GCE

Rewarding Learning

CCEA GCE Specification in
Chemistry

Version 2: 16 November 2021

For first teaching from September 2016
For first award of AS level in Summer 2017
For first award of A level in Summer 2018
Subject Code: 1110

Contents

Subject Code	1110
QAN AS Level	601/8511/9
QAN A Level	601/8512/0

This specification is available online at www.ccea.org.uk

1 Introduction

This specification sets out the content and assessment details for our Advanced Subsidiary (AS) and Advanced GCE courses in Chemistry. First teaching is from September 2016.

Students can take:

- the AS course as a final qualification; or
- the AS units plus the A2 units for a full GCE A level qualification.

We assess the AS units at a standard appropriate for students who have completed the first part of the full course. A2 units have an element of synoptic assessment (to assess students' understanding of the subject as a whole), as well as more emphasis on assessment objectives that reflect higher order thinking skills.

The full Advanced GCE award is based on students' marks from the AS (40 percent) and the A2 (60 percent). The guided learning hours for this specification, as for all GCEs, are:

- 180 hours for the Advanced Subsidiary level award; and
- 360 hours for the Advanced level award.

We will make the first AS awards for the specification in 2017 and the first A level awards in 2018. The specification builds on the broad objectives of the Northern Ireland Curriculum.

If there are any major changes to this specification, we will notify centres in writing. The online version of the specification will always be the most up to date; to view and download this please go to www.ccea.org.uk

1.1 Aims

This specification aims to encourage students to:

- develop their interest in and enthusiasm for chemistry;
- develop their interest in the further study of chemistry and the careers associated with courses related to the subject;
- draw together different areas of knowledge, skills and understanding;
- develop essential knowledge and understanding of the different areas of the subject and how they relate to each other;
- appreciate how society makes decisions about scientific issues and how the subject contributes to the success of the economy and society;
- develop competence and ability in practical, mathematical and problem-solving skills;
- develop and demonstrate a deep appreciation of scientific skills, and knowledge and understanding of how science works; and
- demonstrate that they understand and can apply key concepts.

1.2 Key features

The following are important features of this specification.

- It includes six externally assessed units: four are theory units and two are practical-based units.
- It allows students to develop their chemistry knowledge, understanding and skills.
- Assessment at A2 includes a greater variety of question styles, more demanding evaluative tasks, extended writing, and synoptic assessment that encourages students to develop their understanding of the subject as a whole. The contexts set in examination questions address contemporary chemistry.
- It can give students a sound basis for progression to higher education.
- A range of support is available, including specimen assessment materials, exemplar schemes of work and teacher guidance.

1.3 Prior attainment

Students do not need to have reached a particular level of attainment before beginning to study this specification. However, the specification builds on the knowledge, understanding and skills developed within GCSE Science: Chemistry or GCSE Science: Double Award. The GCE specification incorporates AS. The A2 section of the GCE builds on the foundations of knowledge, understanding and skills developed at AS level.

1.4 Classification codes and subject combinations

Every specification has a national classification code that indicates its subject area. The classification code for this qualification is 1110.

Please note that if a student takes two qualifications with the same classification code, universities and colleges that they apply to may take the view that they have achieved only one of the two GCEs. The same may occur with any two GCE qualifications that have a significant overlap in content, even if the classification codes are different. Because of this, students who have any doubts about their subject combinations should check with the universities and colleges that they would like to attend before beginning their studies.

2 Specification at a Glance

The table below summarises the structure of the AS and A level courses:

Content	**Assessment**	**Weightings**
AS 1: Basic Concepts in Physical and Inorganic Chemistry	External written examination 1 hour 30 mins Students answer Section A containing 10 multiple-choice questions (10 marks) and Section B containing a number of structured questions (80 marks).	40% of AS 16% of A level
AS 2: Further Physical and Inorganic Chemistry and an Introduction to Organic Chemistry	External written examination 1 hour 30 mins Students answer Section A containing 10 multiple-choice questions (10 marks) and Section B containing a number of structured questions (80 marks).	40% of AS 16% of A level
AS 3: Basic Practical Chemistry	Practical Booklet A consists of a variety of practical tasks (25 marks). Students take the assessment in the laboratory. 1 hour 15 mins Practical Booklet B consists of a variety of questions testing knowledge of practical techniques, observations and calculations (55 marks). Students take the examination in an examination hall. 1 hour 15 mins	20% of AS 8% of A level

Content	Assessment	Weightings
A2 1: Further Physical and Organic Chemistry	External written examination 2 hours Students answer Section A containing 10 multiple-choice questions (10 marks) and Section B containing a number of structured questions (100 marks).	40% of A2 24% of A level
A2 2: Analytical, Transition Metals, Electrochemistry and Organic Nitrogen Chemistry	External written examination 2 hours Students answer Section A containing 10 multiple-choice questions (10 marks) and Section B containing a number of structured questions (100 marks).	40% of A2 24% of A level
A2 3: Further Practical Chemistry	Practical Booklet A consists of a variety of practical tasks (30 marks). Students take the assessment in the laboratory. 1 hour 15 mins Practical Booklet B consists of a variety of questions testing knowledge of practical techniques, observations and calculations (60 marks). Students take the examination in an examination hall. 1 hour 15 mins	20% of A2 12% of A level

3 Subject Content

We have divided this course into six units: three units at AS level and three units at A2. This section sets out the content and learning outcomes for each unit.

3.1 Unit AS 1: Basic Concepts in Physical and Inorganic Chemistry

In this unit, students develop important basic chemical skills such as:

- writing balanced symbol equations and redox equations;
- determining oxidation states; and
- calculating chemical quantities using the mole as an amount of substance.

They study basic atomic structure and how the chemical properties of elements depend on their atomic structure, and in particular on the arrangement of electrons around the nucleus. The students are introduced to the central role of bonding and intermolecular forces in influencing the physical properties of compounds. They also consider the trends and reactions of Group VII elements in detail.

This unit also allows students to develop the important quantitative techniques they need to measure mass, make up solutions and titrate. The section on analytical tests enables students to gain experience in qualitative practical skills such as observation.

Mathematical skills that students develop in this unit include:

- calculating a relative atomic mass from isotopic composition data, using simple probability to calculate the peak heights for the mass spectrum of chlorine molecules and using logarithms to compare successive ionisation energies for an element (1.2.5, 1.2.7, 1.2.12);
- using an algebraic method to work out the oxidation number of an element within a complex species, balancing equations for redox reactions by combining ionic half-equations (1.7.1, 1.7.5);
- converting between units such as cm^3 and dm^3, using standard form with Avogadro’s constant, rearranging formulae for calculating moles in solids and in solutions (1.1.5, 1.9.5); and
- drawing the 3D shapes of molecules with up to six electron pairs around a central atom (1.6.2).

Content	**Learning Outcomes**
1.1 Formulae, equations and amounts of substance	Students should be able to: 1.1.1 write formulae of ionic compounds by predicting the ionic charge from the position of an element in the Periodic Table and by recalling the following molecular ions and their formulae (the systematic names for these ions are not given − *see Section 1.7.6*): • sulfate, SO_4^{2-}; • sulfite, SO_3^{2-}; • thiosulfate, $S_2O_3^{2-}$; • hydrogensulfate, HSO_4^-; • hydrogencarbonate, HCO_3^-; • carbonate, CO_3^{2-}; • nitrate, NO_3^-; • nitrite, NO_2^-; • phosphate, PO_4^{3-}; • chlorate, ClO_3^-; • hypochlorite, ClO^-; • hydroxide, HO^-; • dichromate, $Cr_2O_7^{2-}$; • chromate, CrO_4^{2-}; • permanganate, MnO_4^-; and • ammonium, NH_4^+; 1.1.2 write and balance equations for unfamiliar reactions given appropriate information; 1.1.3 write balanced equations (full and ionic), including state symbols, for all reactions studied; 1.1.4 define and demonstrate understanding of the terms Avogadro's constant, the mole and molar mass; 1.1.5 use Avogadro's constant in calculations; 1.1.6 calculate reacting masses of substances, including examples in which some reactants are in excess; and 1.1.7 demonstrate understanding of the terms anhydrous, hydrated and water of crystallisation and calculate the moles of water of crystallisation present from percentage composition, mass composition or experimental data.

Content	Learning Outcomes
1.2 Atomic structure	Students should be able to: 1.2.1 describe the properties of electrons, protons and neutrons in terms of their location in the atom and their relative masses and charges; 1.2.2 explain the terms atomic number and mass number and use them to deduce the numbers of protons, neutrons and electrons in an atom or ion; 1.2.3 define the terms relative atomic mass and relative isotopic mass in terms of the carbon-12 standard; 1.2.4 define and demonstrate understanding of the term isotopes; 1.2.5 define the terms relative molecular mass (for molecules) and relative formula mass (for ionic compounds) in terms of the carbon-12 standard and calculate their values from relative atomic masses; 1.2.6 interpret mass spectra of elements by calculating relative atomic mass from isotopic abundances and vice versa; 1.2.7 predict the mass spectra of diatomic elements, for example chlorine; 1.2.8 deduce the electronic configuration of atoms and ions up to krypton in terms of shells and subshells using the building up principle (s, p and d notation and electrons in boxes notation); 1.2.9 demonstrate understanding that an orbital is a region within an atom that can hold up to two electrons with opposite spins and describe the shape of s- and p-orbitals; 1.2.10 classify an element as belonging to the s-, p-, d- or f-block according to its position in the Periodic Table; and 1.2.11 define and write equations for the first and successive ionisation energies of an element in terms of one mole of gaseous atoms and ions.

Content	**Learning Outcomes**
1.2 Atomic structure (cont.)	Students should be able to:
	1.2.12 demonstrate understanding that successive ionisation energies can be used to predict the group of an element, and that graphs of successive ionisation energies against number of electrons removed, for an element, give evidence for the existence of shells;
	1.2.13 explain the trend in the first ionisation energies of atoms down Groups and across Periods in terms of nuclear charge, distance of outermost electron from the nucleus, shielding and stability of filled and half-filled subshells;
	1.2.14 demonstrate understanding that graphs of first ionisation energies of elements up to krypton provide evidence for the existence of shells and subshells;
1.3 Bonding	1.3.1 demonstrate understanding that ionic bonding is the electrostatic attraction between oppositely charged ions formed by electron transfer;
	1.3.2 construct dot and cross diagrams for ionically bonded compounds, for example elements in Groups I, II, VI and VII, the ions of which have a noble gas structure;
	1.3.3 explain that a covalent bond is the electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms;
	1.3.4 define the term lone pair;
	1.3.5 describe the co-ordinate bond as a shared pair of electrons, with both electrons supplied by one atom, for example the ammonium ion NH_4^+;
	1.3.6 construct dot and cross diagrams for molecules and ions with co-ordinate, single, double and triple covalent bonds; and
	1.3.7 define the octet rule and state its limitations, for example in $BeCl_2$ and BF_3.

Content	**Learning Outcomes**
1.3 Bonding (cont.)	Students should be able to: 1.3.8 define the term electronegativity and explain the trend in the electronegativity of elements down Groups and across Periods; 1.3.9 explain that bond polarity arises when covalently bonded atoms have different electronegativities and use partial charges to show that a bond is polar; 1.3.10 demonstrate understanding that metallic bonding is the attraction between positive ions and delocalised electrons in a lattice;
1.4 Intermolecular forces	1.4.1 describe intermolecular forces as van der Waals' forces (viewed as attractions between induced dipoles), permanent dipole-dipole attractions and hydrogen bonding (between molecules containing N, O or F and the H atom of -OH, -NH or HF); 1.4.2 demonstrate understanding of the relationships between these attractive forces and physical properties, such as melting point, boiling point and solubility of covalent molecular substances (*see Section 1.5.2*);
1.5 Structure	1.5.1 describe the following types of structure: • the giant ionic lattice of sodium chloride; • the metallic lattice of metals; • the giant covalent structures of graphite and diamond; and • molecular covalent structures, for example iodine; 1.5.2 explain the characteristic physical properties of these structures, including melting and boiling points, hardness (graphite and diamond only) and electrical conductivity, in terms of structure and bonding; and 1.5.3 explain the trend in melting point across the Period sodium to argon in terms of structure and bonding.

Content	**Learning Outcomes**
1.6 Shapes of molecules and ions	Students should be able to: 1.6.1 demonstrate understanding that the shape of a molecule or ion is determined by the repulsion between the electron pairs surrounding a central atom; 1.6.2 use valence shell electron pair repulsion (VSEPR) theory to explain the shapes and bond angles of molecules and ions with up to six outer pairs of electrons around the central atom, including linear, bent, trigonal planar, tetrahedral, pyramidal, octahedral, square planar, trigonal bipyramidal, T-shaped; 1.6.3 explain the departure of the bond angles in NH_3 (107°) and H_2O (104.5°) from the predicted tetrahedral (109.5°) in terms of the increasing repulsion between bonding pair-bonding pair, lone pair-bonding pair and lone pair-lone pair electrons; 1.6.4 demonstrate understanding of the difference between polar bonds and polar molecules and use the shape and dipoles present to predict whether a given molecule is polar;
1.7 Redox	1.7.1 calculate the oxidation state for an element in a compound or ion, including peroxides and metal hydrides; 1.7.2 define the term redox and explain oxidation and reduction in terms of electron transfer and changes in oxidation state; 1.7.3 demonstrate understanding that oxidising agents gain electrons and are reduced and reducing agents lose electrons and are oxidised; and 1.7.4 define disproportionation and use oxidation numbers to classify a redox reaction as disproportionation.

Content	Learning Outcomes
1.7 Redox (cont.)	Students should be able to: 1.7.5 write half-equations and combine half-equations to give a balanced redox equation; 1.7.6 use Roman numerals to indicate the oxidation number when an element has compounds or ions with different oxidation numbers, for example chlorate(I) and chlorate(V);
1.8 Halogens	1.8.1 recall the colours of the elements and explain the trends within the Group, limited to physical state at room temperature, melting and boiling points; 1.8.2 compare the solubility and colours of the halogens in water and non-aqueous solvents, for example hexane; 1.8.3 describe the reaction of the halogens with cold dilute and hot concentrated aqueous sodium hydroxide and explain the disproportionation in these reactions; 1.8.4 recall the reaction of chlorine with water to form chloride ions and chlorate(I) ions; 1.8.5 describe the trend in oxidising ability of the halogens down the Group applied to displacement reactions of the halogens with other halide ions in solution; 1.8.6 demonstrate understanding of the reactions of solid halides with concentrated sulfuric and phosphoric acid in relation to the relative reducing ability of the hydrogen halides/halide ions; 1.8.7 compare the advantages and disadvantages of adding chlorine or ozone to drinking water; and
1.9 Acid-base titrations	1.9.1 demonstrate understanding of the concept of weak and strong acids and bases in terms of dissociation of hydrogen ions and hydroxide ions.

Content	**Learning Outcomes**
1.9 Acid-base titrations (cont.)	Students should be able to: 1.9.2 demonstrate understanding of the techniques and procedures used when experimentally carrying out acid-base titrations involving strong acid/strong base, strong acid/weak base and weak acid/strong base, for example determining the degree of hydration in a sample of sodium carbonate, and analysis of vinegar; 1.9.3 select the correct indicator for each type of titration and recall the colour changes of phenolphthalein and methyl orange at the end point; 1.9.4 identify uncertainties in measurements and calculate the uncertainty when two burette readings are used to calculate a titre value; 1.9.5 select appropriate titration data, ignoring outliers, in order to calculate mean titres; 1.9.6 calculate concentrations and volumes for titration calculations; 1.9.7 demonstrate knowledge of the term molarity, M, and the units of concentration, for example mol dm^{-3} and g dm^{-3}; 1.9.8 describe the techniques and procedures used to prepare a standard solution of required concentration;
1.10 Qualitative tests	1.10.1 use a chemical test for the gases H_2, O_2, Cl_2, CO_2, HCl and NH_3; 1.10.2 demonstrate understanding of how to carry out a flame test using nichrome wire; and 1.10.3 use cation tests, including: • flame tests to identify the metal ions Li^+, Na^+, K^+, Ca^{2+}, Ba^{2+} and Cu^{2+}; and • adding sodium hydroxide solution and warming to identify ammonium ion.

Content	**Learning Outcomes**
1.10 Qualitative tests (cont.)	Students should be able to: 1.10.4 use anion tests, including: • adding barium chloride solution to identify sulfate ion; • adding acidified silver nitrate solution to distinguish between chloride, bromide and iodide (followed by adding dilute and concentrated ammonia solution); and • adding dilute acid to test for carbonate ion and identifying the gas produced; and 1.10.5 use starch to identify iodine.

3.2 Unit AS 2: Further Physical and Inorganic Chemistry and an Introduction to Organic Chemistry

Organic chemistry forms a major part of this unit. Students work on the chemistry of alkanes, alkenes, halogenoalkanes and alcohols. They receive a qualitative introduction to equilibrium and kinetics and cover thermochemistry in some depth. They also explore properties and chemistry of the Group II elements in detail.

In this unit, students further develop key practical skills and techniques in areas such as:

- measuring and determining heat changes in chemical reactions;
- preparing, isolating and purifying liquid organic compounds;
- converting one organic functional group into another; and
- producing gases.

Students should use curly arrows when drawing reaction mechanisms for indicated organic reactions, with the exception of radical mechanisms. Curly arrows represent the movement of electron pairs.

Mathematical skills that students develop in this unit include:

- representing shapes of molecules with suitable sketches, plotting data to investigate trends in boiling points of alkanes (2.2.4, 2.3.2);
- manipulating data on the solubilities of hydroxides (2.11.6);
- calculating the yield of a reaction or an atom economy (2.1.4, 2.1.6);
- calculating reacting gas volumes from chemical equations (2.1.3);
- plotting and extrapolating graphs of temperature rise against time for displacement reactions, calculating enthalpy changes in J and in kJ mol^{-1}, using algebra to solve Hess’s law problems, and calculating enthalpy changes using bond enthalpies (2.8.7, 2.8.10, 2.8.11);
- calculating rates from reaction time, plotting graphs of a variable linked to a chemical reaction against time, and having an appreciation of the nature of the graph for a Maxwell–Boltzmann distribution (2.9.1, 2.9.3); and
- deriving an algebraic expression and a rearranged expression for the equilibrium constant (2.10.3).

Content	Learning Outcomes
2.1 Formulae and amounts of a substance	Students should be able to: 2.1.1 define the terms empirical formula and molecular formula and explain the relationship between them; 2.1.2 calculate empirical and molecular formulae using data, given composition by mass or percentage composition; 2.1.3 define molar gas volume and calculate reacting gas volumes from chemical equations; 2.1.4 define percentage yield and calculate percentage yields using chemical equations and experimental data; 2.1.5 use a percentage yield to determine the amount of reagent(s) needed for a reaction; 2.1.6 define atom economy and calculate atom economies using chemical equations;
2.2 Nomenclature and isomerism in organic compounds	2.2.1 define and demonstrate understanding of the terms structural and geometric isomerism, homologous series and functional group; 2.2.2 apply International Union of Pure and Applied Chemistry (IUPAC) rules for nomenclature to name organic compounds with up to six carbon atoms and one or more functional groups; 2.2.3 draw and name structural isomers of aliphatic compounds containing up to six carbon atoms, excluding cyclic structures; 2.2.4 draw structural and skeletal formulae for organic compounds; 2.2.5 demonstrate understanding that geometrical isomers result from restricted rotation due to an energy barrier about the carbon-carbon double bond and exist in E and Z forms; and 2.2.6 draw and identify the structural formulae of E and Z isomers.

Content	Learning Outcomes
2.3 Alkanes	Students should be able to: 2.3.1 recall that alkanes are described as saturated hydrocarbons; 2.3.2 explain, in terms of van der Waals' forces, the variation in boiling points between alkanes with different numbers of carbon atoms; 2.3.3 explain, in terms of van der Waals' forces, the variation in boiling points between structural isomers of an alkane with the same molecular formula; 2.3.4 describe the complete and incomplete combustion of alkanes in air and link the appearance of the flame to the amount of carbon present; 2.3.5 recall that pollutants such as carbon monoxide, carbon, oxides of nitrogen and sulfur, and unburned hydrocarbons are produced during the combustion of alkane fuels; 2.3.6 recall that the percentage of carbon dioxide in the atmosphere has risen from 0.03% to 0.04% because of combustion of organic compounds and is believed to have caused global warming; 2.3.7 explain how a catalytic converter reduces the environmental impact of burning alkane fuels; 2.3.8 describe the substitution reactions of alkanes by chlorine and by bromine; 2.3.9 define the terms radical, homolytic fission and heterolytic fission; and 2.3.10 outline the radical substitution mechanism involved in the photochemical halogenation of alkanes in terms of initiation, propagation and termination steps.

Content	Learning Outcomes
2.4 Alkenes	Students should be able to: 2.4.1 define the term unsaturated hydrocarbon and explain why alkenes are described as unsaturated hydrocarbons; 2.4.2 recall the qualitative test for alkenes using bromine water; 2.4.3 use sigma and pi bonds to explain the relative bond strength and relative bond length of the C=C bond; 2.4.4 recall that the C=C bond is a centre of high electron density and use this to explain the difference in reactivity of alkanes and alkenes; 2.4.5 describe the catalytic hydrogenation of alkenes using finely divided nickel; 2.4.6 describe the reaction of chlorine, bromine, hydrogen chloride and hydrogen bromide with alkenes; 2.4.7 define the terms electrophile and heterolytic fission; 2.4.8 recall the mechanism of electrophilic addition between chlorine, bromine, hydrogen chloride and hydrogen bromide with alkenes using curly arrows; 2.4.9 explain, with reference to the stability of the carbocation intermediates involved, the formation of major and minor products during the electrophilic addition of hydrogen bromide to unsymmetrical alkenes; and 2.4.10 describe the addition polymerisation of alkenes, for example ethene and propene.

Content	Learning Outcomes
2.5 Halogenoalkanes	Students should be able to: 2.5.1 explain the variation in boiling points of halogenoalkanes with different halogen atoms; 2.5.2 explain the variation in boiling points of structural isomers of a halogenoalkane with the same molecular formula; 2.5.3 classify a halogenoalkane as primary, secondary or tertiary; 2.5.4 describe the laboratory preparation of a liquid organic compound, such as a halogenoalkane, from the corresponding alcohol; 2.5.5 describe the reaction of halogenoalkanes with aqueous alkali, ammonia and potassium cyanide; 2.5.6 define the term nucleophile and outline the nucleophilic substitution mechanism involved in the reaction between primary and tertiary halogenoalkanes and aqueous alkali; 2.5.7 describe and explain, with reference to bond enthalpy, the relative rates of hydrolysis of primary halogenoalkanes with the same number of carbon atoms and different halogen atoms; 2.5.8 describe elimination of hydrogen halides from symmetrical and unsymmetrical halogenoalkanes using ethanolic potassium hydroxide; and 2.5.9 recall that chlorofluorocarbons (CFCs) are a major factor in reducing the ozone layer and allowing more harmful ultraviolet radiation to reach the Earth's surface.

Content	**Learning Outcomes**
2.6 Alcohols	Students should be able to: 2.6.1 refer to the effect of hydrogen bonding on boiling point and solubility of alcohols with water; 2.6.2 classify an alcohol as primary, secondary or tertiary; 2.6.3 recall the preparation of alcohols from halogenoalkanes; 2.6.4 describe the complete and incomplete combustion of alcohols and their use as an alternative fuel; 2.6.5 describe the reaction of alcohols with sodium, hydrogen bromide and phosphorus pentachloride; 2.6.6 describe the oxidation of alcohols using acidified potassium dichromate(VI), with reference to formation of aldehydes and carboxylic acids from primary alcohols, formation of ketones from secondary alcohols and resistance to oxidation of tertiary alcohols;
2.7 Infrared spectroscopy	2.7.1 explain that the absorption of infrared radiation arises from molecular vibrations; 2.7.2 demonstrate understanding that groups of atoms within a molecule absorb infrared radiation at characteristic frequencies; and 2.7.3 use infrared spectra to deduce functional groups present in organic compounds given wavenumber data.

Content	**Learning Outcomes**
2.8 Energetics	Students should be able to: 2.8.1 define the terms exothermic and endothermic and understand that chemical reactions are usually accompanied by heat changes; 2.8.2 recall standard conditions as 100 kPa and 298 K; 2.8.3 define the term standard enthalpy change, $\Delta H^{\ominus}$; 2.8.4 construct a simple enthalpy level diagram; 2.8.5 define the standard enthalpy of combustion, formation and neutralisation, namely $\Delta_c H^{\ominus}$, $\Delta_f H^{\ominus}$ and $\Delta_n H^{\ominus}$; 2.8.6 recall experimental methods to determine enthalpy changes; 2.8.7 calculate enthalpy changes from experimental data using the equation $q = mc\Delta T$; 2.8.8 demonstrate an understanding of the principle of conservation of energy and define Hess's Law; 2.8.9 construct enthalpy cycles using Hess's Law; 2.8.10 calculate enthalpy changes indirectly using Hess's Law; 2.8.11 define the term average bond enthalpy and calculate the enthalpy change of a reaction using average bond enthalpies; 2.8.12 calculate average bond enthalpies given enthalpy changes of reaction; and 2.8.13 explain why enthalpy changes of reaction calculated using average bond enthalpies differ from those determined using Hess's Law.

Content	Learning Outcomes
2.9 Kinetics	Students should be able to: 2.9.1 recall how factors, including concentration, pressure, temperature and catalyst, affect the rate of a chemical reaction; 2.9.2 use the collision theory and the concept of activation energy to qualitatively explain how these factors affect the reaction rate; 2.9.3 demonstrate a qualitative understanding of the Maxwell–Boltzmann distribution of molecular energies in gases and interpret curves for different temperatures and for catalysed and uncatalysed reactions; 2.9.4 relate the concept of activation energy to the Maxwell–Boltzmann distribution;
2.10 Equilibrium	2.10.1 demonstrate understanding that many chemical reactions are reversible and define the terms dynamic equilibrium, homogeneous and heterogeneous; 2.10.2 deduce the qualitative effects of changes of temperature, pressure, concentration and catalysts on the position of equilibrium for a closed homogeneous system; 2.10.3 deduce an expression for the equilibrium constant K_c and its units for a given homogeneous equilibrium system; 2.10.4 relate the magnitude of K_c to the position of equilibrium and extent of reaction; 2.10.5 describe and explain the conditions used in industrial processes, for example the Haber process for the formation of ammonia and the Contact process for sulfuric acid; and 2.10.6 demonstrate understanding of the importance of a compromise between equilibrium and reaction rate in the chemical industry.

Content	Learning Outcomes
2.11 Group II elements and their compounds	Students should be able to: 2.11.1 explain why these are regarded as s-block elements; 2.11.2 recall and explain the trends within the Group, limited to electronic configuration, atomic radius and first ionisation energy; 2.11.3 investigate and describe the reactions of the elements with oxygen, water and dilute acids; 2.11.4 describe the basic nature of the oxides and their reactions with water and dilute acids; 2.11.5 recall the use of magnesium oxide in indigestion remedies and the use of calcium carbonate in toothpaste; 2.11.6 state the trends in thermal stability of the carbonates and hydroxides and explain these trends, with reference to the charges and sizes of the cations; 2.11.7 recall the use of calcium carbonate to make calcium oxide (quick lime) and calcium hydroxide (slaked lime) and their use in producing cement and concrete; 2.11.8 recall the solubility trends of the sulfates and hydroxides; and 2.11.9 demonstrate understanding of how solubility curves are drawn from experimental data.

3.3 Unit AS 3: Basic Practical Chemistry

In this unit, students have opportunities to carry out practical activities. These activities are embedded throughout the learning outcomes of the course. Some of these activities are listed below. Students might not carry out all of the practical work listed below; however, they must know the reasons why certain practical techniques need to be carried out. They must also master certain basic practical skills.

The practical examination is in two parts: A and B. Students take Part A in the laboratory. It emphasises observation, although students also have opportunities to record and present data. Some of the chemical reactions in this section appear in Units AS 1 and AS 2. However, because this section deals with observation and not deduction, it may incorporate reactions that are unfamiliar to students. In some situations, the chemical reaction will be familiar to students, for example a white precipitate being formed when barium chloride is added to a solution. However, with unfamiliar chemicals, the reactions will not always be familiar to students. Students are not expected to make deductions. Teachers do not have to determine the titre. A titration result is equivalent to an observation.

Part B is independent of Part A, but, there may be some areas that overlap. Part B has theoretical questions on practical situations. It is the more demanding part of the practical examination. Students apply their knowledge to practical situations listed in this specification.

Learning Outcomes	**Specification Reference**
Students should be able to:	
• determine the formula of a hydrated compound by weighing and heating a hydrated salt to constant mass;	1.1.7
• use the deflection of a stream of liquid from a burette to indicate polarity or lack of polarity within a molecule;	1.3.9
• carry out tests of electrical conductivity on solids and liquids and aqueous solutions of ionic and covalent substances; and	1.5.2
• determine the solubility of chlorine and iodine in aqueous and non-aqueous solvents.	1.8.2

Learning Outcomes	**Specification Reference**
Students should be able to:	
• produce a reactivity order of the halogens using the displacement reactions of the halogens with other halide ions in solution;	1.8.5
• carry out the reactions of the halides with concentrated sulfuric and phosphoric acids and perform chemical tests for the products (excluding hydrogen sulfide);	1.8.6
• carry out an acid-base titration to determine the concentration of acid/base, the degree of hydration in a hydrated metal carbonate and the percentage of ethanoic acid in vinegar;	1.9.2
• prepare solutions of known concentration;	1.9.8
• use chemical tests listed in 'Qualitative tests' to identify unknown substances;	1.10
• test for unsaturation using bromine water;	2.4.2
• prepare a halogenoalkane using the techniques of refluxing, separating with a funnel, removing acidity, drying and distillation;	2.5.4
• prepare alcohols from halogenoalkanes using alkali;	2.5.5
• investigate the relative rates of hydrolysis of halogenoalkanes;	2.5.7
• carry out the elimination of hydrogen halides from halogenoalkanes using ethanolic potassium hydroxide;	2.5.8
• carry out test tube reactions of alcohols with sodium, hydrogen bromide/hydrobromic acid and phosphorus pentachloride; and	2.6.5
• prepare aldehydes, carboxylic acids and ketones from alcohols using acidified potassium dichromate(VI).	2.6.6

Learning Outcomes	**Specification Reference**
Students should be able to:	
• determine the enthalpy changes for combustion and neutralisation using simple apparatus; and	2.8.6
• react Group II metals and other metals with oxygen, water and dilute acids and determine the masses of solids and volumes of gases produced.	2.11.3

3.4 Unit A2 1: Further Physical and Organic Chemistry

This unit builds on the knowledge of physical and organic chemistry that students acquired at AS level. Students quantitatively study rates of reaction, equilibria, enthalpy, entropy and free energy changes. They consider acids, bases and buffer solutions from a qualitative and quantitative viewpoint.

Students expand their study of organic chemistry to include optical isomerism and compounds containing the carbonyl group and aromatic compounds. We accept equations that represent oxidising agents as [O] and reducing agents as [H].
We expect students to have knowledge of IUPAC rules for systematically naming molecules with up to six carbon atoms in the main chain.

Mathematical skills that students can develop in this unit include:

- calculating the missing value from a Born–Haber cycle using algebraic expressions (4.1.2);
- constructing expressions for K_c and calculating values with relevant units, estimating the change to the value of an equilibrium constant when a variable changes (4.4.2);
- using logarithms for converting from concentration to pH and vice versa, rearranging K_a expressions into expressions suitable for calculating pH of a buffer solution, and plotting and interpreting titration curves (4.5.3, 4.5.5, 4.5.6);
- plotting and justifying the shapes of rate-concentration and concentration-time graphs (4.3.4); and
- representing chiral molecules with appropriate diagrams (4.6.3).

Content	**Learning Outcomes**
4.1 Lattice enthalpy	Students should be able to: 4.1.1 define and demonstrate understanding of the term lattice enthalpy; 4.1.2 construct Born–Haber cycles and carry out associated calculations, such as the halides and oxides of Groups I and II; and 4.1.3 define and demonstrate understanding of the enthalpy changes associated with the dissolving of ionic compounds in water and carry out associated calculations.

Content	**Learning Outcomes**
4.2 Enthalpy, entropy and free energy	Students should be able to: 4.2.1 recall that enthalpy change is not sufficient to explain feasible change, for example the endothermic reaction between ammonium carbonate and ethanoic acid; 4.2.2 recall that the balance between entropy change and enthalpy change determines the feasibility of a reaction; 4.2.3 recall that entropy is a measure of disorder; 4.2.4 calculate the standard entropy change, $\Delta S^{\ominus}$, in a chemical reaction using standard entropy data; 4.2.5 use the equation $\Delta G = \Delta H - T\Delta S$ to calculate standard free energy changes; 4.2.6 recall that processes are feasible when the free energy change is negative; 4.2.7 recall that when the enthalpy change and the entropy change have the same sign, the feasibility of the process depends on the temperature, and calculate the temperature at which these processes start or cease to be feasible;
4.3 Rates of reaction	4.3.1 use simple rate equations in the form: rate = $k[A]^X[B]^Y$ (where x and y are 0, 1 or 2); 4.3.2 demonstrate understanding of the terms: • rate of reaction; • order; and • rate constant; 4.3.3 deduce simple rate equations from experimental data; and 4.3.4 deduce, from a concentration-time or a rate-concentration graph, the rate of reaction and/or the order with respect to a reactant.

Content	**Learning Outcomes**
4.3 Rates of reaction (cont.)	Students should be able to: 4.3.5 recall that there is a relationship between the rate equation and mechanism, for example the S_N1 and S_N2 mechanisms, for the alkaline hydrolysis of primary and tertiary halogenoalkanes; 4.3.6 define and demonstrate understanding of the term rate determining step; 4.3.7 suggest experimental methods suitable for the study of the rate of a reaction, for example iodine titrations and colorimetry; 4.3.8 explain, qualitatively, the effect of temperature and activation energy on rate constants;
4.4 Equilibrium	4.4.1 calculate equilibrium concentrations, given suitable data; 4.4.2 calculate the numerical values, with units, for the equilibrium constant $K_{c,}$ given suitable data limited to homogeneous systems;
4.5 Acid-base equilibria	4.5.1 use the Brønsted–Lowry theory of acids and bases to describe proton transfer in acid-base equilibria, including the idea of conjugate acid-base pairs; 4.5.2 define and demonstrate understanding of the terms K_w, K_a, pH, pK_w and pK_a and recall the associated units where appropriate; 4.5.3 carry out calculations involving pH for strong acids, strong bases and weak acids; 4.5.4 define and demonstrate understanding of the term buffer solution and give a qualitative explanation of how buffer solutions work; 4.5.5 calculate the pH of a buffer solution made from a weak monobasic acid and sodium hydroxide; and 4.5.6 recall how titration curves are determined by experiment.

Content	**Learning Outcomes**
4.5 Acid-base equilibria (cont.)	Students should be able to: 4.5.7 use titration curves to explain the choice of indicator; 4.5.8 predict whether a salt solution would be acidic, alkaline or neutral, based on relative strengths of the parent acid and base;
4.6 Isomerism	4.6.1 demonstrate knowledge and understanding of how structural isomerism can exist between molecules that belong to different families of compounds; 4.6.2 recall that asymmetric (chiral) centres give rise to optical isomers that exist as non-superimposable mirror images; 4.6.3 draw 3D representations of optical isomers; 4.6.4 recall that optical isomers rotate the plane of plane polarised light in opposite directions; 4.6.5 define and demonstrate understanding of the term optically active and explain why racemic mixtures are optically inactive; 4.6.6 demonstrate knowledge and understanding of how drug action may be determined by the stereochemistry of the drug and how receptor sites can be stereospecific;
4.7 Aldehydes and ketones	4.7.1 recall the molecular and structural formulae of aldehydes and ketones, including branched structures, with up to six carbon atoms in the main chain; 4.7.2 explain the boiling points and solubility of aldehydes and ketones by making reference to intermolecular forces; and 4.7.3 recall that aldehydes and ketones can be prepared from the corresponding primary or secondary alcohol using a suitable oxidising agent.

Content	**Learning Outcomes**
4.7 Aldehydes and ketones (cont.)	Students should be able to:
	4.7.4 recall the reaction of aldehydes and ketones with hydrogen cyanide;
	4.7.5 describe the mechanism for the nucleophilic addition reaction of hydrogen cyanide and propanone;
	4.7.6 explain why racemic mixtures can be produced when hydrogen cyanide reacts with aldehydes and ketones;
	4.7.7 recall equations for the reaction of aldehydes and ketones with 2,4-dinitrophenylhydrazine; to produce 2,4-dinitrophenylhydrazones which may be used for identification purposes (no practical details are needed, and no practical activity is required or expected for these reactions)
	4.7.8 recall that aldehydes and ketones can be distinguished using acidified potassium dichromate(VI), Fehling's solution and Tollens' reagent (with Fehling's solution and Tollens' reagent viewed as Cu^{2+} and Ag^{+} respectively);
	4.7.9 recall that aldehydes and ketones can be reduced using lithium tetrahydridoaluminate(III) (lithal);
4.8 Carboxylic acids	4.8.1 recall the molecular and structural formulae of carboxylic acids, including branched structures, with up to six carbon atoms in the main chain;
	4.8.2 explain the boiling points and solubility of carboxylic acids by making reference to intermolecular attractions;
	4.8.3 recall, including practical details, that carboxylic acids can be prepared from primary alcohols and aldehydes;
	4.8.4 recall that carboxylic acids, or their salts, can also be formed by acid or base catalysed hydrolysis of esters and nitriles; and
	4.8.5 recall that carboxylic acids form salts with sodium carbonate, sodium hydroxide and ammonia.

Content	**Learning Outcomes**
4.8 Carboxylic acids (cont.)	Students should be able to: 4.8.6 recall the reaction of carboxylic acids with alcohols, phosphorus pentachloride and lithium tetrahydridoaluminate(III) (lithal);
4.9 Derivatives of carboxylic acids	4.9.1 recall that derivatives of carboxylic acids include esters and acyl chlorides; 4.9.2 recall the molecular and structural formulae of monoesters and of acyl chlorides; 4.9.3 explain the boiling points and solubility of monoesters by making reference to intermolecular forces; 4.9.4 recall that esters can be formed from alcohols using carboxylic acids or acyl chlorides; 4.9.5 recall the laboratory preparation of a liquid ester from a carboxylic acid and an alcohol; 4.9.6 recall the structure of fats and oils as esters of propane-1,2,3-triol (glycerol) and fatty acids; 4.9.7 recall the transesterification reactions of esters with alcohols and carboxylic acids and the use of these reactions to produce biodiesel and margarines; 4.9.8 recall that margarines/spreads are produced from the hardening of oils by catalytic hydrogenation using finely divided nickel; 4.9.9 recall the reactions of acyl chlorides with water and alcohols;
4.10 Aromatic chemistry	4.10.1 explain the structure of the benzene molecule with reference to delocalised π electrons; and 4.10.2 explain the reactivities of benzene and alkenes related to the relative stabilities of the π electron systems, for example the resistance of benzene to addition of bromine compared with an alkene.

Content	**Learning Outcomes**
4.10 Aromatic chemistry (cont.)	Students should be able to: 4.10.3 explain the mechanisms of the monobromination, mononitration, monoalkylation and monoacylation of benzene, including equations for the formation of the electrophile; 4.10.4 recall the names of the electrophiles for the bromination and nitration of benzene; and 4.10.5 prepare methyl-3-nitrobenzoate from methyl benzoate to illustrate nitration of the benzene ring.

3.5 Unit A2 2: Analytical, Transition Metals, Electrochemistry and Organic Nitrogen Chemistry

In this unit, students examine how various instrumental methods such as nuclear magnetic resonance (nmr) and chromatography are used for determining structure. They study redox and complex ion formation with transition metals as well as organic nitrogen compounds such as amines, amides and amino acids. They use further techniques in volumetric analysis and learn about polymer chemistry and chemistry in medicine.

Mathematical skills that students develop in this unit include:

- analysing fragmentation patterns and peak heights in mass spectra (5.1);
- calculating redox potentials, balancing redox equations from half-cells and carrying out calculations involving redox titrations (5.6.2, 5.3);
- investigating the geometry of different transition metal complexes (5.5.9);
- calculating R_f values, interpreting a variety of different spectra, calculating relative molecular masses, and using the (n+1) rule for proton nmr (5.4.3, 5.1.3, 5.2.6); and
- carrying out calculations involving the deduction of the emf of cells from standard electrode potentials (5.6.2).

Content	**Learning Outcomes**
5.1 Mass spectrometry	Students should be able to: 5.1.1 recall the meaning of and identify the base peak, molecular ion peak, M+1 peak and fragmentation ions in a mass spectrum; 5.1.2 suggest formulae for the fragment ions in a given mass spectrum; and 5.1.3 distinguish between molecules of the same relative molecular mass (RMM)/mass using high resolution mass spectrometry.

Content	Learning Outcomes
5.2 Nuclear magnetic resonance spectroscopy	Students should be able to: 5.2.1 demonstrate understanding of the difference between low resolution and high resolution nmr spectra; 5.2.2 demonstrate understanding of the reasons for using TMS (tetramethylsilane) as a standard; 5.2.3 demonstrate recognition of chemically equivalent hydrogen atoms; 5.2.4 demonstrate understanding that chemical shifts depend on the chemical environment of hydrogen atoms; 5.2.5 use integration curves to determine the relative number of hydrogen atoms in different chemical environments; 5.2.6 apply the n+1 rule to analyse spin-spin splitting, limited to doublets, triplets and quartets where n is the number of hydrogen atoms on an adjacent carbon atom; 5.2.7 deduce a molecular structure from an nmr spectrum, limited to simple splitting patterns;
5.3 Volumetric analysis	5.3.1 titrate iodine with sodium thiosulfate using starch as an indicator and estimate oxidising agents, for example hydrogen peroxide and iodate(V) ions, by their reactions with excess acidified potassium iodide; 5.3.2 titrate acidified potassium manganate(VII) with iron(II) and other reducing agents; 5.3.3 deduce titration equations, given the half-equations for the oxidant and the reductant; and 5.3.4 demonstrate understanding of the method of back titration, for example by determining the purity of a Group II metal oxide or carbonate.

Content	Learning Outcomes
5.4 Chromatography	Students should be able to:
	5.4.1 describe and explain how paper (one-way and two-way), thin-layer (TLC) and gas-liquid (GLC) chromatography are carried out qualitatively and quantitatively;
	5.4.2 interpret GLC data in terms of the percentage composition of a mixture;
	5.4.3 interpret one-way and two-way paper and TLC chromatograms, including calculations of Rf values;
5.5 Transition metals	5.5.1 recall that transition metals or their ions have an incomplete d-shell, variable oxidation states, catalytic activity, and form coloured complexes;
	5.5.2 deduce the electronic configuration of transition metals and their ions and explain their stabilities based on the filling of the subshells;
	5.5.3 demonstrate understanding that complexes consist of a central metal atom or ion surrounded by a number of ligands, defined as anions or molecules possessing lone pairs of electrons;
	5.5.4 explain that ligands are molecules or atoms that contain a lone pair which can be donated to a transition metal atom or ion;
	5.5.5 explain the meaning of and deduce co-ordination numbers in complexes;
	5.5.6 deduce the oxidation number of transition metals in complexes and use them to explain redox and disproportionation reactions; and
	5.5.7 demonstrate understanding of the distinction between monodentate, for example Cl^-, H_2O and NH_3, bidentate, for example $NH_2CH_2CH_2NH_2$ (represented by en), and polydentate ligands (edta).

Content	Learning Outcomes
5.5 Transition metals (cont.)	Students should be able to: 5.5.8 explain the relative strengths of ligands in terms of the availability of lone pairs; 5.5.9 demonstrate understanding of the ligand replacement reactions of hexaaquacopper(II) ions with concentrated hydrochloric acid and ammonia solution, including colours and shapes of the complexes; 5.5.10 explain ligand replacement in terms of positive entropy changes, for example a bidentate ligand displacing two monodentate ligands; 5.5.11 recall the colours of the aqueous complexes of Cr^{3+}, Cr(VI), Mn^{2+}, Fe^{2+}, Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, V^{2+}, V^{3+}, V(IV) and V(V); 5.5.12 use, as qualitative detection tests, the formation of precipitates of the hydroxides of Cr^{3+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Co^{2+}, Ni^{2+} and Cu^{2+} with NaOH(aq) and NH_3(aq) and, where appropriate, their subsequent dissolution; 5.5.13 recall the reduction of VO_2^+ (acidified ammonium metavanadate) by zinc to form VO^{2+}, V^{3+} and V^{2+}; 5.5.14 deduce, given appropriate emf values, reagents for the interconversion of vanadium between its oxidation states and combine half-cells to give an overall equation for a reaction;
5.6 Electrode potentials	5.6.1 define standard electrode potential, $E^\ominus$, explain the construction and significance of the hydrogen electrode and demonstrate understanding of the importance of conditions when measuring electrode potentials; and 5.6.2 use standard electrode potentials to predict feasibility and direction of reactions, to calculate the emf and demonstrate understanding of the limitations of such predictions in terms of concentrations and kinetics.

Content	**Learning Outcomes**
5.6 Electrode potentials (cont.)	Students should be able to: 5.6.3 use conventional representations for cells; 5.6.4 classify cells into non-rechargeable, rechargeable and fuel cells and state examples of each; 5.6.5 demonstrate understanding of the electrode reactions in a lithium cell; 5.6.6 demonstrate understanding that a fuel cell uses the energy from the reaction of a fuel with oxygen to generate a voltage; 5.6.7 recall the electrode reactions that occur in an alkaline hydrogen-oxygen fuel cell; 5.6.8 recall the environmental issues associated with cells;
5.7 Amines	5.7.1 recall the molecular and structural formulae of amines with up to six carbon atoms, with reference to primary, secondary and tertiary amines; 5.7.2 refer to the effect of hydrogen bonding on boiling point and solubility with water; 5.7.3 recall the formation of primary aliphatic amines by reduction of nitriles using lithium tetrahydridoaluminate(III) (lithal) and by the reaction of ammonia with alkyl halides; 5.7.4 explain the formation of phenylamine by reduction of nitrobenzene using tin and concentrated hydrochloric acid, to form the phenylammonium salt, followed by liberation of the free amine by addition of alkali; 5.7.5 recall the formation of salts by the reaction of amines with mineral acids and the liberation of amines from their salts using alkali; and 5.7.6 explain the relative basic strengths of ammonia, primary, secondary, tertiary aliphatic amines and phenylamine using the availability of the lone pair on the nitrogen atom.

Content	Learning Outcomes
5.7 Amines (cont.)	Students should be able to: 5.7.7 recall the reaction of amines with ethanoyl chloride and use this reaction to identify unknown amines; 5.7.8 explain the formation of benzenediazonium chloride from phenylamine and recall the coupling of diazonium ions with phenol and phenylamine; 5.7.9 explain the colour of compounds such as dyestuffs and indicators based on the extent of delocalisation of electrons leading to the closer proximity of electronic energy levels;
5.8 Amides	5.8.1 recall the preparation of amides via the reaction of carboxylic acids with ammonia and the reaction of amines with acyl chlorides; 5.8.2 recall the hydrolysis of amides with acids and alkalis; 5.8.3 recall the dehydration of amides with phosphorus pentoxide to form nitriles; 5.8.4 explain the basicity of amides relative to amines, with reference to the delocalisation of the lone pair on the nitrogen atom;
5.9 Amino acids	5.9.1 recall the formulae of glycine and alanine; 5.9.2 explain the optical activity of amino acids; 5.9.3 explain the formation of dipolar ions (zwitterions) from amino acid molecules; 5.9.4 explain the solubility of amino acids in water and their relatively high melting point; 5.9.5 recall the reactions of amino acids with sodium carbonate, copper(II) sulfate and nitrous acid; and 5.9.6 recall the primary, secondary and tertiary structures of a protein and the formation of peptide links.

Content	Learning Outcomes
5.9 Amino acids (cont.)	Students should be able to:
	5.9.7 define enzymes as biological catalysts and use the concept of induced fit to explain enzyme action;
	5.9.8 recall the use of enzymes in washing powders and their economic advantage in operating at lower temperatures;
	5.9.9 explain that an enzyme is a protein and provides a path of lower activation energy;
	5.9.10 explain the effect of pH and temperature on enzyme activity;
5.10 Polymer chemistry	5.10.1 demonstrate understanding that condensation polymers are formed from molecules containing COOH, OH and NH_2 groups and be able to draw polymer structures from monomers and vice versa;
	5.10.2 demonstrate understanding of the formation, structure and uses of the polyester polyethylene terephthalate;
	5.10.3 demonstrate understanding of the formation, structure and uses of the polyamide nylon;
	5.10.4 recall that polyesters and polyamides can be hydrolysed and are, therefore, biodegradable;
5.11 Chemistry in medicine	5.11.1 recall the use of digestion remedies, for example hydroxides and carbonates, to cure excess acid in the stomach (*link with Section 1.9*);
	5.11.2 use a back titration to determine the percentage of an active ingredient in an indigestion remedy (*link with Section 5.3.4*);
	5.11.3 recall methods to deal with excessive pH values of skin and explain the use of corrosive chemicals in removing warts (*link with Sections 1.9 and 2.11.5*); and
	5.11.4 recall and explain the use of silver nitrate in the treatment of eye diseases.

Content	**Learning Outcomes**
5.11 Chemistry in medicine (cont.)	Students should be able to: 5.11.5 explain the action of anticancer drugs, for example cisplatin, in preventing DNA replication in cancer cells and how varying the structure of cisplatin affects the efficiency of anticancer activity; 5.11.6 use volumetric analysis to determine the concentration of aspirin in solution (*link with Section 5.3*); 5.11.7 recall the synthesis of aspirin from salicylic acid using ethanoic anhydride and reasons for its use as a sodium salt; 5.11.8 use TLC and GLC MS to identify drugs and their purity (*link with Section 5.4*); 5.11.9 explain the role of iron(II) in haemoglobin in the transportation of oxygen in blood and the poisonous nature of carbon monoxide (*link with Section 2.3.5*); and 5.11.10 explain the role of edta in sequestering calcium ions and how this prevents the clotting of blood (*link with Section 5.5.7*).

3.6 Unit A2 3: Further Practical Chemistry

In this unit, students carry out practical activities. These activities are embedded throughout the learning outcomes of the course. Some of these activities are listed below. They form the general basis for the questions on practical work. Students might not carry out all of the practical work listed below, but they must know the reasons why certain practical techniques need to be carried out. They must also master certain basic practical skills. At A2, the practical skills and techniques that the students use overlap with those they have acquired at AS level.

The practical examination is in two parts: A and B. Part A is a series of practical activities that students carry out in the laboratory. These activities test students' observational skills as they record and present data and may involve a chemical that students have not encountered before, as they test the skill of observation. Students may observe a more complex series of chemical reactions than at AS level, for example in transition metal chemistry.

Students may answer questions on titration. Teachers do not have to determine the titre. At A2, students should have a higher level of accuracy in the titre of the titration.

Part B is independent of part A. Part B has theoretical questions on practical situations. Students apply their knowledge to practical situations listed in this specification, but may have to apply theoretical knowledge to unfamiliar situations.

Learning Outcomes	**Specification Reference**
Students should be able to:	
• carry out experiments to determine the rate of a reaction using a variety of methods to determine the concentration of reactants and/or products;	4.3.7
• make buffer solutions from calculated quantities of salts and acids and determine their pH values using universal indicator (UI) paper and a pH meter; and	4.5.5
• determine the shape of a titration curve by measuring the pH using specialised pH paper or a pH meter for the titration of an acid with a base.	4.5.6

Learning Outcomes	**Specification Reference**
Students should be able to:	
• determine the pH of a variety of salts using pH paper or a pH meter to illustrate the relative strength of acid and base;	4.5.8
• use Fehling's solution and Tollens' reagent to distinguish between aldehydes and ketones;	4.7.9
• prepare a carboxylic acid from an alcohol;	4.8.3
• carry out test tube reactions of a carboxylic acid with sodium carbonate, sodium hydroxide and aqueous ammonia and measure the pH changes;	4.8.5
• prepare a liquid ester from a carboxylic acid and an alcohol;	4.9.5
• titrate iodine with sodium thiosulfate using starch and hence estimate oxidising agents by their reaction with excess acidified potassium iodide;	5.3.1
• titrate acidified potassium manganate(VII) with reducing agents;	5.3.2
• determine the purity of a Group II metal oxide or carbonate by back titration;	5.3.4
• carry out paper and thin-layer chromatography and measure the Rf values of the components and interpret the chromatograms;	5.4.1, 5.4.3
• use ethylene diamine, phenylamine and aqueous ammonia to demonstrate ligand replacement based on lone pair availability;	5.5.8
• demonstrate the relative strengths of ligands using hydrated copper(II) ions and hydrochloric acid; and	5.5.9
• carry out qualitative detection tests for the formation of transition metal hydroxides with sodium hydroxide and aqueous ammonia.	5.5.12

Learning Outcomes	**Specification Reference**
Students should be able to:	
• carry out the reduction of acidified ammonium metavanadate with zinc and observe the sequence of colours;	5.5.13
• determine the electrode potentials of a series of cells and predict their values using standard electrode potentials;	5.6.2
• determine the amount of a carbonate, for example calcium carbonate or magnesium carbonate, in an indigestion tablet;	5.11.2
• prepare aspirin using salicylic acid and ethanoic anhydride; and	5.11.7
• use chromatography to compare the purity of laboratory-made aspirin with commercial tablets.	5.11.8

4 Scheme of Assessment

4.1 Assessment opportunities

Each unit is available for assessment in the summer series each year. It is possible to resit individual AS and A2 assessment units once and count the better result for each unit towards an AS or A level qualification. Candidates' results for individual assessment units can count towards a qualification until we withdraw the specification.

4.2 Assessment objectives

There are three assessment objectives for this specification. Candidates must:

- demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures (AO1);
- apply knowledge and understanding of scientific ideas, processes, techniques and procedures:
  - in a theoretical context;
  - in a practical context; and
  - when handling quantitative and qualitative data (AO2); and
- analyse, interpret and evaluate scientific information, ideas and evidence (in relation to particular issues) to:
  - make judgements and reach conclusions; and
  - develop and refine practical design and procedures (AO3).

4.3 Assessment objective weightings

The table below sets out the assessment objective weightings for each assessment unit and the overall A level qualification:

Percentage Assessment Objective Weightings					
	AO1	**AO2**	**AO3**	**AS**	**A level**
AS 1	7	7	2	16	16
AS 2	6	8	2	16	16
AS 3	1	2	5	8	8
A2 1	8	11	5		24
A2 2	9	11	4		24
A2 3	2	3	7		12
Total	33	42	25	40	100

4.4 Quality of written communication

In AS and A level Chemistry, candidates must demonstrate their quality of written communication. They need to:

- 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 that suit their purpose and complex subject matter; and
- organise information clearly and coherently, using specialist vocabulary where appropriate.

Quality of written communication is assessed in responses to questions and tasks that require extended writing. These questions will be highlighted on the examination papers and assessed using a three-tier banded mark scheme.
There will be an extended writing question in the AS theory examination papers and a minimum of two extended writing questions in the A2 theory examination papers.

4.5 Synoptic assessment at A2

The A2 assessment units include some synoptic assessment, which encourages candidates to develop their understanding of the subject as a whole. In our GCE Chemistry specification, synoptic assessment involves:

- building on material from the AS units;
- bringing together and making connections between areas of knowledge and skills that they have explored throughout the course; and
- continuing to use fundamental concepts and mathematical skills developed at AS level.

4.6 Higher order thinking skills

The A2 assessment units provide opportunities to demonstrate higher order thinking skills by incorporating:

- a wider range of question types to address different skills, including planning, manipulative skills, data analysis, and interpreting and evaluating results in the practical assessments;
- more demanding evaluative opportunities involving novel and current developments in chemistry that require candidates to apply their knowledge to unfamiliar situations;
- questions that require candidates to make more connections between all of the sections of the specification, including AS; and
- extended writing.

4.7 Mathematical skills

Candidates must learn and gain competence in different mathematical areas to develop the skills, knowledge and understanding of chemistry. The following tables show the different areas of mathematics required in a chemistry context.

All the mathematical content must be assessed within the lifetime of the specification and a minimum of 20 percent of the marks is assigned to mathematical content across all the examinations in a series. **The skills highlighted in bold type are only tested in A2 units.**

We will assess candidates' mathematical skills at Level 2 or higher. Although we assess candidates' lower-level mathematical skills in the examinations, these will not count towards the 20 percent weighting.

The following mathematical skills will be counted as Level 2 (or higher) mathematics:

- application and understanding that requires the candidate to select data or equations to use; and
- problem solving that involves using mathematics from different areas and making decisions about how to proceed.

The following mathematical skills will not be counted as Level 2 (or higher) mathematics:

- simple substitution with little choice of equation or data; and
- structured question formats using GCSE mathematics.

Candidates use their numeracy skills and apply mathematical concepts in a practical context. They must:

- plot and interpret graphs; and
- process and analyse data using appropriate mathematical skills as set out in the following mathematical tables.

Mathematical Skills	**Exemplification of mathematical skill in the context of A level (assessment is not limited to the examples given below)**
Arithmetic and numerical computation	
Recognise and make use of appropriate units in calculations	Candidates may be tested on their ability to: • convert between units, for example cm^3 to dm^3, as part of volumetric calculations; • give units for an equilibrium constant or a rate constant; • understand that different units are used in similar topic areas, so conversions may be necessary, for example entropy in J mol^{-1} K^{-1} and enthalpy changes in $kJmol^{-1}$;
Recognise and use expressions in decimal and ordinary form	• use an appropriate number of decimal places in calculations, for example for pH; • carry out calculations using numbers in standard and ordinary form, for example use of Avogadro's number; • **understand standard form when applied to areas such as (but not limited to) K_w**; • convert between numbers in standard and ordinary form; • understand that significant figures need to be retained when making conversions between standard and ordinary form, for example 0.0050 mol dm^{-3} is equivalent to 5.0×10^{-3} mol dm^{-3};
Use ratios, fractions and percentages	• calculate percentage yields; • calculate the atom economy of a reaction; • construct and/or balance equations;
Estimate results	• **evaluate the effect of changing experimental parameters on measurable values, for example how the value of K_c would change with temperature given different specified conditions**;
Use calculators to find and use power, **exponential** and **logarithmic functions**	• carry out calculations using the Avogadro constant; • **carry out pH and pK_a calculations**; and • **make appropriate mathematical approximations in buffer calculations**.

Mathematical Skills	**Exemplification of mathematical skill in the context of A level (assessment is not limited to the examples given below)**
Handling data	
Use an appropriate number of significant figures	Candidates may be tested on their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures; • understand that calculated results can only be reported to the limits of the least accurate measurement;
Find arithmetic means	• calculate weighted means, for example the calculation of an atomic weight based on supplied isotopic abundances; • select appropriate titration data (identification of outliers) in order to calculate mean titres; and
Identify uncertainties in measurements and use simple techniques to determine uncertainty when data is combined	• determine uncertainty when two burette readings are used to calculate a titre value.

Mathematical Skills	**Exemplification of mathematical skill in the context of A level (assessment is not limited to the examples given below)**
Algebra	
Understand and use the symbols: =, <, <<, >>, >, ∝, ~, equilibrium sign	No exemplification required
Change the subject of an equation	Candidates may be tested on their ability to: • carry out structured and unstructured mole calculations, for example calculate a rate constant *k* from a rate equation;
Substitute numerical values into algebraic equations using appropriate units for physical quantities	• carry out structured and unstructured mole calculations; • **carry out rate calculations**; • **calculate the value of an equilibrium constant K_C**;
Solve algebraic equations	• carry out Hess's law calculations; • **calculate a rate constant *k* from a rate equation**; and
Use logarithms in relation to quantities that range over several orders of magnitude	• **carry out pH and pK_a calculations**.

Mathematical Skills	**Exemplification of mathematical skill in the context of A level (assessment is not limited to the examples given below)**
Graphs	
Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: • interpret and analyse spectra; • **determine the order of a reaction from a graph**; • **derive rate expression from a graph**;
Plot two variables from experimental or other data	• plot concentration-time graphs from collected or supplied data and draw an appropriate best-fit curve;
Determine the slope and intercept of a linear graph	• calculate the rate constant of a zero-order reaction by determining the gradient of a concentration-time graph;
Calculate rate of change from a graph showing a linear relationship	• calculate the rate constant of a zero-order reaction by determining the gradient of a concentration-time graph; and
Draw and use the slope of a tangent to a curve as a measure of rate of change	• determine the order of a reaction using the initial rates method.

Mathematical Skills	**Exemplification of mathematical skill in the context of A level (assessment is not limited to the examples given below)**
Geometry and trigonometry	
Use angles and shapes in regular 2D and 3D structures	Candidates may be tested on their ability to: • predict and/or identify shapes of and bond angles in molecules with and without a lone pair(s), for example NH_3, CH_4 or H_2O;
Visualise and represent 2D and 3D forms, including 2D representations of 3D objects	• draw different forms of isomers; • **identify chiral centres from a 2D or 3D representation**;
Understand the symmetry of 2D and 3D shapes	• describe the types of stereoisomerism shown by molecules/complexes; and • **identify chiral centres from a 2D or 3D representation**.

4.8 How science works

We assess candidates' practical skills through theory examinations and practical assessments. This specification is unique in having practical assessments at AS level and at A2. In GCE Chemistry, the practical assessments are 20 percent of the total marks. This specification is committed to giving a high importance to practical work. We mark both the practical assessment and the practical theory examination.

Please note that questions on practical chemistry are not limited to the practical units: they also feature in the theory examinations, but to a lesser extent.

Question papers assess candidates' abilities in the following skills.

Independent thinking

Candidates:

- solve problems set in a practical context − sometimes these contexts come directly from the specification, but they can also be unfamiliar situations;
- apply chemistry knowledge to practical contexts; and/or
- apply investigative approaches and methods to practical work.

Using and applying scientific methods and practices

Candidates:

- comment on experimental design and evaluate chemical methods;
- present data in an appropriate way, based on the chemistry background;
- evaluate results and draw conclusions using measured uncertainties and calculated errors; and/or
- identify variables or uncertainties, including those that need to be controlled.

Using numeracy and applying mathematical concepts in a practical context

Candidates:

- plot and interpret graphs;
- process and analyse data using mathematical skills that are exemplified in this specification; and/or
- consider margins of error, accuracy and precision of data.

Using instruments and equipment

Candidates know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in this specification.

Practical skills developed through teaching and learning

Candidates carry out aspects of practical work, listed below, throughout the course. It helps them to develop a variety of skills. The teacher demonstrates most of these. The nature of these skills means that they are rarely examined in examination papers. However, we anticipate that developing such skills can impact considerably on the candidates' performance in the more formal aspects of the course. Although it is not possible to assess candidates' skills in using websites, textbooks and other printed sources of scientific information when using examination papers, we encourage candidates to use an investigative approach in various areas of the specification. For example, in the area of chemistry in medicine, candidates research how aspirin was developed and how to co-ordinate practical activities such as chromatography and organic purification. Candidates also link the theoretical aspects of practical chemistry, for example linking percentage yield or synthetic steps with yields and atom economy to real-life situations.

When carrying out practical work, candidates must:

- use a range of practical equipment and materials safely and correctly;
- follow written instructions on the exam paper carefully and accurately;
- make and record observations in a logical and systematic way;
- keep appropriate records of practical activities;
- present information and data in a scientific way; and
- use appropriate software and tools to process data, carry out research and report findings.

Using apparatus and techniques

There is a wide range of practical skills in GCE Chemistry. Although there are often different ways of carrying out certain experiments, the following list does not always specify which technique candidates should use. Often, the technique they should use is based on what is ascertained to be the best technique and/or what is viable based on the cost of chemicals and apparatus. This also depends on whether the candidates themselves perform these experiments or the teacher demonstrates them.

Candidates must:

- observe health and safety regulations at all times; and
- handle solids, liquids and gases safely and carefully.

This includes irritant, flammable and toxic substances. All apparatus and chemicals should be available in a GCE chemistry laboratory.

Candidates must:

- use appropriate apparatus to record a range of measurements, including mass, time, temperature and the volumes of gases and liquids;
- use a variety of heating methods, for example water baths, electric heaters that are controlled or uncontrolled, oil baths and sand baths, and understand the reasons for selecting them;
- measure pH values using narrow and wide range pH paper and a pH meter and use a pH probe on a data logger if available;
- use volumetric flasks to prepare standard solutions of various volumes and safely use a burette and a pipette with acid-base indicators to carry out titrations of weak or strong acids with weak or strong alkalis;
- use apparatus to carry out reflux and adapt the apparatus for distillation, setting up the equipment using a variety of glassware, including Quickfit®, retort stands and clamps;
- use apparatus to carry out filtration, including fluted and unfluted filter paper and filtration under reduced pressure;
- use qualitative tests for cations and anions and organic functional groups;
- purify organic and inorganic solids by recrystallisation and be able to determine which solvent to use where appropriate;
- purify liquids by using a separating funnel used for washing with various reagents and final distillation(s);
- use melting point apparatus that could be in the form of a metal block or an oil bath;
- use thin-layer and 2D/3D paper chromatography;
- set up electrochemical cells and measure voltages; and
- measure rates of reaction using at least two different methods, for example an initial rate method such as a clock reaction and a continuous monitoring method.

4.9 Reporting and grading

We report the results of individual assessment units on a uniform mark scale that reflects the assessment weighting of each unit.

We award AS qualifications on a five grade scale from A to E, with A being the highest. We award A level qualifications on a six grade scale from A* to E, with A* being the highest. To determine candidates' grades, we add the uniform marks obtained in individual assessment units.

To be awarded an A*, candidates need to achieve a grade A on their full A level qualification and at least 90 percent of the maximum uniform marks available for the A2 units. If candidates fail to attain a grade E, we report their results as unclassified (U).

The grades we award match the grade descriptions in Section 5 of this specification.

We determine the grades awarded by aggregating the uniform marks obtained on individual assessment units.

5 Grade Descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded depends in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of candidates' performance in the assessment may be balanced by better performances in others.

The requirement for all AS and A level specifications to assess candidates' quality of written communication will be met through all three assessment objectives.

AS Grade Descriptions

Grade	Description
AS **Grade A**	For AO1, candidates characteristically: • demonstrate knowledge and understanding of most principles, concepts and facts in the AS specification; • select relevant information from the AS specification; • organise and present information clearly in appropriate forms; and • write equations for most straightforward chemical reactions using scientific terminology. For AO2, candidates characteristically: • apply principles and concepts in familiar and new contexts, involving several steps in the argument; • 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; • comment critically on statements, conclusions or data; • accurately carry out most structured calculations specified for AS; • use a range of chemical equations; and • successfully translate data presented as prose, diagrams, drawings, tables or graphs from one form to another.

Grade	Description
	For AO3, candidates characteristically: • devise and plan experimental and investigative activities, selecting appropriate techniques; • demonstrate safe and skilful practical techniques; • make observations and measurements with appropriate precision and record these methodically; and • interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.
AS **Grade E**	For AO1, candidates characteristically: • demonstrate knowledge and understanding of some principles and facts in the AS specification; • select some relevant information from the AS specification; • present information using basic terminology from the AS specification; and • write equations for some straightforward reactions. For AO2, candidates characteristically: • apply a given principle to material presented in familiar or closely related contexts, involving only a few steps in the argument; • describe some trends or patterns shown by data presented in tabular or graphical form; • identify, when directed, inconsistencies in conclusions or data; • carry out some steps within calculations; • use simple chemical equations; and • translate data presented from one form to another, in some contexts. For AO3, candidates characteristically: • devise and plan some aspects of experimental and investigative activities; • demonstrate safe practical techniques; • make observations and measurements and record them; and • interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 Grade Descriptions

Grade	Description
A2 **Grade A**	For AO1, candidates characteristically: • demonstrate detailed knowledge and understanding of most principles, concepts and facts in the specification; • select relevant information from the specification; • organise and present information clearly in appropriate forms using scientific terminology; and • write equations for most chemical reactions. For AO2, candidates characteristically: • apply principles and concepts in familiar and new contexts, involving several steps in the argument; • 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; • critically evaluate statements, conclusions or data; • carry out complex calculations specified for A level accurately; • use chemical equations in a range of contexts; • successfully translate data presented as prose, diagrams, drawings, tables or graphs from one form to another; • select a wide range of facts, principles and concepts; and • link together appropriate facts, principles and concepts from different areas of the specification. For AO3, candidates characteristically: • devise and plan experimental and investigative activities, selecting appropriate techniques; • demonstrate safe and skilful practical techniques; • make observations and measurements with appropriate precision and record these methodically; and • interpret, explain, evaluate and communicate the results of their own and others’ experimental and investigative activities, in appropriate contexts.

Grade	**Description**
A2 **Grade E**	For AO1, candidates characteristically: • demonstrate knowledge and understanding of some principles, concepts and facts in the specification; • select some relevant information from the specification; and • present information using basic terminology from the specification. For AO2, candidates characteristically: • apply given principles or concepts in familiar and new contexts involving a few steps in the argument; • describe and provide a limited explanation of trends or patterns shown by complex data presented in tabular or graphical form; • identify, when directed, inconsistencies in conclusions or data; • carry out some steps within calculations; • use some chemical equations; • successfully translate data from one form to another in some contexts; • select some facts, principles and concepts; and • link together some facts, principles and concepts from different areas of the specification. For AO3, candidates characteristically: • devise and plan some experimental and investigative activities; • demonstrate safe practical techniques; • make observations and measurements and record them; and • interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

6 Guidance on Assessment

There are six external assessment units in this specification, three at AS level and three at A2:

- Unit AS 1: Basic Concepts in Physical and Inorganic Chemistry;
- Unit AS 2: Further Physical and Inorganic Chemistry and an Introduction to Organic Chemistry;
- Unit AS 3: Basic Practical Chemistry;
- Unit A2 1: Further Physical and Organic Chemistry;
- Unit A2 2: Analytical, Transition Metals, Electrochemistry and Organic Nitrogen Chemistry; and
- Unit A2 3: Further Practical Chemistry.

The external assessment focuses on candidates' knowledge, understanding and analysis of the content of each unit.

A minimum of 20 percent of the marks across all the examinations in a series is assigned to mathematical skills in a chemistry context.

6.1 Units AS 1 and AS 2

The assessments for Units AS 1 and AS 2 both consist of two sections in one examination script.

- Section A has ten multiple-choice questions, each worth one mark.
- Section B is worth 80 marks. It has a variety of question styles, all worth differing amounts of marks. The questions assess knowledge and understanding of the unit content, skills and competences. There is one extended writing question that assesses quality of written communication in both the Unit AS 1 and Unit AS 2 examinations.
- Questions in the theory units may assess candidates' practical knowledge and data analysis taken from the specification content.
- Questions in the Unit AS 2 assessment may require candidates to apply prior knowledge and understanding from Unit AS 1 in a Unit AS 2 context.
- A minimum of 20 percent of the marks in both examinations is assigned to mathematical skills in a chemistry context.

6.2 Units A2 1 and A2 2

The assessments for Units A2 1 and A2 2 both consist of two sections in one examination script.

- Section A has ten multiple-choice questions, each worth one mark.
- Section B is worth 100 marks. It has a variety of question styles, all worth differing amounts of marks. The questions assess knowledge and understanding of the unit content, skills and competences.
- There are two extended writing questions that assess quality of written communication in both the Unit A2 1 and Unit A2 2 papers.

- A minimum of 20 percent of the marks in both examinations is assigned to mathematical skills in a chemistry context.
- Questions in the theory units may assess candidates’ practical knowledge and data analysis.
- Some of the questions in the Unit A2 1 and Unit A2 2 assessments are synoptic and may require candidates’ prior knowledge and understanding from the AS content. The Unit A2 2 examination may also require candidates to apply prior knowledge and understanding from Unit A2 1 in a Unit A2 2 context.

6.3 Practical Units AS 3 and A2 3

- Practical assessments are made up of two parts. Candidates take them on separate timetabled days. Any aspects of practical chemistry that occur in the specification content can be assessed.
- Practical Booklet A (25 marks for AS and 30 marks for A2) assesses candidates’ hands-on practical skills, including handling and manipulating apparatus and chemicals, and observation, recording, accuracy and precision.
  This assessment is carried out in the laboratory under teacher invigilation.
- Practical Theory Booklet B (55 marks for AS and 60 marks for A2) assesses candidates’ practical theory skills, including planning, deduction, experimental calculations, data analysis, problem solving, evaluation and interpretation. Candidates take this examination in an examination hall under external invigilation.
- Candidates must take into account any health and safety considerations for all apparatus and chemicals for the practical tasks in Practical Booklet A. They should develop an awareness of the risk assessments for each of the chemicals through the teaching and learning of the experiments during the course.
- There is a progression in the complexity of practical skills assessed from Unit AS 3 to Unit A2 3.
- We externally assess Practical Booklet A and Practical Theory Booklet B.

7 Links and Support

7.1 Support

The following resources are available to support this specification:

- our Chemistry microsite at www.ccea.org.uk
- specimen assessment materials; and
- guidance notes for teachers.

We also intend to provide:

- past papers and mark schemes;
- Chief Examiner's reports;
- schemes of work;
- centre support visits;
- support days for teachers;
- CCEA specific Chemistry factsheets;
- a CCEA specific e-book;
- videos of some of the experiments listed in this specification;
- videos of interviews with higher education and industry representatives;
- teacher and student support documents;
- practical manual and resource list; and
- exemplification of standards.

7.2 Curriculum objectives

This specification supports centres to build on the broader Northern Ireland Curriculum objectives to develop the young person:

- as an individual;
- as a contributor to society; and
- as a contributor to the economy and environment.

It can contribute to meeting the requirements of the Northern Ireland Entitlement Framework at post-16 and the provision of a broad and balanced curriculum.

Curriculum Progression from Key Stage 4

This specification builds on learning from Key Stage 4 and gives students opportunities to develop their subject knowledge and understanding further.

Students will also have opportunities to continue to develop the **Cross-Curricular Skills** and the **Thinking Skills and Personal Capabilities** shown on the next page. The extent of this development depends on the teaching and learning methodology the teacher uses.

Cross-Curricular Skills

- Communication:
  - Talking and Listening
  - Reading
  - Writing
- Using Mathematics
- Using ICT

Thinking Skills and Personal Capabilities

- Problem Solving
- Working with Others
- Self-Management

For further guidance on the skills and capabilities in this subject, please refer to the supporting schemes of work.

7.3 Examination entries

Entry codes for this subject and details on how to make entries are available on our Qualifications Administration Handbook microsite, which you can access at www.ccea.org.uk

Alternatively, you can telephone our Examination Entries, Results and Certification team using the contact details provided.

7.4 Equality and inclusion

We have considered the requirements of equality legislation in developing this specification and designed it to be as free as possible from ethnic, gender, religious, political and other forms of bias.

GCE qualifications often require the assessment of a broad range of competences. This is because they are general qualifications that prepare students for a wide range of occupations and higher level courses.

During the development process, an external equality panel reviewed the specification to identify any potential barriers to equality and inclusion. Where appropriate, we have considered measures to support access and mitigate barriers.

We can make reasonable adjustments for students with disabilities to reduce barriers to accessing assessments. Students with a physical impairment may instruct a practical assistant to set up equipment, but may have difficulty making observations and manipulating the equipment to carry out the experiment. Students with a visual impairment may find elements of the assessment difficult. They can use technology to take readings and make observations. For this reason, very few students will have a complete barrier to any part of the assessment.

It is important to note that where access arrangements are permitted, they must not be used in any way that undermines the integrity of the assessment. You can find information on reasonable adjustments in the Joint Council for Qualifications document *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications*, available at www.jcq.org.uk

7.5 Contact details

If you have any queries about this specification, please contact the relevant CCEA staff member or department:

- Specification Support Officer: Nuala Tierney
  (telephone: (028) 9026 1200, extension 2292, email: ntierney@ccea.org.uk)

- Subject Officer: Elaine Lennox
  (telephone: (028) 9026 1200, extension 2320, email: elennox@ccea.org.uk)

- Examination Entries, Results and Certification
  (telephone: (028) 9026 1262, email: entriesandresults@ccea.org.uk)

- Examiner Recruitment
  (telephone: (028) 9026 1243, email: appointments@ccea.org.uk)

- Distribution
  (telephone: (028) 9026 1242, email: cceadistribution@ccea.org.uk)

- Support Events Administration
  (telephone: (028) 9026 1401, email: events@ccea.org.uk)

- Information Section (including Freedom of Information requests)
  (telephone: (028) 9026 1200, email: info@ccea.org.uk)

- Moderation
  (telephone: (028) 9026 1200, extension 2236, email: moderationteam@ccea.org.uk)

- Business Assurance (Complaints and Appeals Manager: Heather Clarke)
  (telephone: (028) 9026 1244, email: hclarke@ccea.org.uk).

Appendix 1

Data Leaflet including a Periodic Table of the Elements

This data leaflet is for use with the specimen assessment materials. The same information will be provided with live examination papers.

THE PERIODIC TABLE OF ELEMENTS

Group

I	II											III	IV	V	VI	VII	O
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1																	4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminum 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	[98] **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La*** Lanthanum 57	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	[209] **Po** Polonium 84	[210] **At** Astatine 85	[222] **Rn** Radon 86
[223] **Fr** Francium 87	[226] **Ra** Radium 88	[227] **Ac**† Actinium 89	[261] **Rf** Rutherfordium 104	[262] **Db** Dubnium 105	[266] **Sg** Seaborgium 106	[264] **Bh** Bohrium 107	[277] **Hs** Hassium 108	[268] **Mt** Meitnerium 109	[271] **Ds** Darmstadtium 110	[272] **Rg** Roentgenium 111	**Elements with atomic numbers 112-116 have been reported but not fully authenticated**						

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	145 **Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	162 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	[231] **Pa** Protactinium 91	238 **U** Uranium 92	[237] **Np** Neptunium 93	[242] **Pu** Plutonium 94	[243] **Am** Americium 95	[247] **Cm** Curium 96	[245] **Bk** Berkelium 97	[251] **Cf** Californium 98	[254] **Es** Einsteinium 99	[253] **Fm** Fermium 100	[256] **Md** Mendelevium 101	[254] **No** Nobelium 102	[257] **Lr** Lawrencium 103

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series

$\boxed{{}^{a}_{b}x}$

a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

General Information

1 tonne = 10^6 g
1 metre = 10^9 nm
One mole of any gas at 293K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm^3
Avogadro Constant = 6.02×10^{23} mol^{-1}
Gas constant = 8.31 J mol^{-1} K^{-1}
Planck Constant = 6.63×10^{-34} Js
Specific Heat Capacity of water = 4.2 J g^{-1} K^{-1}
Speed of Light = 3×10^8 ms^{-1}

Characteristic absorptions in IR spectroscopy

Wavenumber/cm^{-1}	**Bond**	**Compound**
550 – 850	C – X (X=Cl, Br, I)	Haloalkanes
750 – 1100	C – C	Alkanes, alkyl groups
1000 – 1300	C – O	Alcohols, esters, carboxylic acids
1450 – 1650	C = C	Arenes
1600 – 1700	C = C	Alkenes
1650 – 1800	C = O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200 – 2300	C ≡ N	Nitriles
2500 – 3200	O – H	Carboxylic acids
2750 – 2850	C – H	Aldehydes
2850 – 3000	C – H	Alkanes, alkyl groups, alkenes, arenes
3200 – 3600	O – H	Alcohols
3300 – 3500	N – H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	**Structure**	
0.5 – 2.0	–C**H**	Saturated alkanes
0.5 – 5.5	–O**H**	Alcohols
1.0 – 3.0	–N**H**	Amines
2.0 – 3.0	–CO–C**H**	Ketones
	–N–C**H**	Amines
	C_6H_5–C**H**	Arene (aliphatic on ring)
2.0 – 4.0	X–C**H**	X = Cl or Br (3.0 – 4.0) X = I (2.0 – 3.0)
4.5 – 6.0	–C=C**H**	Alkenes
5.5 – 8.5	RCON**H**	Amides
6.0 – 8.0	$C_6\mathbf{H}_5$	Arenes (on ring)
9.0 – 10.0	–C**H**O	Aldehydes
10.0 – 12.0	–COO**H**	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

Summary of Changes since First Issue

(Most recent changes are indicated in red on the latest version)

Revision History Number	**Date of Change**	**Page Number**	**Change Made**
Version 1	N/A	N/A	First issue
Version 2	21.10.2021	Page 33, 45, 62	Insertions and Deletions