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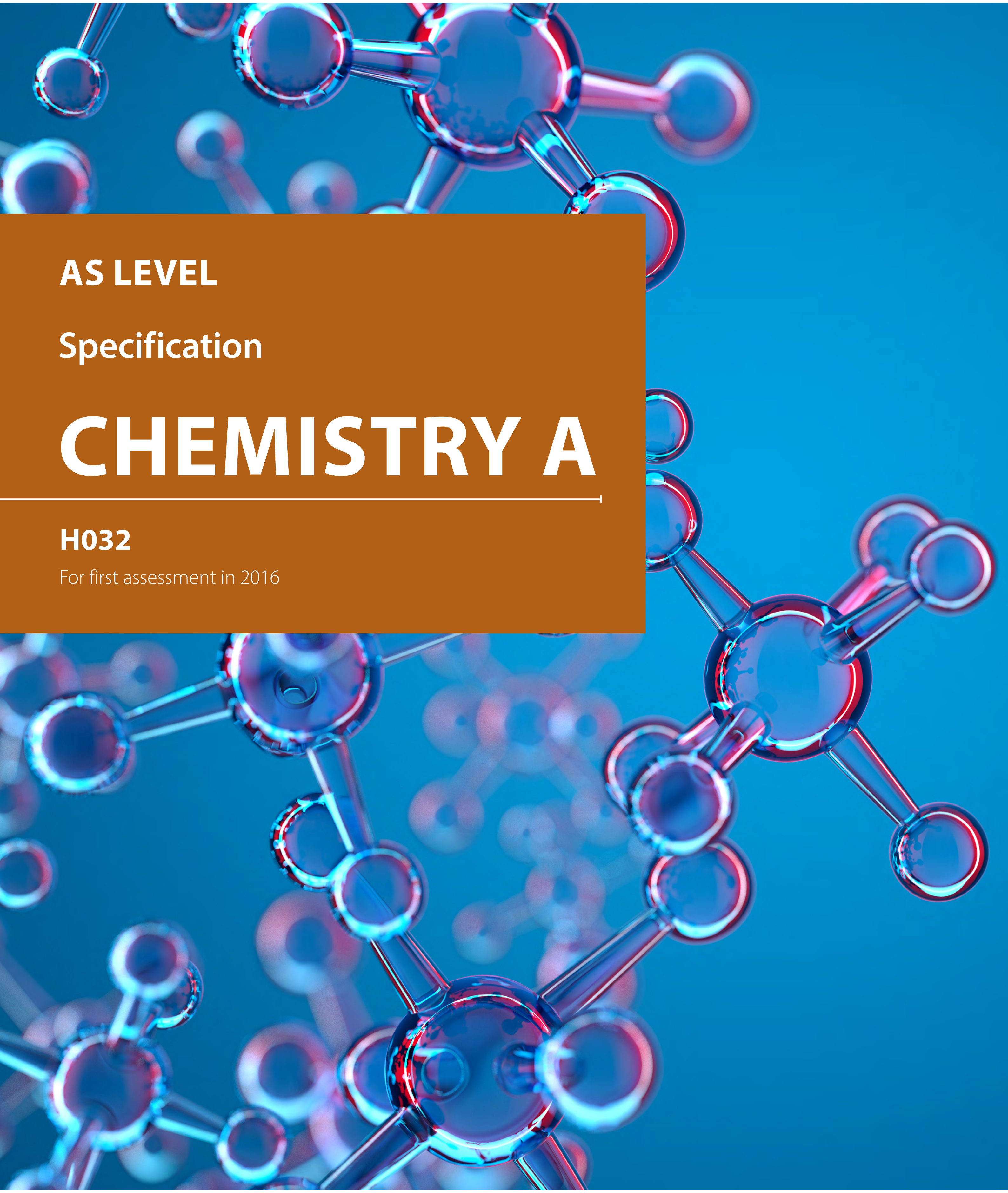

AS LEVEL

Specification

CHEMISTRY A

H032

For first assessment in 2016

Version 1.4 (April 2023)

ocr.org.uk/chemistrya

Disclaimer

Specifications are updated over time. Whilst every effort is made to check all documents, there may be contradictions between published resources and the specification, therefore please use the information on the latest specification at all times. Where changes are made to specifications these will be indicated within the document, there will be a new version number indicated, and a summary of the changes. If you do notice a discrepancy between the specification and a resource please contact us at: resources.feedback@ocr.org.uk

We will inform centres about changes to specifications. We will also publish changes on our website. The latest version of our specifications will always be those on our website (ocr.org.uk) and these may differ from printed versions.

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Contents

Introducing…

Introducing…
AS Level Chemistry A (from September 2015)

This specification allows teachers to adopt a flexible approach to the delivery of AS Level Chemistry. The course has been designed to enable centres to deliver the content modules (Modules 2–4) using the framework provided or to design a customised course. Practical work done to support teaching of the content will serve to cover the requirements of the practical skills module (Module 1), which is assessed in written examinations.

The specification is divided into chemical topics, each containing different key concepts of chemistry. Throughout the specification, cross-references indicate the relevance of individual learning outcomes to the mathematical criteria that are embedded in the assessments.

This specification incorporates the Ofqual GCE Subject Level Conditions and Requirements for Chemistry.

Contact the team

We have a dedicated team of people working on our AS Level Chemistry qualifications.

If you need specialist advice, guidance or support, get in touch as follows:

- **01223 553998**
- **scienceGCE@ocr.org.uk**
- **@OCR_science**

Teaching and learning resources

We recognise that the introduction of a new specification can bring challenges for implementation and teaching. Our aim is to help you at every stage and we're working hard to provide a practical package of support in close consultation with teachers and other experts, so we can help you to make the change.

Designed to support progression for all

Our resources are designed to provide you with a range of teaching activities and suggestions so you can select the best approach for your particular students. You are the experts on how your students learn and our aim is to support you in the best way we can.

We want to…

- Support you with a body of knowledge that grows throughout the lifetime of the specification
- Provide you with a range of suggestions so you can select the best activity, approach or context for your particular students
- Make it easier for you to explore and interact with our resource materials, in particular to develop your own schemes of work
- Create an ongoing conversation so we can develop materials that work for you.

Plenty of useful resources

You'll have four main types of subject-specific teaching and learning resources at your fingertips:

- Delivery Guides
- Transition Guides
- Topic Exploration Packs
- Lesson Elements.

Along with subject-specific resources, you'll also have access to a selection of generic resources that focus on skills development and professional guidance for teachers.

Skills Guides – we've produced a set of Skills Guides that are not specific to Chemistry, but each covers a topic that could be relevant to a range of qualifications – for example, communication, legislation and research. Download the guides at **ocr.org.uk/skillsguides**

Active Results – a free online results analysis service to help you review the performance of individual students or your whole school. It provides access to detailed results data, enabling more comprehensive analysis of results in order to give you a more accurate measurement of the achievements of your centre and individual students. For more details refer to **ocr.org.uk/activeresults**

Professional development

Take advantage of our improved Professional Development Programme, designed with you in mind. Whether you want to come to face-to-face events, look at our new digital training or search for training materials, you can find what you're looking for all in one place at the CPD Hub.

An introduction to the new specifications

We'll be running events to help you get to grips with our AS Level Chemistry A qualification.

These events are designed to help prepare you for first teaching and to support your delivery at every stage.

Watch out for details at **cpdhub.org.uk**

To receive the latest information about the training we'll be offering, please register for AS Level email updates at **ocr.org.uk/updates**

1 Why choose an OCR AS Level in Chemistry A?

1a. Why choose an OCR qualification?

Choose OCR and you've got the reassurance that you're working with one of the UK's leading exam boards. Our new AS Level in Chemistry A course has been developed in consultation with teachers, employers and Higher Education to provide students with a qualification that's relevant to them and meets their needs.

We're part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment plays a leading role in developing and delivering assessments throughout the world, operating in over 150 countries.

We work with a range of education providers, including schools, colleges, workplaces and other institutions in both the public and private sectors. Over 13,000 centres choose our A levels, GCSEs and vocational qualifications including Cambridge Nationals and Cambridge Technicals.

Our Specifications

We believe in developing specifications that help you bring the subject to life and inspire your students to achieve more.

We've created teacher-friendly specifications based on extensive research and engagement with the teaching community. They're designed to be straightforward and accessible so that you can tailor the delivery of the course to suit your needs. We aim to encourage learners to become responsible for their own learning, confident in discussing ideas, innovative and engaged.

We provide a range of support services designed to help you at every stage, from preparation through to the delivery of our specifications. This includes:

- A wide range of high-quality creative resources including:
  - delivery guides
  - transition guides
  - topic exploration packs
  - lesson elements
  - …and much more.
- Access to Subject Advisors to support you through the transition and throughout the lifetime of the specifications.
- CPD/Training for teachers to introduce the qualifications and prepare you for first teaching.
- Active Results – our free results analysis service to help you review the performance of individual students or whole schools.
- **ExamBuilder** – our free online past papers service that enables you to build your own test papers from past OCR exam questions.

All AS level qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's AS Level in Chemistry A is QN: 601/5256/4.

1b. Why choose an OCR AS Level in Chemistry A?

We appreciate that one size doesn't fit all so we offer two suites of qualifications in each science:

Chemistry A – a content-led approach. A flexible approach where the specification is divided into topics, each covering different key concepts of chemistry. Teaching of practical skills is integrated with the theoretical topics and they're assessed both through written papers and, for A level only, the Practical Endorsement.

Chemistry B (Salters) – a context-led approach. Learners study chemistry in a range of different contexts, conveying the excitement of contemporary chemistry. Ideas are introduced in a spiral way with topics introduced in an early part of the course reinforced later. The 'B' specification places a particular emphasis on an investigational and problem-solving approach to practical work and is supported by extensive new materials developed by the University of York Science Education Group.

All of our specifications have been developed with subject and teaching experts. We have worked in close consultation with teachers and representatives from Higher Education (HE) with the aim of including up-to-date relevant content within a framework that is interesting to teach and administer within all centres (large and small).

Our new AS Level Chemistry A qualification builds on our existing popular course. We've based the redevelopment of our AS level sciences on an understanding of what works well in centres large and small and have updated areas of content and assessment where stakeholders have identified that improvements could be made. We've undertaken a significant amount of consultation through our science forums (which include representatives from learned societies, HE, teaching and industry) and through focus groups with teachers. Our papers and specifications have been trialled in centres during development to make sure they work well for all centres and learners.

The content changes are an evolution of our legacy offering and will be familiar to centres already following our courses, but are also clear and logically laid out for centres new to OCR, with assessment models that are straightforward to administer. We have worked closely with teachers and HE representatives to provide high quality support materials to guide you through the new qualifications.

Aims and learning outcomes

OCR's AS Level in Chemistry A specification aims to encourage learners to:

- develop essential knowledge and understanding of different areas of the subject and how they relate to each other
- develop and demonstrate a deep appreciation of the skills, knowledge and understanding of scientific methods
- develop competence and confidence in a variety of practical, mathematical and problem solving skills
- develop their interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject
- understand how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society (as exemplified in 'How Science Works' (HSW)).

1c. What are the key features of this specification?

Our Chemistry A specification is designed with a content-led approach and provides a flexible approach to teaching. The specification:

- retains and refreshes the popular topics from the legacy OCR Chemistry qualification (H158)
- is laid out clearly in a series of teaching modules with Additional guidance added where required to clarify assessment requirements
- is co-teachable with the A level
- embeds practical requirements within the teaching modules. Whilst the Practical Endorsement is not part of AS Level in Chemistry A, opportunities for carrying out activities that would count towards the Practical Endorsement are indicated throughout the specification, in the Additional guidance column, by use of **PAG**, refer to the A level specification, Section 5, for Practical Endorsement requirements
- exemplifies the mathematical requirements of the course (see Section 5)
- highlights opportunities for the introduction of key mathematical requirements (see Section 5 and the additional guidance column for each module) into your teaching
- identifies, within the Additional guidance how the skills, knowledge and understanding of How Science Works (HSW) can be incorporated within teaching.

Teacher support

The extensive support offered alongside this specification includes:

- **delivery guides** – providing information on assessed content, the associated conceptual development and contextual approaches to delivery
- **transition guides** – identifying the levels of demand and progression for different key stages for a particular topic and going on to provide links to high quality resources and ‘checkpoint tasks’ to assist teachers in identifying learners ‘ready for progression’
- **lesson elements** – written by experts, providing all the materials necessary to deliver creative classroom activities
- **Active Results** (see Section 1a)
- **ExamBuilder** (see Section 1a)
- **mock examinations service** – a free service offering a practice question paper and mark scheme (downloadable from a secure location).

Along with:

- Subject Advisors within the OCR science team to help with course queries
- teacher training
- *Science Spotlight* (our termly newsletter)
- OCR Science community
- Practical Skills Handbook
- Maths Skills Handbook.

1d. How do I find out more information?

Whether new to our specifications, or continuing on from our legacy offerings, you can find more information on our webpages at: **www.ocr.org.uk**

Visit our subject pages to find out more about the assessment package and resources available to support your teaching. The science team also release a termly newsletter *Science Spotlight* (despatched to centres and available from our subject pages).

Find out more?

Contact the Subject Advisors: **ScienceGCE@ocr.org.uk**, 01223 553998.

Visit our Online Support Centre at **support.ocr.org.uk**

Check what CPD events are available:
www.cpdhub.ocr.org.uk

Follow us on Twitter: **@ocr_science**

2 The specification overview

2a. Overview of AS Level in Chemistry A (H032)

Learners must complete both components (01 and 02) to be awarded the OCR AS Level in Chemistry A.

Content Overview	Assessment Overview	
Content is split into four teaching modules: • Module 1 – Development of practical skills in chemistry • Module 2 – Foundations in chemistry • Module 3 – Periodic table and energy • Module 4 – Core organic chemistry Both components assess content from all four modules.	Breadth in chemistry (01)* 70 marks 1 hour 30 minutes written paper	**50%** of total AS level
	Depth in chemistry (02)* 70 marks 1 hour 30 minutes written paper	**50%** of total AS level

*Both components include synoptic assessment.

2b. Content of AS Level in Chemistry A (H032)

The AS Level in Chemistry A specification content is divided into four teaching modules and each module is further divided into key topics.

Each module is introduced with a summary of the chemistry it contains and each topic is also introduced with a short summary text. The assessable content is then divided into two columns: **Learning outcomes** and **Additional guidance**.

The Learning outcomes may all be assessed in the examination. The Additional guidance column is included to provide further advice on delivery and the expected skills required from learners.

References to HSW (Section 5) are included in the guidance to highlight opportunities to encourage a wider understanding of science.

The mathematical requirements in Section 5 are also referenced by the prefix M to link the mathematical skills required for AS Level Chemistry to examples of chemistry content where those mathematical skills could be linked to learning.

Module 1 of the specification content relates to the practical skills learners are expected to gain throughout the course, which are assessed throughout the written examinations.

Practical activities are embedded within the learning outcomes of the course to encourage practical activities in the laboratory, enhancing learners' understanding of chemical theory and practical skills.

The specification has been designed to be co-teachable with the A Level in Chemistry A qualification.

Learners studying the A level study modules 1 to 4 and then continue with the A level only modules 5 and 6 in year 13. The internally assessed Practical Endorsement skills also form part of the full A Level (see module 1.2. in the A Level specification).

A summary of the content for the AS level course is as follows:

Module 1 – Development of practical skills in chemistry

- Practical skills assessed in a written examination

Module 2 – Foundations in chemistry

- Atoms, compounds, molecules and equations
- Amount of substance
- Acid–base and redox reactions
- Electrons, bonding and structure

Module 3 – Periodic table and energy

- The periodic table and periodicity
- Group 2 and the halogens
- Qualitative analysis
- Enthalpy changes
- Reaction rates and equilibrium (qualitative)

Module 4 – Core organic chemistry

- Basic concepts
- Hydrocarbons
- Alcohols and haloalkanes
- Organic synthesis
- Analytical techniques (IR and MS)

2c. Content of modules 1 to 4

Module 1: Development of practical skills in chemistry

Chemistry is a practical subject and the development of practical skills is fundamental to understanding the nature of chemistry. Chemistry A gives learners many opportunities to develop the fundamental skills needed to collect and analyse empirical data. Skills in planning, implementing, analysing and evaluating, as outlined in 1.1, will be assessed in the written papers.

1.1 Practical skills assessed in a written examination

Practical skills are embedded throughout all modules in this specification.

Learners will be required to develop a range of practical skills throughout the course in preparation for the written examinations.

1.1.1 Planning

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	experimental design, including to solve problems set in a practical context	Including selection of suitable apparatus, equipment and techniques for the proposed experiment. Learners should be able to apply scientific knowledge based on the content of the specification to the practical context. HSW3
(b)	identification of variables that must be controlled, where appropriate	
(c)	evaluation that an experimental method is appropriate to meet the expected outcomes.	HSW6

1.1.2 Implementing

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to use a wide range of practical apparatus and techniques correctly	As outlined in the content of the specification. HSW4
(b)	appropriate units for measurements	*M0.0*
(c)	presenting observations and data in an appropriate format.	HSW8

1.1.3 Analysis

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	processing, analysing and interpreting qualitative and quantitative experimental results	Including reaching valid conclusions, where appropriate. HSW5
(b)	use of appropriate mathematical skills for analysis of quantitative data	Refer to Section 5 for a list of mathematical skills that learners should have acquired competence in as part of the course. HSW3
(c)	appropriate use of significant figures	*M1.1*
(d)	plotting and interpreting suitable graphs from experimental results, including:	*M3.2*
	(i) selection and labelling of axes with appropriate scales, quantities and units	
	(ii) measurement of gradients.	*M3.3, M3.4, M3.5*

1.1.4 Evaluation

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to evaluate results and draw conclusions	HSW6
(b)	the identification of anomalies in experimental measurements	
(c)	the limitations in experimental procedures	
(d)	precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus	*M1.3*
(e)	refining experimental design by suggestion of improvements to the procedures and apparatus.	HSW3

Module 2: Foundations in chemistry

This module acts as an important bridge into AS and A Level Chemistry from the study of chemistry within science courses at GCSE level.

This module provides learners with a knowledge and understanding of the important chemical ideas that underpin the study of AS Chemistry:

- atomic structure
- quantitative chemistry: formulae, equations, amount of substance and the mole
- reactions of acids
- oxidation number and redox reactions
- bonding and structure.

The importance of these basic chemical concepts is seen as a prerequisite for all further chemistry modules, and it is recommended that this module should be studied first during this course.

This module allows learners to develop important quantitative techniques involved in measuring masses, gas and solution volumes, including use of volumetric apparatus.

Learners are also able to develop their mathematical skills during their study of amount of substance and when carrying out quantitative practical work.

2.1 Atoms and reactions

This section builds directly from GCSE Science, starting with basic atomic structure and isotopes.

Important basic chemical skills are developed: writing chemical formulae, constructing equations and calculating chemical quantities using the concept of amount of substance.

The role of acids, bases and salts in chemistry is developed in the context of neutralisation reactions.

Finally, redox reactions are studied within the context of oxidation number and electron transfer.

2.1.1 Atomic structure and isotopes

	Learning outcomes	**Additional guidance**
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Atomic structure and isotopes		
(a)	isotopes as atoms of the same element with different numbers of neutrons and different masses	
(b)	atomic structure in terms of the numbers of protons, neutrons and electrons for atoms and ions, given the atomic number, mass number and any ionic charge	HSW1 Different models for atomic structure can be used to explain different phenomena, e.g. the Bohr model explains periodic properties. HSW7 The changing accepted models of atomic structure over time. The use of evidence to accept or reject particular models.

Relative mass

(c)	explanation of the terms *relative isotopic mass* (mass compared with 1/12th mass of carbon-12) and *relative atomic mass (*weighted mean mass compared with 1/12th mass of carbon-12*)*, based on the mass of a ^{12}C atom, the standard for atomic masses	Definitions required.
(d)	use of mass spectrometry in: **(i)** the determination of relative isotopic masses and relative abundances of the isotope **(ii)** calculation of the relative atomic mass of an element from the relative abundances of its isotopes	*M0.2, M1.2, M3.1* Knowledge of the mass spectrometer **not** required. Limited to ions with single charges.
(e)	use of the terms *relative molecular mass*, M_r, and *relative formula mass* and their calculation from relative atomic masses.	For simple molecules, the term *relative molecular mass* will be used. For compounds with giant structures, the term *relative formula mass* will be used. Definitions of relative molecular mass and relative formula mass will **not** be required.

2.1.2 Compounds, formulae and equations

	Learning outcomes	**Additional guidance**
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Formulae and equations		
(a)	the writing of formulae of ionic compounds from ionic charges, including: **(i)** prediction of ionic charge from the position of an element in the periodic table **(ii)** recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^+	Note that 'nitrate' and 'sulfate' should be assumed to be NO_3^- and SO_4^{2-}. Charges on ions other than in **(i)** and **(ii)** will be provided.
(b)	construction of balanced chemical equations (including ionic equations), including state symbols, for reactions studied and for unfamiliar reactions given appropriate information.	*M0.2*

2.1.3 Amount of substance

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
The mole		
(a)	explanation and use of the terms: **(i)** *amount of substance* **(ii)** *mole* (symbol ‘mol’), as the unit for amount of substance **(iii)** the *Avogadro constant*, N_A (the number of particles per mole, $6.02 \times 10^{23}\ \mathrm{mol^{-1}}$) **(iv)** *molar mass* (mass per mole, units $\mathrm{g\ mol^{-1}}$) **(v)** *molar gas volume* (gas volume per mole, units $\mathrm{dm^3\ mol^{-1}}$)	*M0.0, M0.1, M0.2, M0.4* Amount of substance will be used in exams using the formula of the substance e.g. amount of $\mathrm{NaC}l$; amount of O_2. In recognition of IUPAC’s review, we will accept both the classical (carbon-12 based) and revised (Avogadro constant based) definitions of the mole in examinations from June 2018 onwards (see **https://iupac.org/new-definition-mole-arrived/**) The value for N_A and the molar gas volume at RTP are provided on the *Data Sheet*.
Determination of formulae		
(b)	use of the terms: **(i)** *empirical formula* (the simplest whole number ratio of atoms of each element present in a compound) **(ii)** *molecular formula* (the number and type of atoms of each element in a molecule)	Definitions **not** required.
(c)	calculations of empirical and molecular formulae, from composition by mass or percentage compositions by mass and relative molecular mass	*M0.2, M2.2, M2.3, M2.4* To include calculating empirical formulae from elemental analysis data.
(d)	the terms *anhydrous*, *hydrated* and *water of crystallisation* and calculation of the formula of a hydrated salt from given percentage composition, mass composition or based on experimental results	*M0.2, M2.2, M2.3, M2.4* **PAG1**
Calculation of reacting masses, gas volumes and mole concentrations		
(e)	calculations, using amount of substance in mol, involving: **(i)** mass **(ii)** gas volume **(iii)** solution volume and concentration	*M0.0, M0.1, M0.4, M1.1, M2.2, M2.3, M2.4* Learners will be expected to express concentration in $\mathrm{mol\ dm^{-3}}$ and $\mathrm{g\ dm^{-3}}$.
(f)	the ideal gas equation: $pV = nRT$	*M0.0, M0.1, M0.4, M1.1, M2.2, M2.3, M2.4* The value for R is provided on the *Data Sheet*. Learners will be expected to express quantities in SI units.

(g)	use of stoichiometric relationships in calculations	*M0.2*
Percentage yields and atom economy		
(h)	calculations to determine: **(i)** the percentage yield of a reaction or related quantities **(ii)** the atom economy of a reaction	*M0.2, M1.1, M2.2, M2.3, M2.4*
(i)	the techniques and procedures required during experiments requiring the measurement of mass, volumes of solutions and gas volumes	**PAG1** HSW4 Many opportunities to carry out experimental and investigative work.
(j)	the benefits for sustainability of developing chemical processes with a high atom economy.	HSW10 Use of processes with high atom economy in chemical industry and other areas.

2.1.4 Acids

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Acids, bases, alkalis and neutralisation		
(a)	the formulae of the common acids (HCl, H_2SO_4, HNO_3 and CH_3COOH) and the common alkalis ($NaOH$, KOH and NH_3) and explanation that acids release H^+ ions in aqueous solution and alkalis release OH^- ions in aqueous solution	
(b)	qualitative explanation of strong and weak acids in terms of relative dissociations	
(c)	neutralisation as the reaction of: **(i)** H^+ and OH^- to form H_2O **(ii)** acids with bases, including carbonates, metal oxides and alkalis (water-soluble bases), to form salts, including full equations	
Acid–base titrations		
(d)	the techniques and procedures used when preparing a standard solution of required concentration and carrying out acid–base titrations	**PAG2** HSW4 Many opportunities to carry out experimental and investigative work.
(e)	structured and non-structured titration calculations, based on experimental results of familiar and non-familiar acids and bases.	*M0.1, M0.2, M1.1, M1.2, M2.2, M2.3, M2.4*

2.1.5 Redox

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Oxidation number		
(a)	rules for assigning and calculating oxidation number for atoms in elements, compounds and ions	Learners will be expected to know oxidation numbers of O in peroxides and H in metal hydrides.
(b)	writing formulae using oxidation numbers	HSW8 Appropriate use of oxidation numbers in written communication.
(c)	use of a Roman numeral to indicate the magnitude of the oxidation number when an element may have compounds/ions with different oxidation numbers	Examples should include, but not be limited to, iron(II) and iron(III). Learners will be expected to write formulae from names such as chlorate(I) and chlorate(III) and *vice versa*. Note that 'nitrate' and 'sulfate', with no shown oxidation number, are assumed to be NO_3^- and SO_4^{2-}. HSW8 Systematic and unambiguous nomenclature.
Redox reactions		
(d)	oxidation and reduction in terms of: **(i)** electron transfer **(ii)** changes in oxidation number	Should include examples of s-, p- and d-block elements.
(e)	redox reactions of metals with acids to form salts, including full equations **(see also 2.1.4 c)**	Metals should be from s-, p- and d- blocks e.g. Mg, A*l*, Fe, Zn. Ionic equations **not** required. In **(e)**, reactions with acids will be limited to those producing a salt and hydrogen. Reactions involving nitric acid or concentrated sulfuric acid could be assessed in the context of **(f)**.
(f)	interpretation of redox equations in **(e)**, and unfamiliar redox reactions, to make predictions in terms of oxidation numbers and electron loss/gain.	*M0.2*

2.2 Electrons, bonding and structure

This section introduces the concept of atomic orbitals and develops a deeper understanding of electron configurations linked to the periodic table.

The central role of electrons in ionic and covalent bonding is then studied. The important role of molecules is studied, including an explanation of polarity and intermolecular forces. Finally, this section looks at how bonding and structure contribute to properties of substances.

2.2.1 Electron structure

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Energy levels, shells, sub-shells, atomic orbitals, electron configuration		
(a)	the number of electrons that can fill the first four shells	
(b)	atomic orbitals, including: **(i)** as a region around the nucleus that can hold up to two electrons, with opposite spins **(ii)** the shapes of s- and p-orbitals **(iii)** the number of orbitals making up s-, p- and d-sub-shells, and the number of electrons that can fill s-, p- and d-sub-shells	HSW1,7 Development of models to explain electron structure.
(c)	filling of orbitals: **(i)** for the first three shells and the 4s and 4p orbitals in order of increasing energy **(ii)** for orbitals with the same energy, occupation singly before pairing	Learners are expected to be familiar with the 'electrons in box' representations. HSW1 Development of refined models for electron structure.
(d)	deduction of the electron configurations of: **(i)** atoms, given the atomic number, up to $Z = 36$ **(ii)** ions, given the atomic number and ionic charge, limited to s- and p-blocks up to $Z = 36$.	Learners should use sub-shell notation, i.e. for oxygen: $1s^22s^22p^4$. The electron configurations of Cr and Cu will **not** be assessed.

2.2.2 Bonding and structure

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Ionic bonding		
(a)	ionic bonding as electrostatic attraction between positive and negative ions, and the construction of '*dot-and-cross*' diagrams	
(b)	explanation of the solid structures of giant ionic lattices, resulting from oppositely charged ions strongly attracted in all directions e.g. $NaCl$	
(c)	explanation of the effect of structure and bonding on the physical properties of ionic compounds, including melting and boiling points, solubility and electrical conductivity in solid, liquid and aqueous states	HSW1 Use of ideas about ionic bonding to explain macroscopic properties.
Covalent bonding		
(d)	covalent bond as the strong electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms	
(e)	construction of '*dot-and-cross*' diagrams of molecules and ions to describe: **(i)** single covalent bonding **(ii)** multiple covalent bonding **(iii)** dative covalent (coordinate) bonding	'*Dot-and-cross*' diagrams of up to six electron pairs (including lone pairs) surrounding a central atom.
(f)	use of the term *average bond enthalpy* as a measurement of covalent bond strength	Learners should appreciate that the larger the value of the average bond enthalpy, the stronger the covalent bond. Definition and calculations **not** required. Average bond enthalpies and related calculations are covered in detail in **3.2.1 f**.
The shapes of simple molecules and ions		
(g)	the shapes of, and bond angles in, molecules and ions with up to six electron pairs (including lone pairs) surrounding the central atom as predicted by electron pair repulsion, including the relative repulsive strengths of bonded pairs and lone pairs of electrons	*M4.1, M4.2* Learners should be able to draw 3-D diagrams to illustrate shapes of molecules and ions. HSW1,2 Using electron pair repulsion theory to predict molecular shapes.
(h)	electron pair repulsion to explain the following shapes of molecules and ions: linear, non-linear, trigonal planar, pyramidal, tetrahedral and octahedral	Learners are expected to know that lone pairs repel more than bonded pairs and the bond angles for common examples of each shape including CH_4 (109.5°), NH_3 (107°) and H_2O (104.5°).

Electronegativity and bond polarity

(i)	electronegativity as the ability of an atom to attract the bonding electrons in a covalent bond; interpretation of Pauling electronegativity values	Learners should be aware that electronegativity increases towards F in the periodic table. HSW1,2 Using ideas about electronegativity to predict chemical bond type.
(j)	explanation of: **(i)** a polar bond and permanent dipole within molecules containing covalently-bonded atoms with different electronegativities **(ii)** a polar molecule and overall dipole in terms of permanent dipole(s) and molecular shape	A polar molecule requires polar bonds with dipoles that do not cancel due to their direction e.g. H_2O and CO_2 both have polar bonds but only H_2O has an overall dipole.

Intermolecular forces

(k)	intermolecular forces based on permanent dipole–dipole interactions and induced dipole–dipole interactions	Permanent dipole–dipole and induced dipole–dipole interactions can **both** be referred to as van der Waals' forces. Induced dipole–dipole interactions can also be referred to as London (dispersion) forces. HSW1,2 Dipole interactions as a model to explain intermolecular bonding.
(l)	hydrogen bonding as intermolecular bonding between molecules containing N, O or F and the H atom of –NH, –OH or HF	Including the role of lone pairs.
(m)	explanation of anomalous properties of H_2O resulting from hydrogen bonding, e.g.: **(i)** the density of ice compared with water **(ii)** its relatively high melting and boiling points	HSW1 Use of ideas about hydrogen bonding to explain macroscopic properties.
(n)	explanation of the solid structures of simple molecular lattices, as covalently bonded molecules attracted by intermolecular forces, e.g. I_2, ice	
(o)	explanation of the effect of structure and bonding on the physical properties of covalent compounds with simple molecular lattice structures including melting and boiling points, solubility and electrical conductivity.	

Module 3: Periodic table and energy

The focus of this module is inorganic and physical chemistry, the applications of energy use to everyday life and industrial processes, and current environmental concerns associated with sustainability.

The content within this module assumes knowledge and understanding of the chemical concepts developed in Module 2: Foundations in chemistry.

This module provides learners with a knowledge and understanding of the important chemical ideas that underpin the study of inorganic and physical chemistry:

- the periodic table: periodic and group properties
- enthalpy changes and their determination
- rates of reaction
- reversible reactions and chemical equilibrium
- consideration of energy and yield in improving sustainability.

This module allows learners to develop important qualitative practical skills, especially observational skills required for analysis, and accurate quantitative techniques involved in determination of energy changes and reaction rates.

There are opportunities for developing mathematical skills when studying enthalpy changes and reaction rates and when carrying out quantitative practical work.

Synoptic assessment

This module provides a context for synoptic assessment and the subject content links strongly with content encountered in Module 2: Foundations in chemistry.

- Atoms, moles and stoichiometry
- Acid and redox reactions
- Bonding and structure

Knowledge and understanding of Module 2 will be assumed and examination questions will be set that link its content with this module and other areas of chemistry.

3.1 The periodic table

Periodic trends are first studied to extend the understanding of structure and bonding. Group properties are then studied using Group 2 and the halogens as typical metal and non-metal groups respectively, allowing an understanding of redox reactions to be developed further.

Finally, this section looks at how unknown ionic compounds can be analysed and identified using simple test-tube tests.

3.1.1 Periodicity

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
The structure of the periodic table		
(a)	the periodic table as the arrangement of elements: **(i)** by increasing atomic (proton) number **(ii)** in periods showing repeating trends in physical and chemical properties (periodicity) **(iii)** in groups having similar chemical properties	HSW1,7,11 The development of the Periodic Law and acceptance by the scientific community. HSW7,11 The extension of the periodic table through discovery and confirmation of new elements.
Periodic trend in electron configuration and ionisation energy		
(b)	**(i)** the periodic trend in electron configurations across Periods 2 and 3 **(see also 2.2.1 d)** **(ii)** classification of elements into s-, p- and d-blocks	
(c)	first ionisation energy (removal of 1 mol of electrons from 1 mol of gaseous atoms) and successive ionisation energy, and: **(i)** explanation of the trend in first ionisation energies across Periods 2 and 3, and down a group, in terms of attraction, nuclear charge and atomic radius **(ii)** prediction from successive ionisation energies of the number of electrons in each shell of an atom and the group of an element	*M3.1* Definition required for first ionisation energy only. Explanation to include the small decreases as a result of s- and p-sub-shell energies (e.g. between Be and B) and p-orbital repulsion (e.g. between N and O). HSW1,2 Trends in ionisation energy support the Bohr model of the atom.
Periodic trend in structure and melting point		
(d)	explanation of: **(i)** metallic bonding as strong electrostatic attraction between cations (positive ions) and delocalised electrons **(ii)** a giant metallic lattice structure, e.g. all metals	No details of cubic or hexagonal packing required.
(e)	explanation of the solid giant covalent lattices of carbon (diamond, graphite and graphene) and silicon as networks of atoms bonded by strong covalent bonds	HSW1,9 Use of ideas about bonding to explain the strength and conductive properties of graphene, and its potential applications and benefits.

(f)	explanation of physical properties of giant metallic and giant covalent lattices, including melting and boiling points, solubility and electrical conductivity in terms of structure and bonding	Explanations should be in terms of the types of particle present in a lattice, the relative strength of forces and bonds, and the mobility of the particles involved, as appropriate. HSW1 Use of ideas about bonding to explain macroscopic properties.
(g)	explanation of the variation in melting points across Periods 2 and 3 in terms of structure and bonding **(see also 2.2.2 o)**.	*M3.1* Trend in structure from giant metallic to giant covalent to simple molecular lattice.

3.1.2 Group 2

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Redox reactions and reactivity of Group 2 metals		
(a)	the outer shell s^2 electron configuration and the loss of these electrons in redox reactions to form 2+ ions	
(b)	the relative reactivities of the Group 2 elements Mg → Ba shown by their redox reactions with: **(i)** oxygen **(ii)** water **(iii)** dilute acids	Reactions with acids will be limited to those producing a salt and hydrogen.
(c)	the trend in reactivity in terms of the first and second ionisation energies of Group 2 elements down the group **(see also 3.1.1 c)**	*M3.1* Definition of second ionisation energy is **not** required, but learners should be able to write an equation for the change involved.
Reactions of Group 2 compounds		
(d)	the action of water on Group 2 oxides and the approximate pH of any resulting solutions, including the trend of increasing alkalinity	
(e)	uses of some Group 2 compounds as bases, including equations, for example (but not limited to): **(i)** $Ca(OH)_2$ in agriculture to neutralise acid soils **(ii)** $Mg(OH)_2$ and $CaCO_3$ as 'antacids' in treating indigestion.	

3.1.3 The halogens

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Characteristic physical properties		
(a)	existence of halogens as diatomic molecules and explanation of the trend in the boiling points of Cl_2, Br_2 and I_2, in terms of induced dipole–dipole interactions (London forces) **(see also 2.2.2 k)**	
Redox reactions and reactivity of halogens and their compounds		
(b)	the outer shell s^2p^5 electron configuration and the gaining of one electron in many redox reactions to form 1– ions	Throughout this section, explanations of redox reactions should emphasise electron transfer and oxidation number changes and include full and ionic equations **(see also 2.1.5 Redox)**.
(c)	the trend in reactivity of the halogens Cl_2, Br_2 and I_2, illustrated by reaction with other halide ions	Including colour change in aqueous and organic solutions.
(d)	explanation of the trend in reactivity shown in **(c)**, from the decreasing ease of forming 1– ions, in terms of attraction, atomic radius and electron shielding	
(e)	explanation of the term *disproportionation* as oxidation and reduction of the same element, illustrated by: **(i)** the reaction of chlorine with water as used in water treatment **(ii)** the reaction of chlorine with cold, dilute aqueous sodium hydroxide, as used to form bleach **(iii)** reactions analogous to those specified in **(i)** and **(ii)**	
(f)	the benefits of chlorine use in water treatment (killing bacteria) contrasted with associated risks (e.g. hazards of toxic chlorine gas and possible risks from formation of chlorinated hydrocarbons)	HSW9,10,12 Decisions on whether or not to chlorinate water depend on balance of benefits and risks, and ethical considerations of people's right to choose. Consideration of other methods of purifying drinking water.
Characteristic reactions of halide ions		
(g)	the precipitation reactions, including ionic equations, of the aqueous anions Cl^-, Br^- and I^- with aqueous silver ions, followed by aqueous ammonia, and their use as a test for different halide ions.	Complexes with ammonia are **not** required other than observations. **PAG4** HSW4 Qualitative analysis.

3.1.4 Qualitative analysis

Learning outcomes	Additional guidance
Learners should be able to demonstrate and apply their knowledge and understanding of:	
Tests for ions	
(a) qualitative analysis of ions on a test-tube scale; processes and techniques needed to identify the following ions in an unknown compound:	
(i) anions: • CO_3^{2-}, by reaction with H^+(aq) forming CO_2(g) **(see 2.1.4 c)** • SO_4^{2-}, by precipitation with Ba^{2+}(aq) • Cl^-, Br^-, I^- **(see 3.1.3 g)**	Sequence of tests required is carbonate, sulfate then halide. ($BaCO_3$ and Ag_2SO_4 are both insoluble.) **PAG4** HSW4 Qualitative analysis.
(ii) cations: NH_4^+, by reaction with warm NaOH(aq) forming NH_3.	

3.2 Physical chemistry

This section introduces physical chemistry within the general theme of energy.

Learners first study the importance of enthalpy changes, their uses and determination from experimental results including enthalpy cycles.

This section then investigates the ways in which a change in conditions can affect the rate of a chemical reaction, in terms of activation energy, the Boltzmann distribution and catalysis.

Reversible reactions are then studied, including the dynamic nature of chemical equilibrium and the influence of conditions upon the position of equilibrium.

Finally, the integrated roles of enthalpy changes, rates, catalysts and equilibria are considered as a way of increasing yield and reducing energy demand, improving the sustainability of industrial processes.

3.2.1 Enthalpy changes

Learning outcomes	Additional guidance
Learners should be able to demonstrate and apply their knowledge and understanding of:	
Enthalpy changes: Δ*H* of reaction, formation, combustion and neutralisation	
(a) explanation that some chemical reactions are accompanied by enthalpy changes that are exothermic (Δ*H*, negative) or endothermic (Δ*H*, positive)	
(b) construction of enthalpy profile diagrams to show the difference in the enthalpy of reactants compared with products	*M3.1*

(c) qualitative explanation of the term *activation energy*, including use of enthalpy profile diagrams	*M3.1* Activation energy in terms of the minimum energy required for a reaction to take place.
(d) explanation and use of the terms: **(i)** *standard conditions* and *standard states* (physical states under standard conditions) **(ii)** *enthalpy change of reaction* (enthalpy change associated with a stated equation, $\Delta_r H$) **(iii)** *enthalpy change of formation* (formation of 1 mol of a compound from its elements, $\Delta_f H$) **(iv)** *enthalpy change of combustion* (complete combustion of 1 mol of a substance, $\Delta_c H$) **(v)** *enthalpy change of neutralisation* (formation of 1 mol of water from neutralisation, $\Delta_{neut} H$)	Definitions required for enthalpy changes of formation, combustion and neutralisation only. Standard conditions can be considered as 100 kPa and a stated temperature, 298 K.
(e) determination of enthalpy changes directly from appropriate experimental results, including use of the relationship: $q = mc\Delta T$	*M0.0, M0.2, M2.2, M2.3, M2.4* **PAG3**
Bond enthalpies	
(f) **(i)** explanation of the term *average bond enthalpy* (as the breaking of 1 mol of bonds in gaseous molecules) **(ii)** explanation of exothermic and endothermic reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds **(iii)** use of average bond enthalpies to calculate enthalpy changes and related quantities **(see also 2.2.2 f)**	*M0.0, M0.2, M2.2, M2.3, M2.4* Formal definition of average bond enthalpy **not** required. Learners are expected to understand that an actual bond enthalpy may differ from the average value.
Hess' law and enthalpy cycles	
(g) Hess' law for construction of enthalpy cycles and calculations to determine indirectly: **(i)** an enthalpy change of reaction from enthalpy changes of combustion **(ii)** an enthalpy change of reaction from enthalpy changes of formation **(iii)** enthalpy changes from unfamiliar enthalpy cycles	*M0.0, M0.2, M1.1, M2.2, M2.3, M2.4, M3.1* Definition of Hess' law **not** required. Unfamiliar enthalpy cycles will be provided. HSW2 Application of the principle of conservation of energy to determine enthalpy changes.
(h) the techniques and procedures used to determine enthalpy changes directly and indirectly.	*M3.1, M3.2* **PAG3** HSW4 Opportunities for carrying out experimental and investigative work.

3.2.2 Reaction rates

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Simple collision theory		
(a)	the effect of concentration, including the pressure of gases, on the rate of a reaction, in terms of frequency of collisions	
(b)	calculation of reaction rate from the gradients of graphs measuring how a physical quantity changes with time	*M3.1, M3.2, M3.5* Suitable physical quantities to monitor could include concentration, gas volume, mass, etc.
Catalysts		
(c)	explanation of the role of a catalyst: **(i)** in increasing reaction rate without being used up by the overall reaction **(ii)** in allowing a reaction to proceed via a different route with lower activation energy, as shown by enthalpy profile diagrams	Details of processes are **not** required.
(d)	**(i)** explanation of the terms *homogeneous* and *heterogeneous* catalysts	
	(ii) explanation that catalysts have great economic importance and benefits for increased sustainability by lowering temperatures and reducing energy demand from combustion of fossil fuels with resulting reduction in CO_2 emissions	HSW9,10 Benefits to the environment of improved sustainability weighed against toxicity of some catalysts.
(e)	the techniques and procedures used to investigate reaction rates including the measurement of mass, gas volumes and time	**PAG9** HSW4 Many opportunities to carry out experimental and investigative work.
The Boltzmann distribution		
(f)	qualitative explanation of the Boltzmann distribution and its relationship with activation energy **(see also 3.2.1 c)**	*M3.1*
(g)	explanation, using Boltzmann distributions, of the qualitative effect on the proportion of molecules exceeding the activation energy and hence the reaction rate, for: **(i)** temperature changes **(ii)** catalytic behaviour **(see also 3.2.2 c)**.	*M3.1* HSW1,2,5 Use of Boltzmann distribution model to explain effect on reaction rates.

3.2.3 Chemical equilibrium

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Dynamic equilibrium and le Chatelier's principle		
(a)	explanation that a dynamic equilibrium exists in a closed system when the rate of the forward reaction is equal to the rate of the reverse reaction and the concentrations of reactants and products do not change	
(b)	le Chatelier's principle and its application for homogeneous equilibria to deduce qualitatively the effect of a change in temperature, pressure or concentration on the position of equilibrium	Definition for le Chatelier's principle **not** required. HSW1,2,5 Use of le Chatelier's principle to explain effect of factors on the position of equilibrium.
(c)	explanation that a catalyst increases the rate of both forward and reverse reactions in an equilibrium by the same amount resulting in an unchanged position of equilibrium	
(d)	the techniques and procedures used to investigate changes to the position of equilibrium for changes in concentration and temperature.	Qualitative effects only. HSW4 Opportunities to carry out experimental and investigative work.
(e)	explanation of the importance to the chemical industry of a compromise between chemical equilibrium and reaction rate in deciding the operational conditions	HSW6 Balancing the effects of equilibrium, rate, safety and economics to determine the conditions used in industrial reactions e.g. Haber process.
The equilibrium constant, K_c		
(f)	expressions for the equilibrium constant, K_c, for homogeneous reactions and calculations of the equilibrium constant, K_c, from provided equilibrium concentrations	*M0.2, M1.1, M2.3, M2.4* Learners will **not** need to determine the units for K_c.
(g)	estimation of the position of equilibrium from the magnitude of K_c.	*M0.3* A qualitative estimation only is required.

Module 4: Core organic chemistry

This module introduces organic chemistry and its important applications to everyday life, including current environmental concerns associated with sustainability.

The module assumes knowledge and understanding of the chemical concepts developed in Module 2: Foundations in chemistry.

The module provides learners with a knowledge and understanding of the important chemical ideas that underpin the study of organic chemistry:

- nomenclature and formula representation, functional groups, organic reactions and isomerism
- aliphatic hydrocarbons
- alcohols and haloalkanes
- organic practical skills and organic synthesis
- instrumental analytical techniques to provide evidence of structural features in molecules.

This module also provides learners with an opportunity to develop important organic practical skills, including use of Quickfit apparatus for distillation, heating under reflux and purification of organic liquids.

In the context of this module, it is important that learners should appreciate the need to consider responsible use of organic chemicals in the environment. Current trends in this context include reducing demand for hydrocarbon fuels, processing plastic waste productively, and preventing use of ozone-depleting chemicals.

Synoptic assessment

This module provides a context for synoptic assessment and the subject content links strongly with the content encountered in Module 2: Foundations in chemistry.

- Atoms, moles and stoichiometry
- Acid and redox reactions
- Bonding and structure

Knowledge and understanding of Module 2 will be assumed and examination questions will be set that link its content with this module and other areas of chemistry.

4.1 Basic concepts and hydrocarbons

This section is fundamental to the study of organic chemistry.

This section introduces the various types of structures used routinely in organic chemistry, nomenclature, and the important concepts of homologous series, functional groups, isomerism and reaction mechanisms using curly arrows.

The initial ideas are then developed within the context of the hydrocarbons: alkanes and alkenes.

4.1.1 Basic concepts of organic chemistry

Learning outcomes | **Additional guidance**

Learners should be able to demonstrate and apply their knowledge and understanding of:

Naming and representing the formulae of organic compounds

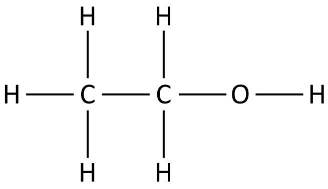
(a) application of IUPAC rules of nomenclature for systematically naming organic compounds

Nomenclature will be limited to the functional groups within this specification.
E.g. $CH_3CH_2CH(CH_3)CH_2OH$ has the systematic name: 2-methylbutan-1-ol.
Learners will be expected to know the names of the first ten members of the alkanes homologous series and their corresponding alkyl groups.

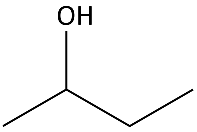
HSW8 Use of systematic nomenclature to avoid ambiguity.
HSW11 The role of IUPAC in developing a systematic framework for chemical nomenclature.

(b) interpretation and use of the terms:

- **(i)** *general formula* (the simplest algebraic formula of a member of a homologous series) e.g. for an alkane: C_nH_{2n+2}
- **(ii)** *structural formula* (the minimal detail that shows the arrangement of atoms in a molecule) e.g. for butane: $CH_3CH_2CH_2CH_3$ or $CH_3(CH_2)_2CH_3$
- **(iii)** *displayed formula* (the relative positioning of atoms and the bonds between them) e.g. for ethanol:



- **(iv)** *skeletal formula* (the simplified organic formula, shown by removing hydrogen atoms from alkyl chains, leaving just a carbon skeleton and associated functional groups) e.g. for butan-2-ol:

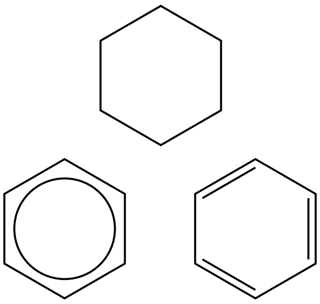


M4.2

See also **2.1.3 b** for empirical formula and molecular formula.
Definitions **not** required.

In structural formulae, the carboxyl group will be represented as COOH and the ester group as COO.

The symbols below will be used for cyclohexane and benzene:



HSW8 Communication using organic chemical structures; selecting the appropriate type of formula for the context.

Functional groups	
(c) interpretation and use of the terms: **(i)** *homologous series* (a series of organic compounds having the same functional group but with each successive member differing by CH_2) **(ii)** *functional group* (a group of atoms responsible for the characteristic reactions of a compound) **(iii)** *alkyl group* (of formula C_nH_{2n+1}) **(iv)** *aliphatic* (a compound containing carbon and hydrogen joined together in straight chains, branched chains or non-aromatic rings) **(v)** *alicyclic* (an aliphatic compound arranged in non-aromatic rings with or without side chains) **(vi)** *aromatic* (a compound containing a benzene ring) **(vii)** *saturated* (single carbon–carbon bonds only) and *unsaturated* (the presence of multiple carbon–carbon bonds, including C=C, C≡C and aromatic rings)	Definition required for homologous series only. R may be used to represent alkyl groups, but also other fragments of organic compounds not involved in reactions. The terms saturated and unsaturated will be used to indicate the presence of multiple carbon–carbon bonds as distinct from the wider term ‘degree of saturation’ used also for any multiple bonds and cyclic compounds.
(d) use of the general formula of a homologous series to predict the formula of any member of the series	
Isomerism	
(e) explanation of the term *structural isomers* (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula	*M4.2*
Reaction mechanisms	
(f) the different types of covalent bond fission: **(i)** homolytic fission (in terms of each bonding atom receiving one electron from the bonded pair, forming two radicals) **(ii)** heterolytic fission (in terms of one bonding atom receiving both electrons from the bonded pair)	

(g)	the term *radical* (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms	Radical mechanisms will be represented by a sequence of equations. Dots, •, are required in all instances where there is a single unpaired electron (e.g. $Cl\bullet$ and $CH_3\bullet$). Dots are not required for species that are diradicals (e.g. O).
(h)	a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond	'Half curly arrows' are **not** required, **see 4.1.2 f**. HSW1,8 Use of the 'curly arrow' model to demonstrate electron flow in organic reactions.
(i)	reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles.	Any relevant dipoles should be included. Curly arrows should start from a bond, a lone pair of electrons or a negative charge. HSW1,2,8 Use of reaction mechanisms to explain organic reactions.

4.1.2 Alkanes

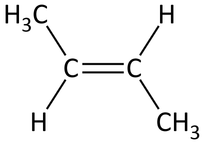
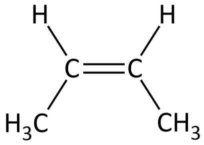
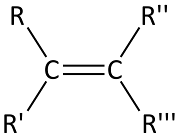
	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Properties of alkanes		
(a)	alkanes as saturated hydrocarbons containing single C–C and C–H bonds as σ-bonds (overlap of orbitals directly between the bonding atoms); free rotation of the σ-bond	Hybridisation **not** required. HSW1 Use of model of orbital overlap to explain covalent bonding in organic compounds.
(b)	explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion **(see also 2.2.2 g–h)**	*M4.1, M4.2* Learners should be able to draw 3-D diagrams.
(c)	explanation of the variations in boiling points of alkanes with different carbon-chain length and branching, in terms of induced dipole–dipole interactions (London forces) **(see also 2.2.2 k)**	*M3.1*
Reactions of alkanes		
(d)	the low reactivity of alkanes with many reagents in terms of the high bond enthalpy and very low polarity of the σ-bonds present **(see also 2.2.2 j)**	HSW1 Use of ideas about enthalpy and polarity to explain macroscopic properties of alkanes.
(e)	complete combustion of alkanes, as used in fuels, and the incomplete combustion of alkane fuels in a limited supply of oxygen with the resulting potential dangers from CO	

(f)	the reaction of alkanes with chlorine and bromine by radical substitution using ultraviolet radiation, including a mechanism involving homolytic fission and radical reactions in terms of initiation, propagation and termination **(see also 4.1.1 f–g)**	Learners are **not** required to use ‘half curly arrows’ in this mechanism. Equations should show which species are radicals using a single ‘dot’, •, to represent the unpaired electron.
(g)	the limitations of radical substitution in synthesis by the formation of a mixture of organic products, in terms of further substitution and reactions at different positions in a carbon chain.	

4.1.3 Alkenes

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Properties of alkenes		
(a)	alkenes as unsaturated hydrocarbons containing a C=C bond comprising a π-bond (sideways overlap of adjacent p-orbitals above and below the bonding C atoms) and a σ-bond (overlap of orbitals directly between the bonding atoms) **(see also 4.1.2 a)**; restricted rotation of the π-bond	Hybridisation is **not** required. HSW1 Use of the model of orbital overlap to explain covalent bonding in organic compounds.
(b)	explanation of the trigonal planar shape and bond angle around each carbon in the C=C of alkenes in terms of electron pair repulsion **(see also 2.2.2 g–h, 4.1.2 b)**	*M4.1, M4.2*

Stereoisomerism in alkenes

(c) **(i)** explanation of the terms: • *stereoisomers* (compounds with the same structural formula but with a different arrangement in space) • *E/Z isomerism* (an example of stereoisomerism, in terms of restricted rotation about a double bond and the requirement for two different groups to be attached to each carbon atom of the C=C group) • *cis–trans isomerism* (a special case of *E/Z* isomerism in which two of the substituent groups attached to each carbon atom of the C=C group are the same) **(ii)** use of Cahn–Ingold–Prelog (CIP) priority rules to identify the *E* and *Z* stereoisomers	*M4.2, M4.3*  *E*-but-2-ene *(trans)*  *Z*-but-2-ene *(cis)* Use of *E* as equivalent to *trans* and *Z* as equivalent to *cis* is only consistently correct when there is an H on each carbon atom of the C=C bond. Assigning CIP priorities to double or triple bonds within R groups is **not** required: 
(d) determination of possible *E*/*Z* or *cis–trans* stereoisomers of an organic molecule, given its structural formula	*M4.2, M4.3*

Addition reactions of alkenes

(e) the reactivity of alkenes in terms of the relatively low bond enthalpy of the π-bond	
(f) addition reactions of alkenes with: **(i)** hydrogen in the presence of a suitable catalyst, e.g. Ni, to form alkanes **(ii)** halogens to form dihaloalkanes, including the use of bromine to detect the presence of a double C=C bond as a test for unsaturation in a carbon chain **(iii)** hydrogen halides to form haloalkanes **(iv)** steam in the presence of an acid catalyst, e.g. H_3PO_4, to form alcohols	
(g) definition and use of the term *electrophile* (an electron pair acceptor)	
(h) the mechanism of electrophilic addition in alkenes by heterolytic fission **(see also 4.1.1 h–i)**	For the reaction with halogens, either a carbocation or a halonium ion intermediate is acceptable. HSW1,2,8 Use of reaction mechanisms to explain organic reactions.

(i) use of Markownikoff's rule to predict formation of a major organic product in addition reactions of H–X to unsymmetrical alkenes, e.g. H–Br to propene, in terms of the relative stabilities of carbocation intermediates in the mechanism

Limited to stabilities of primary, secondary and tertiary carbocations.
Explanation for relative stabilities of carbocations not required.

HSW1,2,5 Use of stability to explain products of organic reactions.

Polymers from alkenes

(j) addition polymerisation of alkenes and substituted alkenes, including:

- **(i)** the repeat unit of an addition polymer deduced from a given monomer
- **(ii)** identification of the monomer that would produce a given section of an addition polymer

Waste polymers and alternatives

(k) the benefits for sustainability of processing waste polymers by:

- **(i)** combustion for energy production
- **(ii)** use as an organic feedstock for the production of plastics and other organic chemicals
- **(iii)** removal of toxic waste products, e.g. removal of HCl formed during disposal by combustion of halogenated plastics (e.g. PVC)

HSW9,10 Benefits of cheap oil-derived plastics counteracted by problems for the environment of landfill; the move to re-using waste, improving the use of resources.

(l) the benefits to the environment of development of biodegradable and photodegradable polymers.

HSW9,10 Benefits of reduced dependency on finite resources and alleviating problems from disposal of persistent plastic waste.

4.2 Alcohols, haloalkanes and analysis

This section introduces two further functional groups: alcohols and haloalkanes, and considers the importance of polarity and bond enthalpy to organic reactions.

Throughout this section, there are many opportunities for developing organic practical skills, including preparation and purification of organic liquids.

Finally, the important techniques of infrared spectroscopy and mass spectrometry are used to illustrate instrumental analysis as a valuable tool for identifying organic compounds.

4.2.1 Alcohols

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Properties of alcohols		
(a)	**(i)** the polarity of alcohols and an explanation, in terms of hydrogen bonding, of the water solubility and the relatively low volatility of alcohols compared with alkanes **(see also 2.2.2 l and 4.1.2 c)**	
	(ii) classification of alcohols into primary, secondary and tertiary alcohols	
Reactions of alcohols		
(b)	combustion of alcohols	
(c)	oxidation of alcohols by an oxidising agent, e.g. $Cr_2O_7^{2-}/H^+$ (i.e. $K_2Cr_2O_7/H_2SO_4$), including: **(i)** the oxidation of primary alcohols to form aldehydes and carboxylic acids; the control of the oxidation product using different reaction conditions **(ii)** the oxidation of secondary alcohols to form ketones **(iii)** the resistance to oxidation of tertiary alcohols	Equations should use [O] to represent the oxidising agent. **PAG7**
(d)	elimination of H_2O from alcohols in the presence of an acid catalyst (e.g. H_3PO_4 or H_2SO_4) and heat to form alkenes	Mechanism **not** required.
(e)	substitution with halide ions in the presence of acid (e.g. $NaBr/H_2SO_4$) to form haloalkanes.	Mechanism **not** required.

4.2.2 Haloalkanes

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Substitution reactions of haloalkanes		
(a)	hydrolysis of haloalkanes in a substitution reaction: **(i)** by aqueous alkali **(ii)** by water in the presence of $AgNO_3$ and ethanol to compare experimentally the rates of hydrolysis of different carbon–halogen bonds	**PAG7**
(b)	definition and use of the term *nucleophile* (an electron pair donor)	
(c)	the mechanism of nucleophilic substitution in the hydrolysis of primary haloalkanes with aqueous alkali **(see also 4.1.1 h–i)**	HSW1,2 Use of reaction mechanisms to explain organic reactions.
(d)	explanation of the trend in the rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I)	
Environmental concerns from use of organohalogen compounds		
(e)	production of halogen radicals by the action of ultraviolet (UV) radiation on CFCs in the upper atmosphere and the resulting catalysed breakdown of the Earth's protective ozone layer, including equations to represent: **(i)** the production of halogen radicals **(ii)** the catalysed breakdown of ozone by $Cl\bullet$ and other radicals e.g. •NO.	Simple equations of the breakdown process are required, e.g. $CF_2Cl_2 \rightarrow CF_2Cl\bullet + \bullet Cl$ $\bullet Cl + O_3 \rightarrow \bullet ClO + O_2$ $\bullet ClO + O \rightarrow \bullet Cl + O_2$ Learners could be expected to construct similar equations for other stated radicals. HSW9,10,11,12 Benefits of CFCs; acceptance of scientific evidence explaining ozone depletion leading to government legislation against CFC use.

4.2.3 Organic synthesis

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Practical skills		
(a)	the techniques and procedures for: **(i)** use of Quickfit apparatus including for distillation and heating under reflux **(ii)** preparation and purification of an organic liquid including: • use of a separating funnel to remove an organic layer from an aqueous layer • drying with an anhydrous salt (e.g. $MgSO_4$, $CaCl_2$) • redistillation	**PAG5** HSW4 Opportunities to carry out experimental and investigative work.
Synthetic routes		
(b)	for an organic molecule containing several functional groups: **(i)** identification of individual functional groups **(ii)** prediction of properties and reactions	Learners will be expected to identify functional groups encountered in this specification: alkanes, alkenes, alcohols and haloalkanes. HSW3 Development of synthetic routes.
(c)	two-stage synthetic routes for preparing organic compounds.	Learners will be expected to be able to devise two-stage synthetic routes by applying transformations between all functional groups studied in this specification. Extra information may be provided on exam papers to extend the learner's toolkit of organic reactions. HSW3 Development of synthetic routes.

4.2.4 Analytical techniques

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Infrared spectroscopy		
(a)	infrared (IR) radiation causes covalent bonds to vibrate more and absorb energy	
(b)	absorption of infrared radiation by atmospheric gases containing C=O, O–H and C–H bonds (e.g. CO_2, H_2O and CH_4), the suspected link to global warming and resulting changes to energy usage	HSW9,10,11,12 Acceptance of scientific evidence explaining global warming has prompted governments towards policies to use renewable energy supplies.
(c)	use of an infrared spectrum of an organic compound to identify: **(i)** an alcohol from an absorption peak of the O–H bond **(ii)** an aldehyde or ketone from an absorption peak of the C=O bond **(iii)** a carboxylic acid from an absorption peak of the C=O bond and a broad absorption peak of the O–H bond	*M3.1* In examinations, infrared absorption data will be provided on the *Data Sheet*. Learners should be aware that most organic compounds produce a peak at approximately 3000 cm^{-1} due to absorption by C–H bonds.
(d)	interpretations and predictions of an infrared spectrum of familiar or unfamiliar substances using supplied data	*M3.1* Restricted to functional groups studied in this specification. HSW3,5 Analysis and interpretation of spectra.
(e)	use of infrared spectroscopy to monitor gases causing air pollution (e.g. CO and NO from car emissions) and in modern breathalysers to measure ethanol in the breath	HSW12 Use of analytical techniques to provide evidence for law courts, e.g. drink driving.
Mass spectrometry		
(f)	use of a mass spectrum of an organic compound to identify the molecular ion peak and hence to determine molecular mass	*M3.1* Limited to ions with single charges. Mass spectra limited to organic compounds containing C, H and O encountered in this specification. Learners should be aware that mass spectra may contain a small M+1 peak from the small proportion of carbon-13. HSW3,5 Analysis and interpretation of spectra.

(g) analysis of fragmentation peaks in a mass spectrum to identify parts of structures	*M3.1* Learners should be able to suggest the structures of fragment ions. HSW3,5 Analysis and interpretation of spectra.

Combined techniques

(h) deduction of the structures of organic compounds from different analytical data including: **(i)** elemental analysis **(see also 2.1.3 c)** **(ii)** mass spectra **(iii)** IR spectra.	*M3.1* Limited to functional groups encountered in this specification. Learners will **not** be expected to interpret mass spectra of organic halogen compounds. HSW3,5,6 Analysis and interpretation of different analytical data.

2d. Prior knowledge, learning and progression

This specification has been developed for learners who wish to continue with a study of chemistry at Level 3 in the National Qualifications Framework (NQF). The AS level specification has been written to provide progression from GCSE Science, GCSE Additional Science, GCSE Further Additional Science or from GCSE Chemistry. Learners who have successfully taken other Level 2 qualifications in Science or Applied Science with appropriate chemistry content may also have acquired sufficient knowledge and understanding to begin the AS Level Chemistry course.

There is no formal requirement for prior knowledge of chemistry for entry onto this qualification.

Other learners without formal qualifications may have acquired sufficient knowledge of chemistry to enable progression onto the course.

Some learners may wish to follow a chemistry course for only one year as an AS, in order to broaden their curriculum, and to develop their interest and understanding of different areas of the subject. Others may follow a co-teachable route, completing the one-year AS course and/or then moving to the two-year A level. For learners wishing to follow an apprenticeship route or those seeking direct entry into chemical science careers, this AS level provides a strong background and progression pathway.

There are a number of Science specifications at OCR. Find out more at **www.ocr.org.uk**

3 Assessment of OCR AS Level in Chemistry A

3a. Forms of assessment

Both externally assessed components (01 and 02) contain some synoptic assessment. Both components additionally contain some extended response questions; in Component 02 some of these are marked using Level of Response mark schemes.

Breadth in chemistry (Component 01)

This component is worth 70 marks and is split into two sections and assesses content from all teaching modules, 1 to 4. Learners answer all questions.

Section A contains multiple choice questions. This section of the paper is worth 20 marks.

Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 50 marks.

Depth in chemistry (Component 02)

This component assesses content from across all teaching modules, 1 to 4. Learners answer all questions. This component is worth 70 marks.

Question styles include short answer (structured questions, problem solving, calculations, practical) and extended response questions, including those marked using Level of Response mark schemes.

3b. Assessment objectives (AO)

There are three assessment objectives in OCR's AS Level in Chemistry A. These are detailed in the table below.

Learners are expected to demonstrate their ability to:

	Assessment Objective
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures.
AO2	Apply knowledge and understanding of scientific ideas, processes, techniques and procedures: • in a theoretical context • in a practical context • when handling qualitative data • when handling quantitative data.
AO3	Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to: • make judgements and reach conclusions • develop and refine practical design and procedures.

AO weightings in AS Level in Chemistry A

The relationship between the assessment objectives and the components are shown in the following table:

Component	**% of AS Level in Chemistry A (H032)**		
	AO1	**AO2**	**AO3**
Breadth in chemistry (H032/01)	22–24	19–21	6–9
Depth in chemistry (H032/02)	13–16	21–24	14–15
Total	**35–40**	**40–45**	**20–24**

3c. Total qualification time

Total qualification time (TQT) is the total amount of time, in hours, expected to be spent by a learner to achieve a qualification. It includes both guided learning hours and hours spent in preparation, study, and assessment. The total qualification time for AS Level in Chemistry A is 180 hours. The total guided learning time is 180 hours.

3d. Assessment availability

There will be one examination series available each year in May/June to **all** learners. All examined components must be taken in the same examination series at the end of the course.

This specification will be certificated from the June 2016 examination series onwards.

3e. Retaking the qualification

Learners can retake the qualification as many times as they wish. They retake all components of the qualification.

3f. Assessment of extended responses

The assessment materials for this qualification provide learners with the opportunity to demonstrate their ability to construct and develop a sustained and coherent line of reasoning and marks for extended responses are integrated into the marking criteria. Extended response questions are included in both externally assessed components. This includes two questions in Component 02, which will be assessed using questions marked by Level of Response, in which the quality of the extended response is explicitly rewarded. These questions will be clearly identified in the assessment papers.

3g. Synoptic assessment

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

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the AS level course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. Both components within Chemistry A contain an element of synoptic assessment.

Synoptic assessment requires learners to make and use connections within and between different areas of chemistry, for example, by:

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

3h. Calculating qualification results

A learner's overall qualification grade for AS Level in Chemistry A will be calculated by adding together their marks from the two components taken to give their total weighted mark.

This mark will then be compared to the qualification level grade boundaries for the relevant exam series to determine the learner's overall qualification grade.

4 Admin: what you need to know

The information in this section is designed to give an overview of the processes involved in administering this qualification so that you can speak to your exams officer. All of the following processes require you to submit something to OCR by a specific deadline.

More information about the processes and deadlines involved at each stage of the assessment cycle can be found in the Administration area of the OCR website.

OCR's Admin overview is available on the OCR website at **http://www.ocr.org.uk/administration**.

4a. Pre-assessment

Estimated entries

Estimated entries are your best projection of the number of learners who will be entered for a qualification in a particular series.

Estimated entries should be submitted to OCR by the specified deadline. They are free and do not commit your centre in any way.

Final entries

Final entries provide OCR with detailed data for each learner, showing each assessment to be taken. It is essential that you use the correct entry code, considering the relevant entry rules.

Final entries must be submitted to OCR by the published deadlines or late entry fees will apply.

All learners taking AS Level in Chemistry A must be entered using the entry code H032.

Entry option		Components		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
H032	Chemistry A	01	Breadth in chemistry	External assessment
		02	Depth in chemistry	External assessment

Private candidates

Private candidates may enter for OCR assessments.

A private candidate is someone who pursues a course of study independently but takes an examination or assessment at an approved examination centre. A private candidate may be a part-time student, someone taking a distance learning course, or someone being tutored privately. They must be based in the UK.

Private candidates need to contact OCR approved centres to establish whether they are prepared to host them as a private candidate. The centre may charge for this facility and OCR recommends that the arrangement is made early in the course.

Further guidance for private candidates may be found on the OCR website: **http://www.ocr.org.uk**

Head of Centre Annual Declaration

The Head of Centre is required to provide a declaration to the JCQ as part of the annual NCN update, conducted in the autumn term, to confirm that all learners at the centre have had the opportunity to undertake the prescribed practical activities.

Any failure by a centre to provide the Head of Centre Annual Declaration will result in your centre status being suspended and could lead to the withdrawal of our approval for you to operate as a centre.

4b. Accessibility and special consideration

Reasonable adjustments and access arrangements allow learners with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do, without changing the demands of the assessment. Applications for these should be made before the examination series. Detailed information about eligibility for access arrangements can be found in the JCQ *Access Arrangements and Reasonable Adjustments.*

Special consideration is a post-assessment adjustment to marks or grades to reflect temporary injury, illness or other indisposition at the time the assessment was taken.

Detailed information about eligibility for special consideration can be found in the JCQ *A guide to the special consideration process.*

4c. External assessment arrangements

Regulations governing examination arrangements are contained in the JCQ *Instructions for conducting examinations*.

Learners are permitted to use a scientific or graphical calculator for both components. Calculators are subject to the rules in the document *Instructions for Conducting Examinations* published annually by JCQ (**www.jcq.org.uk**).

4d. Results and certificates

Grade scale

Advanced Subsidiary qualifications are graded on the scale: A, B, C, D, E, where A is the highest. Learners who fail to reach the minimum standard for E will be Unclassified (U). Only subjects in which grades A to E are attained will be recorded on certificates.

Results

Results are released to centres and learners for information and to allow any queries to be resolved **before** certificates are issued.

Centres will have access to the following results information for each learner:

- the grade for the qualification
- the raw mark for each component
- the total weighted mark for the qualification.

The following supporting information will be available:

- raw mark grade boundaries for each component
- weighted mark grade boundaries for the qualification.

Until certificates are issued, results are deemed to be provisional and may be subject to amendment. A learner's final results will be recorded on an OCR certificate.

The qualification title will be shown on the certificate as 'OCR Level 3 Advanced Subsidiary GCE in Chemistry A'.

4e. Post-results services

A number of post-results services are available:

- **Review of results** – If you are not happy with the outcome of a learner's results, centres may request a review of marking.
- **Missing and incomplete results** – This service should be used if an individual subject result for a learner is missing, or the learner has been omitted entirely from the results supplied.
- **Access to scripts** – Centres can request access to marked scripts.

4f. Malpractice

Any breach of the regulations for the conduct of examinations and coursework may constitute malpractice (which includes maladministration) and must be reported to OCR as soon as it is detected.

Detailed information on malpractice can be found in the *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* published by JCQ.

5 Appendices

5a. Overlap with other qualifications

There is a small degree of overlap between the content of this specification and those for other AS level/A level Sciences.

Examples of overlap include:

Biology

- Amino acids, proteins, chromatography, buffers, pH, catalysis.

Geology

- The atmosphere.

Physics

- Atomic structure.

Science

- Atomic structure.
- The atmosphere, the development of renewable alternatives to finite energy resources, enthalpy changes, rates of reaction, catalysis.
- Amino acids, proteins, infrared spectroscopy, chromatography.

5b. Avoidance of bias

The AS level qualification and subject criteria have been reviewed in order to identify any feature which could disadvantage learners who share a protected Characteristic as defined by the Equality Act 2010. All reasonable steps have been taken to minimise any such disadvantage.

5c. Chemistry A data sheet

Data Sheet for Chemistry A

GCE Advanced Subsidiary and Advanced Level

Chemistry A (H032 / H432)

The information in this sheet is for the use of candidates following Chemistry A (H032 / H432).

General Information

Molar gas volume = 24.0 $dm^3\ mol^{-1}$ at room temperature and pressure, RTP

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

Specific heat capacity of water, $c = 4.18\ J\ g^{-1}\ K^{-1}$

Ionic product of water, $K_w = 1.00 \times 10^{-14}\ mol^2\ dm^{-6}$ at 298 K

1 tonne = 10^6 g

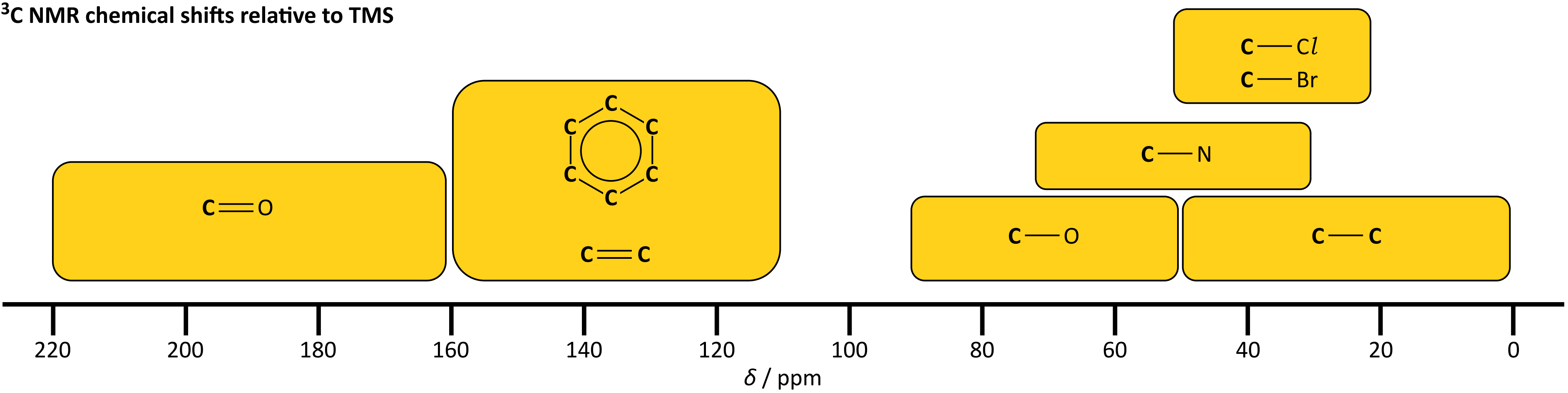
Arrhenius equation: $k = Ae^{-Ea/RT}$ or $\ln k = -E_a/RT + \ln A$

Gas constant, $R = 8.314\ J\ mol^{-1}\ K^{-1}$

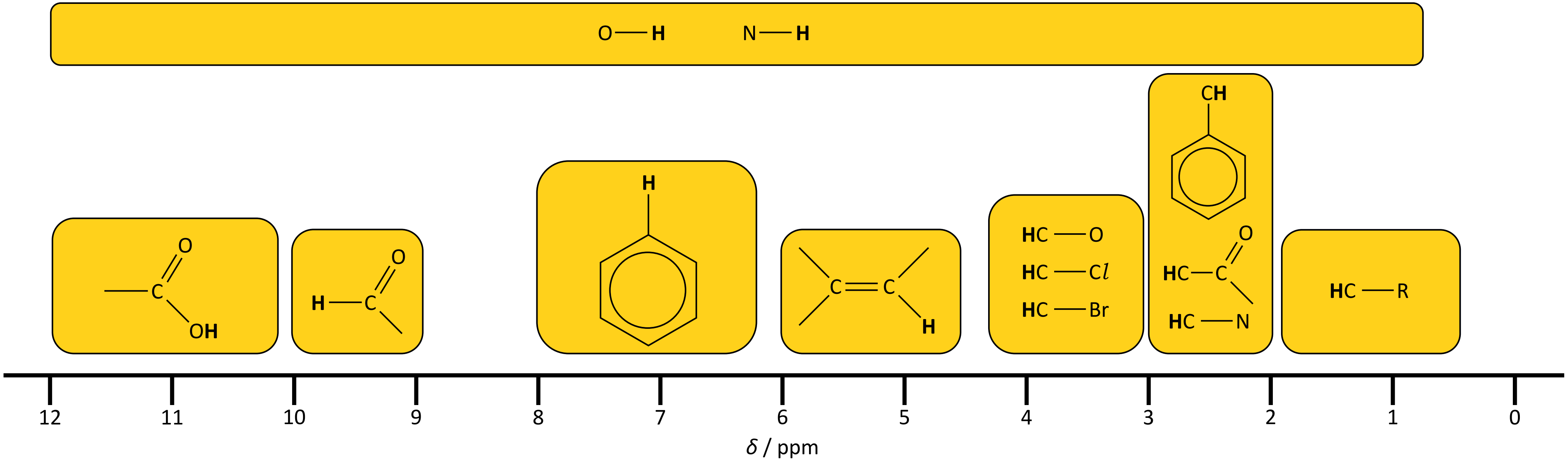
Characteristic infrared absorptions in organic molecules

Bond	Location	Wavenumber / cm^{-1}
C–C	Alkanes, alkyl chains	750–1100
C–X	Haloalkanes (X = C*l*, Br, I)	500–800
C–F	Fluoroalkanes	1000–1350
C–O	Alcohols, esters, carboxylic acids	1000–1300
C=C	Alkenes	1620–1680
C=O	Aldehydes, ketones, carboxylic acids, esters, amides, acyl chlorides and acid anhydrides	1630–1820
aromatic C=C	Arenes	Several peaks in range 1450–1650 (variable)
C≡N	Nitriles	2220–2260
C–H	Alkyl groups, alkenes, arenes	2850–3100
O–H	Carboxylic acids	2500–3300 (broad)
N–H	Amines, amides	3300–3500
O–H	Alcohols, phenols	3200–3600

^{13}C NMR chemical shifts relative to TMS



^{1}H NMR chemical shifts relative to TMS



Chemical shifts are variable and can vary depending on the solvent, concentration and substituents. As a result, shifts may be outside the ranges indicated above.

O**H** and N**H** chemical shifts are very variable and are often broad. Signals are not usually seen as split peaks.
Note that C**H** bonded to ‘shifting groups’ on either side, e.g. O–CH_2–C=O, may be shifted more than indicated above.

The Periodic Table of the Elements

Key
atomic number
Symbol
name
relative atomic mass

(1) 1	(2) 2	3	4	5	6	7	8	9	10	11	12	(3) 13	(4) 14	(5) 15	(6) 16	(7) 17	(0) 18
1 **H** hydrogen 1.0																	2 **He** helium 4.0
3 **Li** lithium 6.9	4 **Be** beryllium 9.0											5 **B** boron 10.8	6 **C** carbon 12.0	7 **N** nitrogen 14.0	8 **O** oxygen 16.0	9 **F** fluorine 19.0	10 **Ne** neon 20.2
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3											13 **Al** aluminium 27.0	14 **Si** silicon 28.1	15 **P** phosphorus 31.0	16 **S** sulfur 32.1	17 **Cl** chlorine 35.5	18 **Ar** argon 39.9
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	24 **Cr** chromium 52.0	25 **Mn** manganese 54.9	26 **Fe** iron 55.8	27 **Co** cobalt 58.9	28 **Ni** nickel 58.7	29 **Cu** copper 63.5	30 **Zn** zinc 65.4	31 **Ga** gallium 69.7	32 **Ge** germanium 72.6	33 **As** arsenic 74.9	34 **Se** selenium 79.0	35 **Br** bromine 79.9	36 **Kr** krypton 83.8
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	42 **Mo** molybdenum 95.9	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 144.9	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.2	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium	92 **U** uranium 238.1	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

5d. How Science Works (HSW)

How Science Works was conceived as being a wider view of science in context, rather than just straightforward scientific enquiry. It was intended to develop learners as critical and creative thinkers, able to solve problems in a variety of contexts.

Developing ideas and theories to explain the operation of matter and how its composition, structure, properties and changes it undergoes, constitutes the basis of life and all nature. *How Science Works* develops the critical analysis and linking of evidence to support or refute ideas and theories. Learners should be aware of the importance that peer review and repeatability have in giving confidence to this evidence.

Learners are expected to understand the variety of sources of data available for critical analysis to provide evidence and the uncertainty involved in its measurement. They should also be able to link that evidence to contexts influenced by culture, politics and ethics.

Understanding *How Science Works* requires an understanding of how scientific evidence can influence ideas and decisions for individuals and society, which is linked to the necessary skills of communication for audience and for purpose with appropriate scientific technology.

Incorporating Section 8 (the skills, knowledge and understanding of *How Science Works*) of the DfE criteria for science into the specification.

The examples given within the specification are not exhaustive but give a flavour of opportunities for integrating HSW within the course.

References in this specification to *How Science Works* (HSW) are to the following statements:

- **HSW1** Use theories, models and ideas to develop scientific explanations
- **HSW2** Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas
- **HSW3** Use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems
- **HSW4** Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts
- **HSW5** Analyse and interpret data to provide evidence, recognising correlations and causal relationships
- **HSW6** Evaluate methodology, evidence and data, and resolve conflicting evidence
- **HSW7** Know that scientific knowledge and understanding develops over time
- **HSW8** Communicate information and ideas in appropriate ways using appropriate terminology
- **HSW9** Consider applications and implications of science and evaluate their associated benefits and risks
- **HSW10** Consider ethical issues in the treatment of humans, other organisms and the environment
- **HSW11** Evaluate the role of the scientific community in validating new knowledge and ensuring integrity
- **HSW12** Evaluate the ways in which society uses science to inform decision making.

5e. Mathematical requirements

In order to be able to develop their skills, knowledge and understanding in AS Level Chemistry, learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

The assessment of quantitative skills will include at least 20% Level 2 (or above) mathematical skills for chemistry (see later for a definition of 'Level 2' mathematics). These skills will be applied in the context of the relevant chemistry.

All mathematical content will be assessed within the lifetime of the specification.

This list of examples is not exhaustive and is not limited to Level 2 examples. These skills could be developed in other areas of specification content from those indicated. For the mathematical requirements for the A Level in Chemistry A see the A level specification.

Additional guidance on the assessment of mathematics within chemistry is available on the OCR website.

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of AS Level Chemistry (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M0 – Arithmetic and numerical computation			
M0.0	Recognise and make use of appropriate units in calculations	Learners may be tested on their ability to: • convert between units e.g. cm^3 to dm^3 as part of volumetric calculations • understand that different units are used in similar topic areas, so that conversions may be necessary e.g. J and kJ.	1.1.2(b), 2.1.3(a,e,f), 3.2.1(e,f,g)
M0.1	Recognise and use expressions in decimal and ordinary form	Learners may be tested on their ability to: • use an appropriate number of decimal places in calculations • carry out calculations using numbers in standard and ordinary form e.g. use of the Avogadro constant • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form e.g. 0.0050 mol dm^{-3} is equivalent to 5.0×10^{-3} mol dm^{-3}.	2.1.3(a,e,f)

	Mathematical skill to be assessed	**Exemplification of the mathematical skill in the context of AS Level Chemistry (assessment is not limited to the examples below)**	**Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)**
M0.2	Use ratios, fractions and percentages	Learners may be tested on their ability to: • calculate percentage yields • calculate the atom economy of a reaction • construct and/or balance equations using ratios.	2.1.1(d), 2.1.2(b), 2.1.3(c,d,g,h), 3.2.3(f)
M0.3	Estimate results	Learners may be tested on their ability to: • estimate the position of equilibrium from the position of K_c.	3.2.3(g)
M0.4	Use calculators to find and use power functions	Learners may be tested on their ability to: • carry out calculations using the Avogadro constant.	2.1.3(a,e,f)
M1 – Handling data			
M1.1	Use an appropriate number of significant figures	Learners 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.	1.1.3(c), 2.1.3(e,f), 2.1.4(e), 3.2.1(g), 3.2.3(f)
M1.2	Find arithmetic means	Learners may be tested on their ability to: • calculate weighted means, e.g. calculation of an atomic mass based on supplied isotopic abundances • select appropriate titration data (i.e. identification of outliers) in order to calculate mean titres.	2.1.1(d), 2.1.4(e)
M1.3	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Learners may be tested on their ability to: • determine uncertainty when two burette readings are used to calculate a titre value.	1.1.4(d)
M2 – Algebra			
M2.1	Understand and use the symbols: =, <, <<, >>, >, ∝, ~, ⇌	No exemplification required.	

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of AS Level Chemistry (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M2.2	Change the subject of an equation	Learners may be tested on their ability to: • carry out structured and unstructured mole calculations.	2.1.3(c,d,e,f), 2.1.4(e), 3.2.1(e,f,g)
M2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Learners may be tested on their ability to: • carry out enthalpy change calculations • calculate the value of an equilibrium constant, K_c.	2.1.3(c,d,e,f), 2.1.4(e), 3.2.1(e,f,g), 3.2.3(f)
M2.4	Solve algebraic equations	Learners may be tested on their ability to: • carry out Hess' law calculations.	2.1.3(c,d,e,f), 2.1.4(e), 3.2.1(e,f,g), 3.2.3(f)
M3 – Graphs			
M3.1	Translate information between graphical, numerical and algebraic forms	Learners may be tested on their ability to: • interpret and analyse spectra.	2.1.1(d), 3.1.1(c,g), 3.2.1(b,c,g), 3.2.2(b,f,g), 4.2.4(c,d,f,g)
M3.2	Plot two variables from experimental or other data	Learners may be tested on their ability to: • plot concentration–time graphs from collected or supplied data • draw lines of best fit • extrapolate and interpolate.	1.1.3(d), 3.2.1(h), 3.2.2(b)
M3.5	Draw and use the slope of a tangent to a curve as a measure of rate of change	Learners may be tested on their ability to: • calculate the rate of a reaction from the gradient of a concentration–time graph for a first or second order reaction.	1.1.3(d), 3.2.2(b)
M4 – Geometry and trigonometry			
M4.1	Use angles and shapes in regular 2-D and 3-D structures	Learners may be tested on their ability to: • predict/identify shapes of and bond angles in molecules with and without a lone pair(s), for example NH_3, CH_4, H_2O etc.	2.2.2(g), 4.1.2(b)
M4.2	Visualise and represent 2-D and 3-D forms including 2-D representations of 3-D objects	Learners may be tested on their ability to: • draw different forms of isomers.	2.2.2(g), 4.1.1(b,e), 4.1.2(b), 4.1.3(c,d)
M4.3	Understand the symmetry of 2-D and 3-D shapes	Learners may be tested on their ability to: • describe the types of stereoisomerism shown by molecules/complexes.	4.1.3(c,d)

Definition of Level 2 mathematics

Within AS Level Chemistry, 20% of the marks available within written examinations will be for assessment of mathematics (in the context of chemistry) at a Level 2 standard, or higher. Lower level mathematical skills will still be assessed within examination papers but will not count within the 20% weighting for chemistry.

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

- application and understanding requiring choice of data or equation to be used
- problem solving involving use of mathematics from different areas of maths and decisions about direction to proceed
- questions involving use of A level mathematical content (as of 2012), e.g. use of logarithmic equations.

The following will not be counted as Level 2 mathematics:

- simple substitution with little choice of equation or data
- structured question formats using GCSE mathematics (based on 2012 GCSE mathematics content).

Additional guidance on the assessment of mathematics within chemistry is available on the OCR website as a separate resource, the Maths Skills Handbook.

5f. Health and Safety

In UK law, health and safety is primarily the responsibility of the employer. In a school or college the employer could be a local education authority, the governing body or board of trustees. Employees (teachers/lecturers, technicians etc), have a legal duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must carry out a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at **http://www.ase.org.uk/resources/health-and-safety-resources/risk-assessments/**

For members, the CLEAPSS® guide, *PS90, Making and recording risk assessments in school science*[1] offers appropriate advice.

Most education employers have adopted nationally available publications as the basis for their Model Risk Assessments.

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

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

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

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[1] These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications website **www.cleapss.org.uk**. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to **www.cleapss.org.uk**.

Summary of updates

Date	Version	Section	Title of Section	Change
May 2018	1.1	Front cover	Disclaimer	Addition of Disclaimer
January 2019	1.2	2c	Content of modules 1 to 4	Guidance on the new definition of moles **2.1.3 (a)** Update to average bond enthalpy guidance **3.2.1 (f)**
April 2020	1.3	1d 4e	How do I find out more information? Post-results services	Insert of Online Support Centre link Enquiries about results changed to Review of results
				Update to specification covers to meet digital accessibility standards
April 2023	1.4	3c	Total qualification time	Update to include total qualification time and guided learning hours to comply with QiW regulations

YOUR CHECKLIST

Our aim is to provide you with all the information and support you need to deliver our specifications.

- ☐ Bookmark OCR website for all the latest resources, information and news on AS and A Level Chemistry A
- ☐ Be among the first to hear about support materials and resources as they become available – register for Chemistry updates
- ☐ Find out about our professional development
- ☐ View our range of skills guides for use across subjects and qualifications
- ☐ Discover our new online past paper service
- ☐ Learn more about Active Results
- ☐ Visit our Online Support Centre

Download high-quality, exciting and innovative AS and A Level Chemistry resources from ocr.org.uk/alevelchemistrya

Free resources and support for our AS Level Chemistry qualification, developed through collaboration between our Chemistry Subject Advisors, teachers and other subject experts, are available from our website. You can also contact our Chemistry Subject Advisors for specialist advice, guidance and support, giving you individual service and assistance whenever you need it.

Contact the team at:

01223 553998

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