling's solution or Tollens' reagent)
	Elimination	know that alkenes can be formed from alcohols by acid catalysed elimination reactions (mechanism not required) appreciate that this method provides a possible route to polymers without using monomers derived from oil
3.2.11	**Analytical Techniques**	
	Mass spectrometry	understand that high resolution mass spectrometry can be used to determine the molecular formula of a compound from the accurate mass of the molecular ion
	Infrared spectroscopy	understand that certain groups in a molecule absorb infrared radiation at characteristic frequencies
		understand that 'fingerprinting' allows identification of a molecule by comparison of spectra
		be able to use spectra to identify particular functional groups and to identify impurities, limited to data presented in wave-number form
		understand the link between absorption of infrared radiation by bonds in CO_2, methane and water vapour and global warming

3.3 Unit 3 Investigative and Practical Skills in AS Chemistry

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities should be set in contexts appropriate to, and reflect the demand of, the AS content. These activities should allow candidates to use their knowledge and understanding of Chemistry in planning, carrying out, analysing and evaluating their work.

The content of Units 1 and 2 provides a basis for different practical topics which may be used for experimental and investigative skills. The experience of dealing with such activities will develop the skills required for the assessment of these skills in the Unit. Examples of suitable experiments that could be considered throughout the course will be provided in the Teacher Resource Bank.

It is expected that candidates will be able to use and be familiar with 'standard' laboratory equipment which is deemed suitable at AS level, throughout their experiences of carrying out their practical activities.

The skills developed in the course of their practical activities are elaborated further in the *How Science Works* section of this specification (see Section 3.7).

In the course of their experimental work, candidates should learn to

- demonstrate and describe ethical, safe and skilful practical techniques
- process and select appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations
- make 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.

The Centre-Assessed Option, Route T

The practical and investigative skills will be centre assessed through

- Investigative Skills Assignment (ISA)
- Practical Skills Assessment (PSA).

The ISA will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test (ISA test) (see Section 3.8).

The PSA requires centre assessment, throughout the AS course, of the candidate's ability to follow and undertake certain standard practical activities across the three areas of Chemistry: Inorganic, Organic and Physical. These practical activities are listed on the next page.

The Externally Marked Option, Route X

The practical and investigative skills will be externally assessed by AQA through

- Practical Skills Verification (PSV) and
- Externally Marked Practical Assignment (EMPA)

The PSV will require candidates to undertake the practical activities identified on the next page, in order to gain experience of a wide range of practical skills. These activities must allow a candidate suitable opportunity to demonstrate safe and skilful practice, as well as producing reliable and valid observations. AQA will require teacher verification, by means of a tick box on the Candidate Record Form, that a candidate is experienced in these skills.

The EMPA, in a similar way to the ISA, will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test (EMPA test) (see Section 3.8).

Practical Skills Assessment

The PSA is designed to credit candidates for the practical work they undertake naturally as part of the course. Further information is provided in Section 3.8, but candidates should complete at least two practical activities from each of the three areas of Chemistry listed below.

AS Inorganic Chemistry

Task	Possible context
Make up a volumetric solution	The preparation of a standard solution of sodium carbonate
Carry out a simple acid-base titration	Determine the concentration of unknown hydrochloric acid by titration
Carry out some inorganic tests	Tests for anions

AS Physical Chemistry

Task	Possible context
Measure an enthalpy change	Use Hess's law to find an unknown enthalpy change, such as the reaction of anhydrous copper(II) sulfate with water to produce hydrated crystals
Determine the M_r of a volatile liquid or the M_r of a gas	Determine the M_r of hexane or the M_r of carbon dioxide
Investigate how the rate of a reaction changes with temperature.	Investigate the rate of reaction of sodium thiosulfate with acid at different temperatures

AS Organic Chemistry

Task	Possible context
Distil a product from a reaction	The preparation of ethanal from the oxidation of ethanol or the preparation of cyclohexene from the dehydration of cyclohexanol
Carry out some organic tests	Tests for alkene, alcohol, acid, aldehyde
Investigate the combustion of alcohols	Use a calorimetric method to measure the enthalpies of combustion in an homologous series of alcohols

3.4 Unit 4 CHEM4 Kinetics, Equilibria and Organic Chemistry

Introduction

This unit develops the concepts of physical chemistry introduced at AS. Kinetics and equilibria are both treated quantitatively. Acids, bases and buffer solutions and the changes in pH during titrations are considered.

The study of organic chemistry is extended to include compounds containing the carbonyl group, aromatic compounds, amines, amino acids and polymers. The final section examines the way in which spectroscopic techniques are used to determine the molecular formulae and structures of organic compounds. The emphasis is on problem solving rather than on spectroscopic theory.

Candidates should

3.4.1	**Kinetics**	
	Simple rate equations	understand and be able to use rate equations of the form Rate = $k[A]^m [B]^n$ where *m* and *n* are the orders of reaction with respect to reactants A and B (*m, n* restricted to values 1, 2 or 0)
	Determination of rate equation	be able to derive the rate equation for a reaction from data relating initial rate to the concentrations of the different reactants
		be able to explain the qualitative effect of changes in temperature on the rate constant *k*
		understand that the orders of reactions with respect to reactants can be used to provide information about the rate determining/limiting step of a reaction
3.4.2	**Equilibria**	
	Equilibrium constant K_c for homogeneous systems	know that K_c is the equilibrium constant calculated from equilibrium concentrations for a system at constant temperature
		be able to construct an expression for K_c for an homogeneous system in equilibrium; be able to perform calculations involving such an expression
	Qualitative effects of changes of temperature and concentration	be able to predict the effects of changes of temperature on the value of the equilibrium constant
		understand that the value of the equilibrium constant is not affected by changes either in concentration or the addition of a catalyst

3

3

3.4.3	**Acids and Bases**	
	Brønsted–Lowry acid–base equilibria in aqueous solution	know that an acid is a proton donor
		know that a base is a proton acceptor
		know that acid–base equilibria involve the transfer of protons
	Definition and determination of pH	know that $pH = -\log_{10}[H^+]$, where [ ] represents the concentration in mol dm^{-3}
		be able to convert concentration into pH and vice versa
		be able to calculate the pH of a solution of a strong acid from its concentration
	The ionic product of water, K_w	know that water is weakly dissociated
		know that $K_w = [H^+][OH^-]$
		be able to calculate the pH of a strong base from its concentration.
	Weak acids and bases K_a for weak acids	know that weak acids and weak bases dissociate only slightly in aqueous solution
		be able to construct an expression, with units, for the dissociation constant K_a for a weak acid
		know that $pK_a = -\log_{10} K_a$
		be able to perform calculations relating the pH of a weak acid to the dissociation constant, K_a, and the concentration
	pH *curves, titrations and indicators*	understand the typical shape of pH curves for acid–base titrations in all combinations of weak and strong monoprotic acids and bases
		be able to use pH curves to select an appropriate indicator
		be able to perform calculations for the titrations of monoprotic and diprotic acids with sodium hydroxide, based on experimental results
	Buffer action	be able to explain qualitatively the action of acidic and basic buffers
		know some applications of buffer solutions
		be able to calculate the pH of acidic buffer solutions
3.4.4	**Nomenclature and Isomerism in Organic Chemistry**	
	Naming organic compounds	be able to apply IUPAC rules for nomenclature not only to the simple organic compounds, limited to chains with up to 6 carbon atoms, met at AS, but also to benzene and the functional groups listed in this unit
	Isomerism	know and understand the meaning of the term *structural isomerism*
		know that E-Z isomerism and optical isomerism are forms of stereoisomerism
		know that an asymmetric carbon atom is chiral and gives rise to optical isomers which exist as non super-imposable mirror images and differ only in their effect on plane polarised light
		understand the meaning of the terms *enantiomer* and *racemate*

		understand why racemates are formed
		be able to draw the structural formulae and displayed formulae of isomers
		Appreciate that drug action may be determined by the stereochemistry of the molecule and that different optical isomers may have very different effects
3.4.5	**Compounds Containing the Carbonyl Group**	
	Aldehydes and ketones	know that aldehydes are readily oxidised to carboxylic acids and that this forms the basis of a simple chemical test to distinguish between aldehydes and ketones (e.g. Fehling's solution and Tollens' reagent)
		appreciate the hazards of synthesis using HCN/KCN
		know that aldehydes can be reduced to primary alcohols and ketones to secondary alcohols using reducing agents such as $NaBH_4$. Mechanisms showing H^- are required (equations showing [H] as reductant are acceptable)
		understand the mechanism of the reaction of carbonyl compounds with HCN as a further example of nucleophilic addition producing hydroxynitriles
	Carboxylic acids and esters	know that carboxylic acids are weak acids but will liberate CO_2 from carbonates
		know that carboxylic acids and alcohols react, in the presence of a strong acid catalyst, to give esters
		know that esters can have pleasant smells
		know the common uses of esters (e.g. in solvents, plasticizers, perfumes and food flavourings)
		know that vegetable oils and animal fats are esters of propane-1,2,3-triol (glycerol)
		know that esters can be hydrolysed
		understand that vegetable oils and animal fats can be hydrolysed to give soap, glycerol and long chain carboxylic (fatty) acids
		know that biodiesel is a mixture of methyl esters of long chain carboxylic acids
	Acylation	know that vegetable oils can be converted into biodiesel by reaction with methanol in the presence of a catalyst
		know the reaction with ammonia and primary amines with acyl chlorides and acid anhydrides
		know the reactions of water, alcohols, ammonia and primary amines with acyl chlorides and acid anhydrides
		understand the mechanism of nucleophilic addition–elimination reactions between water, alcohols, ammonia and primary amines with acyl chlorides
		understand the industrial advantages of ethanoic anhydride over ethanoyl chloride in the manufacture of the drug aspirin

3.4.6	**Aromatic Chemistry**	
	Bonding	understand the nature of the bonding in a benzene ring, limited to planar structure and bond length intermediate between single and double
	Delocalisation stability	understand that delocalisation confers stability to the molecule
		be able to use thermochemical evidence from enthalpies of hydrogenation to illustrate this principle
	Electrophilic substitution	understand that electrophilic attack in arenes results in substitution; mechanisms limited to the monosubstitutions given below
	Nitration	understand that nitration is an important step in synthesis e.g. manufacture of explosives and formation of amines from which dyestuffs are manufactured
		understand the mechanism of nitration, including the generation of the nitronium ion
	Friedel–Crafts acylation reactions	understand that Friedel–Crafts acylation reactions are important steps in synthesis
		understand the mechanism of acylation using $AlCl_3$ as catalyst
3.4.7	**Amines**	
	Base properties (Brønsted–Lowry)	be able to explain the difference in base strength between ammonia, primary aliphatic and primary aromatic amines in terms of the availability of a lone pair on the N atom
	Nucleophilic properties	understand that the nucleophilic substitution reactions (including mechanism) of ammonia and amines with haloalkanes form primary, secondary, tertiary amines and quaternary ammonium salts; know that the latter can be used as cationic surfactants
	Preparation	know that primary aliphatic amines can be prepared from haloalkanes and by the reduction of nitriles
		know that aromatic amines are prepared by the reduction of nitro compounds
3.4.8	**Amino Acids**	
	Acid and base properties	understand that amino acids have both acidic and basic properties, including the formation of zwitterions
	Proteins	understand that proteins are sequences of amino acids joined by peptide links
		understand that hydrolysis of the peptide link produces the constituent amino acids
		know that mixtures of amino acids can be separated by chromotography
		understand the importance of hydrogen bonding in proteins (detailed structures not required)

3.4.9	**Polymers**	
	Addition polymers	be able to draw the repeating unit of addition polymers from monomer structures and vice versa
	Condensation polymers	understand that condensation polymers may be formed by reactions between dicarboxylic acids and diols, between dicarboxylic acids and diamines and between amino acids
		know the linkage of the repeating units of polyesters (e.g. Terylene) and polyamides (e.g. nylon 6,6 and Kevlar)
	Biodegradability and disposal of polymers	understand that polyalkenes are chemically inert and therefore non-biodegradable
		understand that polyesters and polyamides can be broken down by hydrolysis and are, therefore, biodegradable (mechanisms not required)
		appreciate the advantages and disadvantages of different methods of disposal of polymers
		appreciate the advantages and disadvantages of recycling polymers
3.4.10	**Organic Synthesis and Analysis**	
	Applications	be able to deduce how to synthesise organic compounds using the reactions in this specification
		be able to identify organic functional groups using the reactions in the specification

3

3.4.11	**Structure Determination**	
	Data sources	be able to use data from all the analytical techniques listed below to determine the structure of specified compounds
	Mass spectrometry	understand that the fragmentation of a molecular ion $M^{+\bullet} \rightarrow X^{+} + Y^{\bullet}$ gives rise to a characteristic relative abundance spectrum that may give information about the structure of the molecule (rearrangement processes not required)
		know that the more stable X^{+} species give higher peaks, limited to carbocation and acylium (RCO^{+}) ions
	Infrared spectroscopy	be able to use spectra to identify functional groups in this specification
	Nuclear magnetic resonance spectroscopy	understand that nuclear magnetic resonance gives information about the position of ^{13}C or ^{1}H atoms in a molecule
		understand that ^{13}C n.m.r. gives a simpler sprectrum than ^{1}H n.m.r.
		know the use of the δ scale for recording chemical shift
		understand that chemical shift depends on the molecular environment
		understand how integrated spectra indicate the relative numbers of ^{1}H atoms in different environments
		understand that ^{1}H n.m.r. spectra are obtained using samples dissolved in proton-free solvents (e.g. deuterated solvents and CCl_4)
		understand why tetramethylsilane (TMS) is used as a standard
		be able to use the *n* +1 rule to deduce the spin–spin splitting patterns of adjacent, non-equivalent protons, limited to doublet, triplet and quartet formation in simple aliphatic compounds
	Chromatography	know that gas-liquid chromatography can be used to separate mixtures of volatile liquids
		know that separation by column chromatography depends on the balance between solubility in the moving phase and retention in the stationary phase

3.5 Unit 5 CHEM5 Energetics, Redox and Inorganic Chemistry

Candidates should

3.5.1	**Thermodynamics**	
	Enthalpy change (∆H)	be able to define and apply the terms enthalpy of formation, ionisation enthalpy, enthalpy of atomisation of an element and of a compound, bond dissociation enthalpy, electron affinity, lattice enthalpy (defined as either lattice dissociation or lattice formation), enthalpy of hydration and enthalpy of solution
		be able to construct Born–Haber cycles to calculate lattice enthalpies from experimental data. Be able to compare lattice enthalpies from Born–Haber cycles with those from calculations based on a perfect ionic model to provide evidence for covalent character in ionic compounds
		be able to calculate enthalpies of solution for ionic compounds from lattice enthalpies and enthalpies of hydration
		be able to use mean bond enthalpies to calculate an approximate value of ΔH for other reactions
		be able to explain why values from mean bond enthalpy calculations differ from those determined from enthalpy cycles
	Free-energy change (∆G) and entropy change (∆S)	understand that ΔH, whilst important, is not sufficient to explain spontaneous change (e.g. spontaneous endothermic reactions)
		understand that the concept of increasing disorder (entropy change ΔS) accounts for the above deficiency, illustrated by physical change (e.g. melting, evaporation) and chemical change (e.g. dissolution, evolution of CO_2 from hydrogencarbonates with acid)
		be able to calculate entropy changes from absolute entropy values
		understand that the balance between entropy and enthalpy determines the feasibility of a reaction; know that this is given by the relationship $\Delta G = \Delta H - T\Delta S$ (derivation not required). be able to use this equation to determine how ΔG varies with temperature be able to use this relationship to determine the temperature at which a reaction is feasible

3

3.5.2	**Periodicity**	
	Study of the reactions of Period 3 elements Na – Ar to illustrate periodic trends	be able to describe trends in the reactions of the elements with water, limited to Na and Mg
		be able to describe the trends in the reactions of the elements
		Na, Mg, Al, Si, P and S with oxygen, limited to the formation of Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10} and SO_2.
	A survey of the acid base properties of the oxides of Period 3 elements	be able to explain the link between the physical properties of the highest oxides of the elements Na – S in terms of their structure and bonding
		be able to describe the reactions of the oxides of the elements Na – S with water, limited to Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10}, SO_2 and SO_3
		know the change in pH of the resulting solutions across the Period
		be able to explain the trends in these properties in terms of the type of bonding present
		be able to write equations for the reactions which occur between these oxides and given simple acids and bases
3.5.3	**Redox Equilibria**	
	Redox equations	be able to apply the electron transfer model of redox, including oxidation states and half equations to d block elements
	Electrode potentials	know the IUPAC convention for writing half-equations for electrode reactions
		know and be able to use the conventional representation of cells
		understand how cells are used to measure electrode potentials by reference to the standard hydrogen electrode
		know the importance of the conditions when measuring the electrode potential, *E* (Nernst equation not required)
		know that standard electrode potential, $E^\ominus$, refers to conditions of 298 K, 100 kPa and 1.00 mol dm^{-3} solution of ions
	Electrochemical series	know that standard electrode potentials can be listed as an electrochemical series
		be able to use $E^\ominus$ values to predict the direction of simple redox reactions and to calculate the e.m.f. of a cell
	Electrochemical cells	appreciate that electrochemical cells can be used as a commercial source of electrical energy
		appreciate that cells can be non-rechargeable (irreversible), rechargeable and fuel cells
		be able to use given electrode data to deduce the reactions occurring in non-rechargeable and rechargeable cells and to deduce the e.m.f. of a cell
		understand the electrode reactions of a hydrogen-oxygen fuel cell and appreciate that a fuel cell does not need to be electrically recharged
		appreciate the benefits and risks to society associated with the use of these cells

3.5.4	**Transition Metals**	
	General properties of transition metals	know that transition metal characteristics of elements Ti – Cu arise from an incomplete d sub-level in atoms or ions
		know that these characteristics include complex formation, formation of coloured ions, variable oxidation state and catalytic activity
	Complex formation	be able to define the term *ligand*
		know that co-ordinate bonding is involved in complex formation
		understand that a complex is a central metal ion surrounded by ligands
		know the meaning of co-ordination number
		understand that ligands can be unidentate (e.g. H_2O, NH_3 and Cl^-) or bidentate (e.g. $NH_2CH_2CH_2NH_2$ and $C_2O_4^{2-}$) or multidentate (e.g. $EDTA^{4-}$)
		know that haem is an iron(II) complex with a multidentate ligand
	Shapes of complex ions	know that transition metal ions commonly form octahedral complexes with small ligands (e.g. H_2O and NH_3)
		know that transition metal ions commonly form tetrahedral complexes with larger ligands (e.g. Cl^-)
		know that square planar complexes are also formed, e.g. cisplatin
		know that Ag^+ commonly forms the linear complex $[Ag(NH_3)_2]^+$ as used in Tollens' reagent
	Formation of coloured ions	know that transition metal ions can be identified by their colour, limited to the complexes in this unit
		know that colour changes arise from changes in oxidation state, co-ordination number and ligand
		know that colour arises from electronic transitions from the ground state to excited states: $\Delta E = h\nu$
		appreciate that this absorption of visible light is used in spectrometry to determine the concentration of coloured ions
	Variable oxidation states	know that transition elements show variable oxidation states
		know that Cr^{3+} and Cr^{2+} are formed by reduction of $Cr_2O_7^{2-}$ by zinc in acid solution
		know the redox titration of Fe^{2+} with MnO_4^- and $Cr_2O_7^{2-}$ in acid solution
		be able to perform calculations for this titration and for others when the reductant and its oxidation product are given
		know the oxidation of Co^{2+} by air in ammoniacal solution
		know the oxidation in alkaline solution of Co^{2+} and Cr^{3+} by H_2O_2

3

	Catalysis	know that transition metals and their compounds can act as heterogeneous and homogeneous catalysts
	Heterogeneous	know that a heterogeneous catalyst is in a different phase from the reactants and that the reaction occurs at the surface
		understand the use of a support medium to maximise the surface area and minimise the cost (e.g. Rh on a ceramic support in catalytic converters)
		understand how V_2O_5 acts as a catalyst in the Contact Process
		know that a Cr_2O_3 catalyst is used in the manufacture of methanol from carbon monoxide and hydrogen
		know that Fe is used as a catalyst in the Haber Process
		know that catalysts can become poisoned by impurities and consequently have reduced efficiency; know that this has a cost implication (e.g. poisoning by sulfur in the Haber Process and by lead in catalytic converters in cars)
	Homogeneous	know that when catalysts and reactants are in the same phase, the reaction proceeds through an intermediate species (e.g. the reaction between I^- and $S_2O_8^{2-}$ catalysed by Fe^{2+} and autocatalysis by Mn^{2+} in reactions of $C_2O_4^{2-}$ with MnO_4^-).
	Other applications of transition metal complexes	understand the importance of variable oxidation states in catalysis; both heterogeneous and homogeneous catalysts
		understand that Fe(II) in haemoglobin enables oxygen to be transported in the blood, and why CO is toxic
		know that the Pt(II) complex *cisplatin* is used as an anticancer drug
		appreciate the benefits and risks associated with this drug
		understand that $[Ag(NH_3)_2]^+$ is used in Tollens' reagent to distinguish between aldehydes and ketones
3.5.5	**Reactions of Inorganic Compounds in Aqueous Solution**	
	Lewis acids and bases	know the definitions of a Lewis acid and Lewis base; understand the importance of lone pair electrons in co-ordinate bond formation
	Metal-aqua ions	know that metal–aqua ions are formed in aqueous solution: $[M(H_2O)_6]^{2+}$, limited to M = Fe, Co and Cu $[M(H_2O)_6]^{3+}$, limited to M = Al, Cr and Fe
	Acidity or hydrolysis reactions	understand the equilibria $[M(H_2O)_6]^{2+} + H_2O \rightleftharpoons M(H_2O)_5(OH)]^{+} + H_3O^+$ and $[M(H_2O)_6]^{3+} + H_2O \rightleftharpoons [M(H_2O)_5(OH)]^{2+} + H_3O^+$ to show generation of acidic solutions with M^{3+}, and very weakly acidic solutions with M^{2+}

		understand that the acidity of $[M(H_2O)_6]^{3+}$ is greater than that of $[M(H_2O)_6]^{2+}$ in terms of the (charge/size ratio) of the metal ion
		be able to describe and explain the simple test-tube reactions of M^{2+} (aq) ions, limited to M = Fe, Co and Cu, and of M^{3+} (aq) ions, limited to M = Al, Cr and Fe, with the bases OH^-, NH_3 and CO_3^{2-}
		know that MCO_3 is formed but that $M_2(CO_3)_3$ is not formed
		know that some metal hydroxides show amphoteric character by dissolving in both acids and bases (e.g. hydroxides of Al^{3+} and Cr^{3+})
		know the equilibrium reaction $2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$
	Substitution reactions	understand that the ligands NH_3 and H_2O are similar in size and are uncharged, and that ligand exchange occurs without change of co-ordination number (e.g. Co^{2+} and Cr^{3+})
		know that substitution may be incomplete (e.g. the formation of $[Cu(NH_3)_4(H_2O)_2]^{2+}$)
		understand that the Cl^- ligand is larger than these uncharged ligands and that ligand exchange can involve a change of co-ordination number (e.g. Co^{2+} and Cu^{2+})
		know that substitution of unidentate ligand with a bidentate or a multidentate ligand leads to a more stable complex
		understand this chelate effect in terms of a positive entropy change in these reactions

3.6 Unit 6 Investigative and Practical Skills in A2 Chemistry

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities should be set in contexts appropriate to, and reflect the demand of, the A2 content. These activities should allow candidates to use their knowledge and understanding of Chemistry in planning, carrying out, analysing and evaluating their work.

The content of Units 4 and 5 provide a basis for different practical topics which may be used for experimental and investigative skills. The experience of dealing with such activities will develop the skills required for the assessment of these skills in the Unit. Examples of suitable experiments that could be considered throughout the course will be provided in the Teachers' Resource Bank.

It is expected that candidates will be able to use and be familiar with 'standard' laboratory equipment which is deemed suitable at A2 level, throughout their experiences of carrying out their practical activities.

The skills developed in the course of their practical activities are elaborated further in the *How Science Works* section of this specification (see Section 3.7).

In the course of their experimental work, candidates should learn to

- demonstrate and describe ethical, safe and skilful practical techniques
- process and select appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations
- make 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.

The Centre-Assessed Option, Route T

The practical and investigative skills will be centre assessed through two methods

- Investigative Skills Assignment (ISA).
- Practical Skills Assessment (PSA).

The ISA will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test (ISA test) (see Section 3.8).

The PSA will be based around a centre assessment, throughout the A2 course, of the candidate's ability to follow and undertake certain standard practical activities across the three areas of Chemistry: Inorganic, Organic and Physical. These practical activities are listed on the next page.

The Externally Marked Option, Route X

The practical and investigative skills will be externally assessed through

- Practical Skills Verification (PSV) and
- Externally Marked Practical Assignment (EMPA).

The PSV will require candidates to undertake the practical activities identified on the next page, in order to gain experience of a wide range of practical skills. These activities must allow a candidate suitable opportunity to demonstrate safe and skilful practice, as well as producing reliable and valid observations. AQA will require teacher verification, by means of a tick box on the Candidate Record Form, that a candidate is experienced in these skills.

The EMPA, in a similar way to the ISA, will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test (EMPA test) (see Section 3.8).

Practical Skills Assessment

The PSA is designed to credit candidates for the practical work they undertake naturally as part of the course. Further information is provided in Section 3.8, but it is expected that candidates will complete at least two practical activities from each of the three areas of Chemistry listed below.

A2 Inorganic Chemistry

Task	Possible context
Carry out a redox titration	The analysis of iron tablets by titration using acidified potassium manganate(VII)
Investigate the chemistry of transition metal compounds in a series of experiments	The chemistry of copper compounds
Prepare an inorganic complex	The preparation of hexaamminecobalt(III) chloride or the preparation of iron(II) ethandioate

A2 Physical Chemistry

Task	Possible context
Carry out a kinetic study to determine the order of a reaction	An iodine clock experiment e.g. the reaction of sulfite ions with iodate(V) ions
Determine an equilibrium constant	Determine a value of K_c for the reaction of ethanol with ethanoic acid.
Investigate how pH changes when a weak acid reacts with a strong base or when a strong acid reacts with a weak base.	Determine the pH curve for ethanoic acid reacting with sodium hydroxide

A2 Organic Chemistry

Task	Possible context
Prepare a solid organic compound	The preparation of aspirin
Purify an organic solid	The recrystallisation of impure benzenecarboxylic acid from hot water
Test the purity of an organic solid	Determine the melting point of benzenecarboxylic acid

3.7 How Science Works

How Science Works is an underpinning set of concepts and is the means whereby students come to understand how scientists investigate scientific phenomena in their attempts to explain the world about us. Moreover, *How Science Works* recognises the contribution scientists have made to their own disciplines and to the wider world.

Further, it recognises that scientists may be influenced by their own beliefs and that these can affect the way in which they approach their work. Also, it acknowledges that scientists can and must contribute to debates about the uses to which their work is put and how their work influences decision-making in society.

In general terms, it can be used to promote students' skills in solving scientific problems by developing an understanding of:

- the concepts, principles and theories that form the subject content
- the procedures associated with the valid testing of ideas and, in particular, the collection, interpretation and validation of evidence
- the role of the scientific community in validating evidence and also in resolving conflicting evidence.

As students become proficient in these aspects of *How Science Works*, they can also engage with the place and contribution of science in the wider world. In particular, students will begin to recognise:

- the contribution that scientists can make to decision-making and the formulation of policy
- the need for regulation of scientific enquiry and how this can be achieved
- how scientists can contribute legitimately to debates about those claims which are made in the name of science.

An understanding of *How Science Works* is a requirement for this specificatiion and is set out in the following points which are taken direct from the *GCE AS and A Level subject criteria for science subjects*. Each point is expanded in the context of Chemistry. The specification references given illustrate where the example is relevant and could be incorporated.

A	**Use theories, models and ideas to develop and modify scientific explanations**
	Scientists use theories and models to attempt to explain observations. These theories or models can form the basis for scientific experimental work. Scientific progress is made when validated evidence is found that supports a new theory or model.
	Examples in this specification include: • *the use of ionisation energy plots as evidence for electron arrangement in shells and subshells (AS Unit 1, 3.1.1)* • *experiments with cells confirm that electrons are transferred in redox reactions (A2 Unit 5, 3.5.3)*
B	**Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas**
	Scientists use their knowledge and understanding when observing objects and events, in defining a scientific problem and when questioning the explanations of themselves or of other scientists. Scientific progress is made when scientists contribute to the development of new ideas, materials and theories.
	Examples in this specification include: • *explanation of the origin of the hole in the ozone layer (AS Unit 2, 3.2.8)* • *Entropy as a concept to explain spontaneous reactions (A2 Unit 5, 3.5.2)*
C	**Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems**
	Observations ultimately lead to explanations in the form of hypotheses. In turn, these hypotheses lead to predictions that can be tested experimentally. Observations are one of the key links between the 'real world' and the abstract ideas of science. Once an experimental method has been validated, it becomes a protocol that is used by other scientists. ICT can be used to speed up, collect, record and analyse experimental data.
	Examples in this specification include: • *Many opportunities permeating throughout the Practical and Investigative Skills units (Unit 3 and Unit 6)*
D	**Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts**
	Scientists perform a range of experimental skills that include manual and data skills (tabulation, graphical skills etc). Scientists should select and use equipment that is appropriate when making accurate measurements and should record these measurements methodically. Scientists carry out experimental work in such a way as to minimise the risk to themselves, to others and to the materials, including organisms, used.
	Examples in this specification include: • *Many opportunities permeating throughout the Practical and Investigative Skills units (Unit 3 and Unit 6)*

E	**Analyse and interpret data to provide evidence, recognising correlations and causal relationships**
	Scientists look for patterns and trends in data as a first step in providing explanations of phenomena. The degree of uncertainty in any data will affect whether alternative explanations can be given for the data. Anomalous data are those measurements that fall outside the normal, or expected, range of measured values. Decisions on how to treat anomalous data should be made only after examination of the event. In searching for causal links between factors, scientists propose predictive theoretical models that can be tested experimentally. When experimental data confirm predictions from these theoretical models, scientists become confident that a causal relationship exists.
	Examples in this specification include: • *the use of enthalphy of combustion data for a range of alcohols in the development of the idea of mean bond enthalpies (AS Unit 2, 3.2.1)* • *the recognition that entropy change is an important factor in determining the direction of spontaneous reaction (A2 Unit 5, 3.5.1 and 3.5.5)*
F	**Evaluate methodology, evidence and data, and resolve conflicting evidence**
	The validity of new evidence, and the robustness of conclusions that stem from them, is constantly questioned by scientists. Experimental methods must be designed adequately to test predictions. Solutions to scientific problems are often developed when different research teams produce conflicting evidence. Such evidence is a stimulus for further scientific investigation, which involves refinements of experimental technique or development of new hypotheses.
	Examples in this specification include: • *the importance of bond polarity and carbon-halogen bond enthalpy as factors in determining the rate of hydrolysis of haloalkanes (AS Unit 1, 3.1.1)* • *the use of thermochemical evidence from enthalpies of hydrogenation enthalpies as support for the structure of benzene (A2 Unit 4, 3.4.6)*
G	**Appreciate the tentative nature of scientific knowledge**
	Scientific explanations are those that are based on experimental evidence which is supported by the scientific community. Scientific knowledge changes when new evidence provides a better explanation of scientific observations.
	Examples in this specification include: • *the increase in greenhouse gases that may cause global warming (AS Unit 1, 3.1.6)* • *the reactions of metal-aqua ions acting as Lewis bases (A2 Unit 5, 3.5.5)*
H	**Communicate information and ideas in appropriate ways using appropriate terminology**
	By sharing the findings of their research, scientists provide the scientific community with opportunities to replicate and further test their work, thus either confirming new explanations or refuting them. Scientific terminology avoids confusion amongst the scientific community, enabling better understanding and testing of scientific explanations.
	Examples in this specification include: • *IUPAC rules for naming organic compounds have been adopted globally (AS Unit 1, 3.1.5)* • *experiments with cells confirm that electrons are transferred in redox reactions (A2, Unit 5, 3.5.3)*

I	**Consider applications and implications of science and appreciate their associated benefits and risks**
	Scientific advances have greatly improved the quality of life for the majority of people. Developments in technology, medicine and materials continue to further these improvements at an increasing rate. Scientists can predict and report on some of the beneficial applications of their experimental findings. Scientists evaluate, and report on, the risks associated with the techniques they develop and applications of their findings.
	Examples in this specification include: • *the benefits and risks of using chlorine in water treatment (AS Unit 2, 3.2.5)* • *The use of hydrogen-oxygen fuel cells as a source of energy and the hazards associated with their use (A2 Unit 5, 3.5.4)*
J	**Consider ethical issues in the treatment of humans, other organisms and the environment**
	Scientific research is funded by society, either through public funding or through private companies that obtain their income from commercial activities. Scientists have a duty to consider ethical issues associated with their findings. Individual scientists have ethical codes that are often based on humanistic, moral and religious beliefs. Scientists are self-regulating and contribute to decision making about what investigations and methodologies should be permitted.
	Examples in this specification include: • *the environmental and economic advantages of recycling scrap metal (AS Unit 2, 3.2.7)* • *how the relative biodegradability of polymers affects their disposal or reuse (A2, Unit 4, 3.4.9)*
K	**Appreciate the role of the scientific community in validating new knowledge and ensuring integrity**
	The findings of scientists are subject to peer review before being accepted for publication in a reputable scientific journal. The interests of the organisations that fund scientific research can influence the direction of research. In some cases the validity of those claims may also be influenced
	Examples in this specification include: • *the identification of acid rain as a problem (AS Unit 2, 3.2.7)* • *the production of biofuels as carbon neutral fuels (A2 Unit 4, 3.4.4)*
L	**Appreciate the ways in which society uses science to inform decision making**
	Scientific findings and technologies enable advances to be made that have potential benefit for humans. In practice, the scientific evidence available to decision makers may be incomplete. Decision makers are influenced in many ways, including by their prior beliefs, their vested interests, special interest groups, public opinion and the media, as well as by expert scientific evidence
	Examples in this specification include: • *the identification of the release of CO and NO as a problem and the development of catalytic converters to counteract this (AS Unit 2, 3.2.8)* • *the different properties of enantiomers can give rise to different chemical reactions in the body, for example the optical isomers of thalidomide (A2 Unit 4, 3.4.4)*

3.8 Guidance on Internal Assessment

Introduction

The GCE Sciences share a common approach to centre assessment. This is based on the belief that assessment should encourage practical activity in science, and that practical activity should encompass a broad range of activities. This section must be read in conjunction with information in the Teacher Resource Bank.

Practical and Investigative Skills are assessed in Unit 3 and Unit 6, worth, respectively, 20% of the AS Award (and 10% of the Advanced Level Award) and 10% of the full Advanced Level Award.

There are two routes for the assessment of Practical and Investigative Skills

Either

Route T: Practical Skills Assessment (PSA) + Investigative Skills Assignment (ISA) - Teacher-marked

Or

Route X: Practical Skills Verification (PSV) + Externally Marked Practical Assignment (EMPA) - AQA- marked.

Both routes to assessment are available at AS and A2.

Centres can not make entries for the same candidate for both assessment routes [T and X] in the same examination series.

3.8.1 Centre Assessed Route T (PSA/ISA)

Each centre assessed unit comprises

- Practical Skills Assessment (PSA)
- Investigative Skills Assignment (ISA).

The PSA consists of the centre's assessment of the candidate's ability to demonstrate practical skills throughout the course; thus, candidates should be encouraged to carry out practical and investigative work throughout the course of their study. This work should cover the skills and knowledge of *How Science Works* (Section 3.7) and in Sections 3.3 and 3.6.

The ISA has two stages where candidates

- undertake practical work, collect and process data
- complete a written ISA test.

Each stage must be carried out under controlled conditions but may be scheduled at a time convenient to the centre. The written test must be completed in a single, uninterrupted session.

The ISA is set externally by AQA, but internally marked, with marking guidelines provided by AQA.

In a given academic year two ISAs at each of AS and A2 level will be provided.

Practical Skills Assessment (PSA)

Candidates are assessed throughout the course on practical skills, using a scale from 0 to 12. The mark submitted for practical skills should be judged by the teacher. Teachers may wish to use this section for formative assessment and should keep an ongoing record of each candidate's performance but the mark submitted should represent the candidate's practical abilities over the whole course.

The nature of the assessment

Since the skills in this section involve implementation, they must be assessed while the candidate is carrying out practical work. Practical activities are not intended to be undertaken as formal tests and supervisors can provide the level of guidance that would normally be given during teaching. In order to provide appropriate opportunities to demonstrate the necessary skills, instructions provided must not be too prescriptive but should allow candidates to make decisions for themselves, particularly concerning the conduct of practical work, their organisation and the manner in which equipment is used.

The tasks

Tasks are provided in the **three areas** of chemistry; inorganic, physical and organic chemistry.

AS level candidates should undertake at least **two of the tasks** from each of the three areas of chemistry. Each task will score a maximum of 2 marks aggregating to a total score out of 12 marks.

Only marks arising from those tasks designated as AS tasks may be submitted for AS Chemistry.

A2 level candidates should undertake at least **two of the tasks** from each of the three areas of chemistry. Each task will score a maximum of 2 marks aggregating to a total score out of 12 marks. Only marks arising from those tasks designated as A2 tasks may be submitted for A2 Chemistry.

At both AS and A2, centres may choose to carry out all of the available tasks, in which case, the **best two marks** from each area for each candidate should be counted towards the final mark.

A list of the AS and A2 PSA tasks is given in Sections 3.3 and 3.6, respectively. Detailed marking guidance including descriptors for 0, 1 and 2 marks for each PSA task is provided in Section 3.8.3.

Candidates should be awarded marks which reflect their level of performance over the whole course.

AQA may wish to ask for further supporting evidence from centres in relation to the marks awarded for the PSA. Centres should therefore keep records of their candidates' performances in their practical activities throughout the course. (For example, a laboratory diary, log or tick sheet.)

Further guidance for the awarding of marks for the PSA will be provided in the Teacher Resource Bank.

Use of ICT during the PSA

Candidates are encouraged to use ICT where appropriate in the course of developing practical skills, for example in collecting and analysing data.

Investigative Skills Assignment (ISA)

The Investigative Skills Assignment carries 38 marks and has two stages.

Stage 1: Collection and Processing of data

Candidates carry out practical work following an AQA task sheet. Centres may use the task sheet as described or may make minor suitable modifications to materials or equipment, following AQA guidelines. Any modifications made to the task sheet must be agreed in writing with the AQA Assessment Adviser. The task may be conducted in a normal timetabled lesson but must be under controlled conditions.

Candidates collect raw data and represent it in a table of their own design or make observations that are recorded on the *Candidate Results Sheet*. The candidates' work must be handed to the teacher at the end of the session. The teacher assesses the candidates' work following AQA marking guidelines.

There is no specified time limit for this stage.

Stage 2: The ISA written test

The ISA test should be taken as soon as convenient after completion of Stage 1, and under controlled conditions. Each candidate is provided with an ISA test and the candidate's completed material from Stage 1. The teacher uses the AQA marking guidelines to assess the ISA test.

The ISA test is in two Sections.

Section A

This consists of a number of questions relating to the candidate's own data.

Section B

At the start of this section, candidates are supplied with additional data on a related topic. A number of questions relating to analysis and evaluation of the data then follow.

The number of marks allocated to each section may vary slightly with each ISA test.

Use of ICT during the ISA

ICT may be used during the ISA Stages 1 and 2 but teachers should note any restrictions in the ISA marking guidelines or Teachers Notes. Use of the internet is not permitted.

Candidates absent for the practical work

A candidate absent for the practical work (Stage 1) should be given an opportunity to carry out the practical work before they sit the ISA test. This may be with another group or at a different time. In extreme circumstancs, when such arrangements are not possible, the teacher may supply a candidate with class data. In this case candidates cannot be awarded marks for Stage 1, but can still be awarded marks for Stage 2 of the assessment.

Material from AQA

For each ISA, AQA will provide:

- Teachers' Notes
- Task sheet
- ISA test
- Marking guidelines.

This material must be kept under secure conditions within the centre. If it is to be used in more than one session, then the centre must ensure security of the material between sessions. Further details regarding this material will be provided.

Security of assignments

All ISA materials, including marked ISAs, should be treated like examination papers and kept under secure conditions until the publication of results.

General Information

Route T

Administration

In any year a candidate may attempt either or both of the two ISAs.

For each candidate, the teacher should submit to AQA a total mark comprising:

- The PSA mark
- the better ISA mark (if two have been attempted).

The ISA component of this mark must come from one ISA only, i.e. the marks awarded for stages of different ISAs cannot be combined.

Candidates may make only one attempt at a particular ISA. Redrafting is not permitted at any stage during the ISA.

The total mark must be submitted to AQA by the due date in the academic year for which the ISA was published.

Work to be submitted

For each candidate in the sample the following materials must be submitted to the moderator by the deadline issued by AQA.

- the candidate's data from Stage 1 (on the *Candidate Result Sheet*)
- the ISA written test, which includes the *Candidate Record Form*, showing the marks for the ISA and the PSA.

In addition each centre must provide

- *Centre Declaration Sheet*
- Details of any amendments to the task sheet with information supporting the changes from the AQA Assessment Adviser, must be notified to the moderator
- For each group of candidates, a completed *Teacher Results Sheet*.

Working in groups

For the PSA candidates may work in groups provided that any skills being assessed are the work of individual candidates. For the ISA further guidance will be provided in the Teacher Notes.

Other information

Section 6 of this specification outlines further guidance on the supervision and authentication of centre assessed units.

Section 6 also provides information in relation to the internal standardisation of marking for these units. Please note that the marking of both the PSA and the ISA must be internally standardised as stated in Section 6.4.

Further support

AQA supports the units in a number of ways.

- AQA holds annual standardising meetings on a regional basis for all internally assessed components. Section 6 of this specification provides further details about these meetings
- A Teacher Resource Bank which includes further information and guidance
- Assessment Advisers are appointed by AQA to provide advice on internally assessed units. Every centre is allocated an Assessment Adviser.

The Assessment Advisers can provide guidance on

– issues relating to the carrying out of tasks for assessment

– application of marking guidelines

Any amendments to the ISA task sheet must be discussed with the Assessment Adviser and confirmation of the amendments made must be submitted to the AQA moderator.

3.8.2 Externally Marked Route X (PSV/EMPA)

The practical and investigative skills will be assessed through

- Practical Skills Verification (PSV) and
- Externally Marked Practical Assignment (EMPA).

The PSV requires teachers to verify their candidates' ability to demonstrate safe and skilful practical techniques and make valid and reliable observations.

The EMPA has two stages where candidates

- Undertake a themed task
- Complete a written EMPA test

Each stage must be carried out under controlled conditions but may be at a time convenient to the centre. The written test must be completed in a single uninterrupted session.

The EMPA is set and marked by AQA. Only one EMPA at AS and one at A2 will be provided in a given academic year. AQA will stipulate a period of time during which the EMPA (task and written test) must be completed.

Practical Skills Verification

Candidates following this route must undertake the practical activities outlined in sections 3.3 for AS or 3.6 for A2 in order to allow candidates suitable opportunities to demonstrate safe and skilful practical techniques and to make reliable and valid observations. The teacher will confirm on the *Candidate Record Form*, for each candidate that this requirement has been met. Failure to complete the tick box will lead to a mark of zero being awarded to the candidate for the whole of this unit. Knowledge and understanding of the skills in Section 3.3 and 3.6 will be assessed in Section C of the EMPA written tests.

Tasks are provided in the **three areas** of chemistry; inorganic, physical and organic chemistry. Candidates should undertake at least two of the task form from each of the three areas of chemistry.

In order to provide appropriate opportunities to demonstrate the necessary skills, teachers must not be too prescriptive to the instructions they provide but should allow candidates to make decisions for themselves, particularly concerning the conduct of practical work, their organisation and the manner in which equipment is used.

Candidates should be encouraged to carry out practical and investigative work throughout the course. This work should cover the skills and knowledge of *How Science Works* (Section 3.7) and in Sections 3.3 and 3.6. Alternative practical activities may be used provided that candidates are given the opportunity to develop the same skills identified in Section 3.3 or 3.6.

Further guidance for conducting practical activities for the PSV will be provided in the Teacher Resource Bank.

ICT

Candidates may use ICT where appropriate in the course of developing practical skills, for example in collecting and analysing data.

Externally Marked Practical Assignment (EMPA)

The Externally Marked Practical Assignment carries 50 marks and has two stages.

Stage 1: Themed task, collection and processing of data

Candidates carry out practical work following AQA task sheets. The tasks may be conducted in normal timetabled lessons and at a time convenient to the centre but must be under controlled conditions. Candidates collect raw data and represent it in a table of their own design or make observations that are recorded on *Task Sheet 1* and *Task Sheet 2*. The candidates' work must be handed to the teacher at the end of each session.

Centres may use the task sheets, as described, or may make minor suitable modifications to materials or equipment following AQA guidelines. Any modifications made to the task sheets must be agreed in writing with the Assessment Adviser and details must be provided to the AQA Examiner.

There is no specified time limit for this stage.

Stage 2: The EMPA written test

The EMPA test should be taken as soon as convenient after completion of Stage 1 and under controlled conditions. Each candidate is provided with an EMPA test and the candidate's completed material from Stage 1.

The EMPA test is in three Sections.

Section A

This consists of a number of questions relating to the candidate's own data.

Section B

At the start of this section, candidates are supplied with additional data on a related topic. A number of questions relating to analysis and evaluation of the data then follow.

Section C

Candidates answer questions based on knowledge and understanding of the processes outlined in section 3.3 for AS and section 3.6 for A2.

The number of marks allocated to each section may vary with each EMPA test.

Use of ICT during the EMPA

ICT may be used during the EMPA Stages 1 and 2 but teachers should note any restrictions in the Teachers' Notes. Use of the internet is not permitted.

Candidates absent for the practical work

A candidate absent for the practical work (Stage 1) should be given an opportunity to carry out the practical work before they sit the EMPA test. This may be with another group or at a different time. In extreme circumstances, when such arrangements are not possible the teacher may supply a candidate with class data. This must be noted on the *Candidate Record Form*. In this case the candidate cannot be awarded marks for Stage 1, but can still be awarded marks for Stage 2 of the assessment.

Material from AQA

For each EMPA, AQA will provide:

- Teachers' Notes
- Task sheets
- EMPA test

When received, this material must be kept under secure conditions. If it is to be used in more than one session, then the centre must ensure security of material between sessions. Further details regarding this material will be provided.

Security of assignments

Completed EMPAs should be treated like examination papers and kept under secure conditions until sent to the Examiner. All other EMPA materials should be kept under secure conditions until the publication of results.

General Information

Route X

Administration

Only one EMPA will be available in any year at AS and at A2. AQA will stipulate a period of time during which the EMPA (task and test) must be completed.

Candidates may make only one attempt at a particular EMPA and redrafting is not permitted at any stage during the EMPA.

Work to be submitted

The material to be submitted to the examiner for each candidate consists of

- the completed *Task Sheet 1* and *Task Sheet 2*
- the EMPA written test, which includes the *Candidate Record Form*, showing the PSV verification of safe and skilful practical techniques and reliable and valid observations.

In addition each centre must provide

- *Centre Declaration Sheet*
- Details of any amendments to the task sheet with confirmation supporting the changes from the Assessment Adviser
- For each group of candidates, a completed *Teacher Results Sheet*.

Working in groups

For the PSV candidates may work in groups provided that any skills being assessed are the work of individual candidates. For the EMPA further guidance will be provided but the opportunity for group work will not be a common feature.

Other information

Section 6 of this specification outlines further guidance on the supervision and authentication of Internally assessed units.

Further support

AQA supports centres in a number of ways.

- A Teacher Resource Bank which includes further information and guidance
- Assessment Advisers are appointed by AQA to provide advice on internally assessed units. Every centre is allocated an Assessment Adviser.

The Assessment Advisers can provide guidance on issues relating to the carrying out of tasks for assessment. Any amendments to the EMPA task sheet must be discussed with the AQA Assessment Adviser and confirmation of the amendments made must be submitted to the AQA Examiner.

3.8.3 General Marking Guidance for each PSA

Centres should bear in mind that satisfactory completion of a PSA task by the candidate should be judged in the context of an ability to work safely and in an organised manner, when demonstrating appropriate manipulative skills. Each task should be graded on a three point scale (0, 1 or 2 marks) with the following general guidelines for the award of each point on the scale.

Further support

AQA supports the centre assessed units in a number of ways.

- AQA holds annual standardising meetings on a regional basis for all centre assessed components. Section 6 of this specification provides further details about these meetings
- A Teacher Resource Bank which includes further information and guidance from the Principal Moderator.
- Assessment Advisers are appointed by AQA to provide advice on centre assessed units. Every centre is allocated an Assessment Adviser. Contact details for your Assessment Adviser can be obtained by e-mailing your centre name and number to chemistry-gce@aqa.org.uk. The Assessment Advisers can provide guidance on
  - issues relating to the carrying out of assignments for assessment
  - application of marking guidelines
  - administrative issues related to the centre assessed units.

3.8.4 General Marking Guidance for each PSA

Centres should bear in mind that satisfactory completion of a PSA task by the candidate should be judged in the context of an ability to work safely and in an organised manner, when demonstrating appropriate manipulative skills.

Each task should be graded on a three point scale (0, 1 or 2 marks) with the following general guidelines for the award of each point on the scale.

Assessment Descriptors

2 marks	Candidates are able to follow a set of instructions for the task in a safe and organised way. Measurements are precise and within the expected range. Candidates require minimal additional guidance to carry out the task in a competent manner and are able to produce an outcome which is within the expected tolerance for the activity or produce a set of results, most of which are correct.
1 mark	Candidates are able to follow a set of instructions for the task in a reasonably safe way, but could be better organised. Measurements are imprecise or outside the expected range. Candidates require some additional guidance to carry out the task to a standard which is considered appropriate and produce an outcome, which, whilst acceptable, may not be within the expected tolerance for the activity or produce a set of results, only some of which are correct.
0 marks	Candidates have significant difficulty in following a set of instructions for the task and their work is poorly organised or unsafe. Measurements are imprecise or outside the expected range. Candidates require significant additional guidance to carry out the task to a standard which is considered appropriate and produce an outcome which is significantly outside the expected tolerance for the activity or produce a set of results, few of which are correct. The following sections detail, for AS and A2, possible contexts and marking guidance for each area of chemistry.

Practical Skills Assessment: AS Inorganic Chemistry

Task and possible context	Specific marking guidance
Make up a volumetric solution For example: The preparation of a standard solution of sodium carbonate	**2 marks: All** areas of the task are carried out competently. The weighing is precise and within the required range. The transfer of solid to a graduated flask is done with care. The solution is made up to the mark, accurately. **1 mark: One** of the areas of the task is performed poorly. The weighing is imprecise or outside the required range **OR** The transfer of solid to the graduated flask is careless **OR** The solution is made up inaccurately. (e.g. the flask is over-filled) **0 marks: At least two** of the areas of the task are performed poorly. The weighing is imprecise or outside the required range. The transfer of solid to the graduated flask is careless. The solutiion is made up inaccurately.
Carry out a simple acid-base titration For example: Determine the concentration of unknown hydrochloric acid by titration	**2 marks: All** areas of the task are carried out competently. The burette is filled safely with the correct reagent (including below the tap). The pipette and filler, burette and conical flask are all used correctly. The titration results are concordant and the average titre is judged accurate. **1 mark: One** of the areas of the task is performed poorly. The burette is filled with the incorrect reagent or the funnel is left in or the burette is not filled below the tap **OR** One of either, the pipette, pipette filler, burette or conical flask is not used correctly **OR** The titration results are not concordant or the average titre is inaccurate. **0 marks: At least two** of the areas of the task are performed poorly. The burette is filled with the incorrect reagent or the funnel is left in or the burette is not filled below the tap. One of either, the pipette, pipette filler, burette or conical flask is not used correctly. The titration results are not concordant or the average titre is inaccurate.
Carry out some inorganic tests For example: Tests for anions	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are appropriate. The tests (heating, shaking etc.) are carried out safely and with due care. Most of the observations are correct. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are inappropriate **OR** The tests (heating, shaking etc.) are carried out in a careless manner **OR** Only some of the observations are correct. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are inappropriate. The tests (addition, heating, shaking etc.) are carried out in a careless manner. Few of the observations are correct.

Practical Skills Assessment: AS Physical Chemistry

Task and possible context	Specific marking guidance
Measure an enthalpy change For example: Use Hess's law to find an unknown enthalpy change, such as the reaction of anhydrous copper(II) sulfate with water to produce hydrated crystals	**2 marks: All** areas of the task are carried out competently. Masses and volumes are measured precisely and within the required range. Initial/final temperatures are measured precisely and mixing is complete. The results lead to an enthalpy change which is within the expected range. **1 mark: One** of the areas of the task is performed poorly. Masses or volumes are measured imprecisely or not in the required range **OR** Temperatures are measured imprecisely or mixing is incomplete **OR** The results lead to an enthalpy change which is outside the expected range. **0 marks: At least two** of the areas of the task are performed poorly. Masses or volumes are measured imprecisely or not in the required range. Temperatures are measured imprecisely or mixing is incomplete. The results lead to an enthalpy change which is outside the expected range.
Determine the M_r of a volatile liquid or the M_r of a gas For example: Determine the M_r of hexane or the M_r of carbon dioxide	**2 marks: All** areas of the task are carried out competently. The apparatus is weighed precisely and handled carefully. The transfer of liquid or gas is carried out safely and with due care. The apparatus is equilibrated and all necessary measurements taken. **1 mark: One** of the areas of the task is performed poorly. The apparatus is weighed imprecisely or handled without due care **OR** The transfer of liquid or gas is not carried out safely or with due care **OR** The apparatus has not equilibrated or some measurements are not taken. **0 marks: At least two** of the areas of the task are performed poorly. The apparatus is weighed imprecisely or handled without due care. The transfer of liquid or gas is not carried out safely or with due care. The apparatus has not equilibrated or some measurements are not taken.
Investigate how the rate of a reaction changes with temperature For example: Investigate the rate of reaction of sodium thiosulfate with acid at different temperatures	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are appropriate and the apparatus is safe. Heating is carried out with due care and only as long as necessary. The change in the measured rate is within the expected range. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are inappropriate or the apparatus is unsafe **OR** Heating is carried out with insufficient care or longer than necessary **OR** The change in the measured rate is not within the expected range. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are inappropriate or the apparatus is unsafe. Heating is carried out with insufficient care or longer than necessary. The change in the measured rate is not within the expected range

Practical Skills Assessment: AS Organic Chemistry

Task and possible context	Specific marking guidance
Distil a product from a reaction For example: The preparation of ethanal from the oxidation of ethanol or the preparation of cyclohexene from cyclohexanol	**2 marks: All** areas of the task are carried out competently. The apparatus set-up is safe and appropriate. Heating is carried out with due care and only as long as necessary. The yield of product is appropriate. **1 mark: One** of the areas of the task is performed poorly. The apparatus set-up is inappropriate **OR** Heating is carried out with insufficient care or longer than necessary **OR** The yield of product is inappropriate. **0 marks: At least two** of the areas of the task are performed poorly. The apparatus set-up is inappropriate. Heating is carried out with insufficient care or longer than necessary. The yield of product is inappropriate.
Carry out some organic tests For example: Tests for alkene, alcohol, acid, aldehyde	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are appropriate. The tests (heating, shaking etc.) are carried out safely and with due care. Nearly all of the observations are correct. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are inappropriate **OR** The tests (heating, shaking etc.) are carried out in a careless manner **OR** Only some of the observations are correct. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are inappropriate. The tests (addition, heating, shaking etc.) are carried out in a careless manner. Few of the observations are correct.
Investigate the combustion of alcohols For example: Use a calorimetric method to measure the enthalpies of combustion in an homologous series	**2 marks: All** areas of the task are carried out competently. Masses and volumes are measured precisely and within the required range. Initial/final temperatures are measured precisely. The range and trend in enthalpies is as expected for the series. **1 mark: One** of the areas of the task is performed poorly. Masses or volumes are measured imprecisely or not in the required range **OR** Temperatures are measured imprecisely **OR** The range or trend in enthalpies is not as expected for the series. **0 marks: At least two** of the areas of the task are performed poorly. Masses or volumes are measured imprecisely or not in the required range. Temperatures are measured imprecisely. The range or trend in enthalpies is not as expected for the series.

Practical Skills Assessment: A2 Inorganic Chemistry

Task and possible context	Specific marking guidance
Carry out a redox titration For example: The analysis of iron tablets by titration using acidified potassium manganate(VII)	**2 marks: All** areas of the task are carried out competently. The burette is filled safely with the correct reagent (including below the tap) The pipette and filler, burette and conical flask are all used correctly. The titration results are concordant and the average titre is accurate. **1 mark: One** of the areas of the task is performed poorly. The burette is filled with the incorrect reagent or the funnel is left in or the burette is not filled below the tap **OR** One of either the pipette, pipette filler, burette or conical flask is used incorrectly **OR** The titration results are not concordant or the average titre is inaccurate. **0 marks: At least two** of the areas of the task are performed poorly. The burette is filled with the incorrect reagent or the funnel is left in or the burette is not filled below the tap. One of either the pipette, filler, burette or conical flask is used incorrectly. The titration results are not concordant or the average titre is inaccurate.
Investigate the chemistry of transition metal compounds in a series of experiments For example: The chemistry of copper compounds	**2 marks: All** experiments are carried out competently. The quantities of reagents are appropriate. All experiments are carried out safely and with due care. Nearly all of the observations are correct. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are inappropriate **OR** Some of the experiments are carried out in a careless manner **OR** Only some of the observations are correct. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are inappropriate. Many of the experiments are carried out in a careless manner. Few of the observations are correct.
Prepare an inorganic complex For example: The preparation of hexaamminecobalt(III) chloride	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are appropriate for the preparation. The apparatus set-up for the preparation is safe and appropriate. The experiment is carried out safely and produces an appropriate quantity and quality of product. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are inappropriate for the preparation **OR** The apparatus set-up for each experiment is unsafe or inappropriate **OR** The experiments are carried out with insufficient care or the yield is poor. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are inappropriate for the preparation. The apparatus set-up for each experiment is unsafe or inappropriate. The experiments are carried out with insufficient care or the yield is poor.

Practical Skills Assessment: A2 Physical Chemistry

Task and possible context	Specific marking guidance
Carry out a kinetic study to determine the order of a reaction For example: An iodine clock experiment e.g. the reaction of sulfite ions with iodate(V) ions	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are measured precisely. Times are measured accurately and recorded precisely. Sufficient values are on a good straight line and the order of reaction is in the expected range. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are measured imprecisely **OR** Times are measured inaccurately or recorded imprecisely **OR** The values are scattered or the order is not in the expected range. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are measured imprecisely. Times are measured inaccurately or recorded imprecisely. The values are scattered or the order is not in the expected range.
Determine an equilibrium constant For example: Determine a value of K_c for the reaction of ethanol with ethanoic acid	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are measured precisely. The titrations are carried out with due care and data recorded precisely. The value of the equilibrium constant is in the expected range. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are measured imprecisely **OR** Titrations are carried out with insufficient care or data recorded imprecisely **OR** The value of the equilibrium constant is not in the expected range. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are measured imprecisely. Titrations are carried out with insufficient care or data recorded imprecisely. The value of the equilibrium constant is not in the expected range.
Investigate how pH changes when a weak acid reacts with a strong base or when a strong acid reacts with a weak base For example: Determine the pH curve for ethanoic acid reacting with sodium hydroxide	**2 marks: All** areas of the task are carried out competently. The apparatus is used correctly. The pH values are recorded correctly. The pH changes are in the expected range. **1 mark: One** of the areas of the task is performed poorly. The apparatus is used incorrectly **OR** The pH values are recorded incorrectly **OR** The pH changes are not in the expected range. **0 marks: At least two** of the areas of the task are performed poorly. The apparatus is used incorrectly. The pH values are recorded incorrectly. The pH changes are not in the expected range.

Practical Skills Assessment: A2 Organic Chemistry

Task and possible context	Specific marking guidance
Prepare a solid organic compound For example: The preparation of aspirin	**2 marks: All** areas of the task are carried out competently. The quantities of reagents are appropriate for the preparation. The apparatus set-up for the preparation is safe and appropriate. The experiment is carried out safely and produces an appropriate quantity and quality of product. **1 mark: One** of the areas of the task is performed poorly. The quantities of reagents are inappropriate for the preparation **OR** The apparatus set-up for each experiment is unsafe or inappropriate **OR** The experiment is carried out with insufficient care or the yield is poor. **0 marks: At least two** of the areas of the task are performed poorly. The quantities of reagents are inappropriate for the preparation. The apparatus set-up for each experiment is unsafe or inappropriate. The experiment is carried out with insufficient care or the yield is poor.
Purify an organic solid For example: The recrystallisation of impure benzenecarboxylic acid from hot water	**2 marks: All** areas of the task are carried out competently. The quantity of solvent is appropriate. The recrystallisation process is carried out safely and with due care. The quantity and quality of recrystallised product are both appropriate. **1 mark: One** of the areas of the task is performed poorly. The quantity of solvent is inappropriate **OR** The recrystallisation process is carried out with insufficient care **OR** Either the quantity or quality of recrystallised product is inappropriate. **0 marks: At least two** of the areas of the task are performed poorly. The quantity of solvent is inappropriate. The recrystallisation process is carried out with insufficient care. Either the quantity or quality of recrystallised product is inappropriate
Test the purity of an organic solid For example: Determine the melting point of benzenecarboxylic acid	**2 marks: All** areas of the task are carried out competently. The quantity used and the preparation of the solid are appropriate (e.g. dry, powder). The apparatus set-up is safe and appropriate. Heating is carried out with due care and only as long as necessary, giving an accurate value for the melting point. **1 mark: One** of the areas of the task is performed poorly. Either the quantity used or the preparation of the solid is inappropriate **OR** The apparatus set-up is unsafe or inappropriate **OR** Heating is longer than necessary and the m.p. is inaccurate. **0 marks: At least two** of the areas of the task are performed poorly. Either the quantity used or the preparation of the solid is inappropriate. The apparatus set-up is unsafe or inappropriate. Heating is longer than necessary and the m.p. is inaccurate.

3.9 Mathematical Requirements

In order to develop their skills, knowledge and understanding in science, candidates need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as set out below.

	Candidates should be able to:
Arithmetic and computation	• recognise and use expressions in decimal and standard form • use ratios, fractions and percentages • make estimates of the results of calculations (without using a calculator) • use calculators to find and use power, exponential and logarithmic functions (x^n, $1/x$, $\sqrt{x}$, $\log_{10}x$, e^x, $\log_e x$)
Handling data	• use an appropriate number of significant figures • find arithmetic means • construct and interpret frequency tables and diagrams, bar charts and histograms
Algebra	• understand and use the symbols: $=$, $<$, $<<$, $>>$, $>$, $\propto$, $\sim$. • change the subject of an equation by manipulation of the terms, including positive, negative, integer and fractional indices • substitute numerical values into algebraic equations using appropriate units for physical quantities • solve simple algebraic equations • use logarithms in relation to quantities that range over several orders of magnitude
Graphs	• translate information between graphical, numerical and algebraic forms • plot two variables from experimental or other data • understand that $y = mx + c$ represents a linear relationship • determine the slope and intercept of a linear graph • calculate rate of change from a graph showing a linear relationship • draw and use the slope of a tangent to a curve as a measure of rate of change
Geometry and trigonometry	• appreciate angles and shapes in regular 2D and 3D structures • visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects • understand the symmetry of 2D and 3D shapes

4 Scheme of Assessment

4.1 Aims

AS and A Level courses based on this specification should encourage candidates to:

(a) develop their interest in and enthusiasm for the subject, including developing an interest in further study and careers in the subject

(b) appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society

(c) develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of *How Science Works*

(d) develop essential knowledge and understanding of different areas of the subject and how they relate to each other.

4.2 Assessment Objectives (AOs)

The Assessment Objectives are common to AS and A Level. The assessment units will assess the following assessment objectives in the context of the content and skills set out in Section 3 (Subject Content).

AO1: Knowledge and understanding of science and of *How Science Works*

Candidates should be able to:

(a) recognise, recall and show understanding of scientific knowledge

(b) select, organise and communicate relevant information in a variety of forms.

AO2: Application of knowledge and understanding of science and of *How Science Works*

Candidates should be able to:

(a) analyse and evaluate scientific knowledge and processes

(b) apply scientific knowledge and processes to unfamiliar situations, including those related to issues

(c) assess the validity, reliability and credibility of scientific information.

AO3: *How Science Works* – Chemistry

Candidates should be able to:

(a) demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods

(b) make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy

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

Quality of Written Communication (QWC)

In GCE specifications which require candidates to produce written material in English, candidates must:

- 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 where appropriate.

In this specification, QWC will be assessed in all externally assessed units.

Weighting of Assessment Objectives for AS

The table below shows the approximate weighting of each of the Assessment Objectives in the AS units.

Assessment Objectives	Unit Weightings (%)			Overall Weighting of AOs (%)
	Unit 1	Unit 2	Unit 3	
AO1	7	9	1	17
AO2	8	11	1	20
AO3	2	3	8	13
Overall weighting of units (%)	17	23	10	50

Weighting of Assessment Objectives for A Level

The table below shows the approximate weighting of each of the Assessment Objectives in the AS and A2 units

Assessment Objectives	Unit Weightings (%)						Overall Weighting of AOs (%)
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	
AO1	7	9	1	6	6	1	30
AO2	8	11	1	10	10	1	40
AO3	3	3	8	4	4	8	30
Overall weighting of units (%)	17	23	10	20	20	10	100

4.3 National Criteria

This specification complies with the following.

- The Subject Criteria for Science
- The Code of Practice for GCE
- The GCE AS and A Level Qualification Criteria
- The Arrangements for the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland: Common Criteria

4.4 Prior learning

There are no prior learning requirements.

However, we recommend that candidates should have acquired the skills and knowledge associated with a GCSE Additional Science course or equivalent.

Any requirements set for entry to a course following this specification are at the discretion of centres.

4.5 Synoptic Assessment and Stretch and Challenge

The definition of synoptic assessment in the context of science is as follows.

Synoptic assessment requires candidates to make and use connections within and between different areas of science, 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 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.

There is a requirement to formally assess synopticity at A2. Synoptic assessment in Chemistry is assessed in all the A2 units through both the written papers (Unit 4 and Unit 5) and through the written part of the ISA in *Investigative and Practical Skills in A2 Chemistry (Unit 6).*

The units CHEM4 and CHEM5 can be taken in either order. Therefore synoptic assessment in these modules will assume only a knowledge and understanding of the material in the AS modules.

There will be no material from CHEM4 assessed in CHEM5 and no CHEM5 material assessed in CHEM4.

The requirement that Stretch and Challenge is included at A2 will be met in the externally assessed units by:

- using of a variety of stems in questions to avoid a formulaic approach through the use of such words as: analyse, evaluate, compare, discuss
- avoiding assessments being too atomistic, connections between areas of content being used where possible and appropriate
- having some requirement for extended writing
- using a range of question types to address different skills, i.e. not just short answer/structured questions
- asking candidates to bring to bear knowledge and the other prescribed skills in answering questions rather than simply demonstrating a range of content coverage.

4.6 Access to Assessment for Disabled Students

AS/A Levels often require assessment of a broader 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.

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 the competences had been addressed. This will be kept under review and may be amended in the future.

5 Administration

5.1 Availability of Assessment Units and Certification

Examinations and certification for this specification are available as follows:

	Availability of units		Availability of certification	
	AS	A2	AS	A Level
January 2010	1, 2	4, 5	✔	
June 2010	1, 2, 3	4, 5, 6	✔	✔
January 2011 onwards	1, 2	4, 5	✔	✔
June 2011 onwards	1, 2, 3	4, 5, 6	✔	✔

5.2 Entries

Please refer to the current version of Entry Procedures and Codes for up to date entry procedures. You should use the following entry codes for the units and for certification.

Unit 1 – CHEM1

Unit 2 – CHEM2

Unit 3 – **either** CHM3T **or** CHM3X

Unit 4 – CHEM4

Unit 5 – CHEM5

Unit 6 – **either** CHM6T **or** CHM6X

Centres can not make entries for the same candidate for both assessment routes [T and X] in either Unit 3 or Unit 6 in the same examination series.

AS certification – 1421

A Level certification – 2421

5.3 Private Candidates

This specification is available to private candidates under certain conditions. Because of the nature of the centre-assessed units, candidates must be attending an AQA centre which will supervise and assess the work. Private candidates should write to AQA for a copy of *Supplementary Guidance for Private Candidates.*

Entries from private candidates can only be accepted where the candidate is registered with an AQA registered centre that will accept responsibility for:

- supervising the practical components of the PSA/ISA or PSV/EMPA
- supervising the written component of the ISA or EMPA
- prime marking the centre assessed work.

Candidates wishing to repeat or complete the AS and/or A2 components may only register as private candidates if they already have a previously moderated mark for Units 3 and 6, respectively, or if they can find a centre that will comply with the above requirements.

5.4 Access Arrangements and Special Consideration

We have taken note of equality and discrimination legislation and the interests of minority groups in developing and administering this specification.

We follow the guidelines in the Joint Council for Qualifications (JCQ) document: *Access Arrangements, Reasonable Adjustments and Special Consideration: General and Vocational Qualifications.* This is published on the JCQ website (**http://www.jcq.org.uk**) or you can follow the link from our website (**http://www.aqa.org.uk**).

Section 8.4 of the above JCQ document states that "a practical assistant is not permitted to carry out tasks which are the focus of the assessment". Accordingly, only candidates who can carry out the tasks themselves can access marks for the Practical Skills Assessment (PSA) in Unit 3 and Unit 6.

However, so that candidates may obtain experimental results that can be used in the Investigative Skills Assignment (ISA), practical assistants may be used to carry out the manipulation under the candidate's instructions. In these circumstances, as stated in section 2.4 of the JCQ document, marks cannot be gained for demonstrating techniques. The candidates will be able to access the marks available for the other skills: for example, handling and evaluating data collected, and drawing conclusions in AO3.

Access Arrangements

We can make arrangements so that candidates with disabilities can access the assessment. These arrangements must be made **before** the examination. For example, we can produce a Braille paper for a candidate with a visual impairment.

Special Consideration

We can give special consideration to candidates who have had a temporary illness, injury or indisposition at the time of the examination. Where we do this, it is given **after** the examination.

Applications for access arrangements and special consideration should be submitted to AQA by the Examinations Officer at the centre.

5.5 Language of Examinations

We will provide units in English only.

5.6 Qualification Titles

Qualifications based on this specification are:

- AQA Advanced Subsidiary GCE in Chemistry, and
- AQA Advanced Level GCE in Chemistry

5.7 Awarding Grades and Reporting Results

The AS qualification will be graded on a five-point scale: A, B, C, D and E. The full A Level qualification will be graded on a six-point scale: A*, A, B, C, D and E. To be awarded an A*, candidates will need to achieve a grade A on the full A Level qualification and an A* on the aggregate of the A2 units.

For AS and A Level, candidates who fail to reach the minimum standard for grade E will be recorded as U (unclassified) and will not receive a qualification certificate. Individual assessment unit results will be certificated.

5.8 Re-sits and Shelf-life of Unit Results

Unit results remain available to count towards certification, whether or not they have already been used, as long as the specification is still valid.

Candidates may re-sit a unit any number of times within the shelf-life of the specification. The best result for each unit will count towards the final qualification. Candidates who wish to repeat a qualification may do so by re-taking one or more units. The appropriate subject award entry, as well as the unit entry/entries, must be submitted in order to be awarded a new subject grade.

Candidates will be graded on the basis of the work submitted for assessment.

6 Administration of Internally Assessed Units (Route T and Route X)

The Head of Centre is responsible to AQA for ensuring that Centre Assessed work is conducted in accordance with AQA's instructions and JCQ instructions

Centres can not make entries for the same candidate for both assessment routes [T and X] in either Unit 3 or Unit 6 in the same examination series.

6.1 Supervision and Authentication of Centre Assessed Units

The Code of Practice for GCE requires:

- **candidates to** sign the Candidate Record Form (CRF) to confirm that the work submitted is their own, and
- **teachers/assessors** to confirm on the CRF that the work assessed is solely that of the candidate concerned and was conducted under the conditions laid down by the specification.

The completed CRF for each candidate must be attached to his/her work. All teachers who have assessed the work of any candidate entered for each component must sign the declaration of authentication. Failure to sign the authentication statement may delay the processing of the candidates' results.

In all cases, direct supervision is necessary to ensure that the centre assessed work submitted can be confidently authenticated as the candidate's own.

If teachers/assessors have reservations about signing the authentication statements, the following points of guidance should be followed.

- If it is believed that a candidate has received additional assistance and this is acceptable within the guidelines for the relevant specification, the teacher/assessor should award a mark which represents the candidate's unaided achievement. The authentication statement should be signed and information given on the relevant form.
- If the teacher/assessor is unable to sign the authentication statement for a particular candidate, then the candidate's work cannot be accepted for assessment.
- If malpractice is suspected, the Examinations Officer should be consulted about the procedure to be followed.

Route T

All teachers who have assessed the work of any candidate entered for each unit must sign the declaration of authentication.

The practical work for the PSA and ISA (Stage 1) should be carried out in normal lesson time with a degree of supervision appropriate for candidates working in a laboratory. The processing of raw data and the ISA test should be taken in normal lesson time under controlled conditions.

Redrafting of answers to any stage of the ISA is not permitted. Candidates must **not** take their work away from the class.

Material to submit to moderator

For each candidate in the sample, the following material must be submitted to the moderator by the deadline issued by AQA:

- the candidate's data from Stage 1 (on the *Candidate Result Sheet*)
- the ISA written test, which includes the *Candidate Record Form*, showing the marks for the ISA and the PSA

In addition each centre must provide

- *Centre Declaration Sheet*
- Details of any amendments to the task sheet with the information supporting the changes from the Assessment Adviser, if t here are any significant changes
- For each group of candidates, a completed *Teacher Results Sheet*.

Route X

The practical work for the PSV and Stage 1 of the EMPA should be carried out in normal lesson time with a degree of supervision appropriate for candidates working in a laboratory. The processing of raw data and the EMPA written test should be taken in normal lesson time under controlled conditions.

Redrafting of answers to any stage of the EMPA is not permitted. Candidates must **not** take their work away from the class.

Material to submit to examiner

For each candidate, the following material must be submitted to the examiner by the deadline issued by AQA:

- the completed *Task Sheet 1* and *Task Sheet 2*
- the EMPA written test, which includes the *Candidate Record Form*, showing the PSV verification of safe and skilful practical techniques and reliable and valid observations

In addition each centre must provide

- *Centre Declaration Sheet*
- Details of any amendments to the task sheet with the information supporting the changes from the Assessment Adviser, if there are any significant changes
- For each group of candidates, a completed *Teacher Results Sheet*.

6.2 Malpractice

Teachers should inform candidates of the AQA Regulations concerning malpractice.

Candidates must **not**:

- submit work which is not their own
- lend work to other candidates
- submit work typed or word-processed by a third person without acknowledgement.

These actions constitute malpractice, for which a penalty (eg disqualification from the examination) will be applied.

Route T

Where suspected malpractice in centre assessed work is identified by a centre after the candidate has signed the declaration of authentication, the Head of Centre must submit full details of the case to AQA at the earliest opportunity. The form JCQ/M1 should be used. Copies of the form can be found on the JCQ website (**http://www.jcq.org.uk/**).

Malpractice in centre assessed work discovered prior to the candidate signing the declaration of authentication need not be reported to AQA, but should be dealt with in accordance with the centre's internal procedures. AQA would expect centres to treat such cases very seriously. Details of any work which is not the candidate's own must be recorded on the centre assessed work cover sheet or other appropriate place.

Route X

If the teacher administering the EMPA believes that a student is involved in malpractice, he/she should contact AQA.

If the examiner suspects malpractice with the EMPA, at any stage, he/she will raise the matter with the Irregularities Office at AQA. An investigation will be undertaken, in line with the JCQ's policies on Suspected Malpractice in Examinations and Assessments.

6.3 Teacher Standardisation (Route T only)

We will hold annual standardising meetings for teachers, usually in the autumn term, for the centre assessed units. At these meetings we will provide support in developing appropriate centre assessed tasks and using the marking criteria.

If your centre is new to this specification, you must send a representative to one of the meetings. If you have told us you are a new centre, either by submitting an estimate of entry or by contacting the subject team, we will contact you to invite you to a meeting.

We will also contact centres if:

- the moderation of centre assessed work from the previous year has identified a serious misinterpretation of the requirements,
- inappropriate tasks have been set, or
- a significant adjustment has been made to a centre's marks.

In these cases, centres will be expected to send a representative to one of the meetings. For all other centres, attendance is optional. If you are unable to attend and would like a copy of the materials used at the meeting, please contact the subject team at **chemistry-gce@aqa.org.uk**

6.4 Internal Standardisation of Marking (Route T only)

Centres must standardise marking within the centre to make sure that all candidates at the centre have been marked to the same standard. One person must be responsible for internal standardisation. This person should sign the Centre Declaration Sheet to confirm that internal standardisation has taken place.

Internal standardisation involves:

- all teachers marking some trial pieces of work and identifying differences in marking standards
- discussing any differences in marking at a training meeting for all teachers involved in the assessment
- referring to reference and archive material such as previous work or examples from AQA's teacher standardising meetings.

6.5 Annotation of Centre Assessed Work (Route T only)

The Code of Practice for GCE states that the awarding body must require internal assessors to show clearly how the marks have been awarded in relation to the marking criteria defined in the specification and that the awarding body must provide guidance on how this is to be done.

The annotation will help the moderator to see as precisely as possible where the teacher considers that the candidates have met the criteria in the specification.

Work could be annotated by either of the following methods:

- key pieces of evidence flagged throughout the work by annotation either in the margin or in the text
- summative comments on the work, referencing precise sections in the work.

6.6 Submitting Marks and Sample Work for Moderation (Route T only)

The total mark for each candidate must be submitted to AQA and the moderator on the mark forms provided or by Electronic Data Interchange (EDI) by the specified date. Centres will be informed which candidates' work is required in the samples to be submitted to the moderator.

6.7 Factors Affecting Individual Candidates

Teachers should be able to accommodate the occasional absence of candidates by ensuring that the opportunity is given for them to make up missed assessments.

If work is lost, AQA should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. Centres should use the JCQ form JCQ/LCW to inform AQA Candidate Services of the circumstances.

Where special help which goes beyond normal learning support is given, AQA must be informed through comments on the CRF so that such help can be taken into account when moderation takes place.

Candidates who move from one centre to another during the course sometimes present a problem for a scheme of internal assessment. Possible courses of action depend on the stage at which the move takes place. If the move occurs early in the course, the new centre should take responsibility for assessment. If it occurs late in the course, it may be possible to arrange for the moderator to assess the work through the 'Educated Elsewhere' procedure. Centres should contact AQA at the earliest possible stage for advice about appropriate arrangements in individual cases.

6.8 Retaining Evidence and Re-using Marks (Route T only)

The centre must retain the work of all candidates, with CRFs attached, under secure conditions, from the time it is assessed, to allow for the possibility of an enquiry about results. The work may be returned to candidates after the deadline for enquiries about results. If an enquiry about a result has been made, the work must remain under secure conditions in case it is required by AQA.

7 Moderation (Route T only)

7.1 Moderation Procedures

Moderation of the centre assessed work is by inspection of a sample of candidates' work, sent by post from the centre to a moderator appointed by AQA. The centre marks must be submitted to AQA and to the moderator by the specified deadline (see **http://www.aqa.org.uk/deadlines.php**). We will let centres know which candidates' work will be required in the sample to be submitted for moderation.

Following the re-marking of the sample work, the moderator's marks are compared with the centre marks to determine whether any adjustment is needed in order to bring the centre's assessments into line with standards generally. In some cases, it may be necessary for the moderator to call for the work of other candidates in the centre. In order to meet this possible request, centres must retain under secure conditions and have available the centre assessed work and the CRF of every candidate entered for the examination and be prepared to submit it on demand. Mark adjustments will normally preserve the centre's order of merit, but where major discrepancies are found, we reserve the right to alter the order of merit.

7.2 Post-moderation Procedures

On publication of the AS/A Level results, we will provide centres with details of the final marks for the centre assessed unit.

The candidates' work will be returned to the centre after moderation has taken place. The centre will receive a report with, or soon after, the despatch of published results giving feedback on the appropriateness of the tasks set, the accuracy of the assessments made, and the reasons for any adjustments to the marks.

We reserve the right to retain some candidates' work for archiving or standardising purposes.

Appendices

A Performance Descriptions

These performance descriptions show the level of attainment characteristic of the grade boundaries at A Level. They give a general indication of the required learning outcomes at the A/B and E/U boundaries at AS and A2. The descriptions should be interpreted in relation to the content outlined in the specification; they are not designed to define that content.

The grade awarded will depend in practice upon the extent to which the candidate has met the Assessment Objectives (see Section 4) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

AS Performance Descriptions for Chemistry

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**AO1 Knowledge and understanding of science and *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.	**AO2 Application of knowledge and understanding 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.	**AO3 *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 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.

AS Performance Descriptions for Chemistry continued

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
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.

A

A2 performance descriptions for Chemistry

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**AO1 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.	**AO2 Application of knowledge and understanding of science and *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.	**AO3 *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.

A

A2 performance descriptions for Chemistry continued

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
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.

B Spiritual, Moral, Ethical, Social and other Issues

Moral, Ethical, Social and Cultural Issues

It is clear that Chemistry plays a major part in the development of the modern world. This specification is keenly aware of the implications of this development. The general philosophy of the subject is rooted in *How Science Works* (see Section 3.7) This section of the specification makes full references to the moral, ethical, social and cultural issues that permeate Chemistry at this level and science in general.

European Dimension

AQA has taken account of the 1988 Resolution of the Council of the European Community in preparing this specification and associated specimen units. The specification is designed to improve candidates' knowledge and understanding of the international debates surrounding developments in Chemistry and to foster responsible attitudes towards them.

Environmental Education

AQA has taken account of the 1988 Resolution of the Council of the European Community and the Report "Environmental Responsibility: An Agenda for Further and Higher Education" 1993 in preparing this specification and associated specimen units. The study of chemistry as described in this specification can encourage a responsible attitude towards the environment. Examples include: biofuels, the recycling of scrap metals and the biodegradability of polymers.

Avoidance of Bias

AQA has taken great care in the preparation of this specification and specimen units to avoid bias of any kind.

Health and Safety

AQA recognises the need for safe practice in laboratories and tries to ensure that experimental work required for this specification and associated practical work complies with up-to-date safety recommendations.

Nevertheless, centres are primarily responsible for the safety of candidates and teachers should carry out their own risk assessment. Centres are advised to consider relevant information from organisations such as CLEAPPS and read Hazcards where appropriate.

Candidates should make every effort to make themselves aware of any safety hazards involved in their work. As part of their work, they will be expected to undertake risk assessments to ensure their own safety and the safety of associated workers, the components and test equipment.

C Overlaps with other Qualifications

This Specification overlaps, specifically, with GCE specifications in Biology, Human Biology and Physics, as well as AQA GCE Science in Society and Environmental Studies.

The overlap with GCE Mathematics rests only on the use and application of the formula and equations given in Section 3.9.

D Key Skills – Teaching, Developing and Providing Opportunities for Generating Evidence

Introduction

The Key Skills Qualification requires candidates to demonstrate levels of achievement in the Key Skills of Communication, Application of Number and Information Technology.

The units for the 'wider' Key Skills of Improving own Learning and Performance, Working with Others and Problem Solving are also available. The acquisition and demonstration of ability in these 'wider' Key Skills is deemed highly desirable for all candidates, but they do not form part of the Key Skills Qualification.

The units for each Key Skill comprise three sections:

- What you need to know
- What you must do
- Guidance.

Candidates following a course of study based on this specification for Chemistry can be offered opportunities to develop and generate evidence of attainment in aspects of the Key Skills of:

- Communication
- Application of Number
- Information Technology
- Working with Others
- Improving own Learning and Performance
- Problem Solving.

Areas of study and learning that can be used to encourage the acquisition and use of Key Skills, and to provide opportunities to generate evidence for Part B of the units, are signposted on the next page.

The above information is given in the context of the knowledge that Key Skills at level 3 will be available until 2010 with last certification in 2012.

Key Skills Qualifications of Communication, Application of Number and Information and Communication Technology will be phased out and replaced by Functional Skills qualifications in English, Mathematics and ICT from September 2010 onwards. For further information see the AQA website: **http://web.aqa.org.uk/qual/keyskills/com04.php**

Key Skills Opportunities in Chemistry

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Communication						
C3.1a	✔	✔	✔	✔	✔	✔
C3.1b	✔	✔	✔	✔	✔	✔
C3.2	✔	✔	✔	✔	✔	✔
C3.3	✔	✔		✔	✔	
Application of Number						
N3.1	✔	✔	✔	✔	✔	✔
N3.2	✔	✔	✔	✔	✔	✔
N3.3	✔	✔	✔	✔	✔	✔
Information						
ICT3.1	✔	✔	✔	✔	✔	✔
ICT3.2	✔	✔	✔	✔	✔	✔
ICT3.3	✔	✔	✔	✔	✔	✔
Working With Others						
WO3.1	✔	✔		✔	✔	
WO3.2	✔	✔		✔	✔	
WO3.3	✔	✔		✔	✔	
Improving Own Learning and Performance						
LP3.1	✔	✔	✔	✔	✔	✔
LP3.2	✔	✔	✔	✔	✔	✔
LP3.3	✔	✔	✔	✔	✔	✔
Problem Solving						
PS3.1	✔	✔	✔	✔	✔	✔
PS3.2	✔	✔	✔	✔	✔	✔
PS3.3	✔	✔	✔	✔	✔	✔

E Periodic Table

The Periodic Table of the Elements

Key

relative atomic mass **symbol** name atomic (proton) number

1	2											3	4	5	6	7	0
(1)	(2)											(13)	(14)	(15)	(16)	(17)	(18)
							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	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(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	96.0 **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	[267] **Rf** rutherfordium 104	[268] **Db** dubnium 105	[271] **Sg** seaborgium 106	[272] **Bh** bohrium 107	[270] **Hs** hassium 108	[276] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[280] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

* 58 – 71 Lanthanides	140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.3 **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	173.1 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
† 90 – 103 Actinides	232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103

E

GCE Chemistry (2420) 2009 onwards

Qualification Accreditation Number: AS 500/2657/4 - A Level 500/2614/8

To obtain free specification updates and support material or to ask us a question register with Ask AQA:
www.aqa.org.uk/ask-aqa/register

Support meetings are available throughout the life of the specification.
Further information is available at:
http://events.aqa.org.uk/ebooking