Accredited

A LEVEL
Specification

CHEMISTRY A

H432
For first assessment in 2017

ocr.org.uk/alevelchemistrya



OCR
Oxford Cambridge and RSA

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Introducing…
A Level Chemistry A (from September 2015)

This specification allows teachers to adopt a flexible approach to the delivery of A Level Chemistry. The course has been designed to enable centres to deliver the content modules (Modules 2–6) 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 and through the Practical Endorsement.

The specification is divided into chemical topics, each containing different key concepts of chemistry. Certain topics are split over modules, to facilitate co-teaching of the AS Level qualification in Chemistry A with the first year of A Level. Centres that are not co-teaching this course with the AS Level may elect to teach these topics sequentially.

Throughout the specification, cross-references indicate the relevance of individual learning outcomes to the mathematical and practical criteria that are embedded in the assessments.

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

Meet the team

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

Find out more about our Chemistry team at **ocr.org.uk/scienceteam**

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

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

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

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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 A 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 A Level email updates at **ocr.org.uk/updates**.

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1 Why choose an OCR A 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 A 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 A level qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's A Level in Chemistry A is QN: 601/5255/2.

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

1

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 A Level in Chemistry A builds on our existing popular course. We've based the redevelopment of our A 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 A 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)).

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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 (H036)
- 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 AS level
- embeds practical requirements within the teaching modules
- identifies Practical Endorsement requirements and how these can be integrated into teaching of content (see Section 5)
- exemplifies the mathematical requirements of the course (see Section 5)
- highlights opportunities for the introduction of key mathematical requirements (see Section 5d 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
- a consultancy service (to advise on Practical Endorsement requirements)
- Practical Skills Handbook
- Maths Skills Handbook.

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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.

Join our Science community: **http://social.ocr.org.uk/**

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

Follow us on Twitter: **@ocr_science**

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2 The specification overview

2a. Overview of A Level in Chemistry A (H432)

Learners must complete all components (01, 02, 03 and 04).

Content Overview	Assessment Overview	
Content is split into six 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 • Module 5 – Physical chemistry and transition elements • Module 6 – Organic chemistry and analysis Component 01 assesses content from modules 1, 2, 3 and 5. Component 02 assesses content from modules 1, 2, 4 and 6. Component 03 assesses content from all modules (1 to 6).	Periodic table, elements and physical chemistry (01) 100 marks 2 hours 15 minutes written paper	**37%** of total A level
	Synthesis and analytical techniques (02) 100 marks 2 hours 15 minutes written paper	**37%** of total A level
	Unified chemistry (03) 70 marks 1 hour 30 minutes written paper	**26%** of total A level
	Practical Endorsement in chemistry (04) (non exam assessment)	Reported separately (see Section 5)

All components include synoptic assessment.

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2b. Content of A Level in Chemistry A (H432)

The A Level in Chemistry A specification content is divided into six 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 examinations (with the exception of some of the skills in module **1.2** which will be assessed directly through the Practical Endorsement). 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 A Level Chemistry to examples of chemistry content where those mathematical skills could be linked to learning.

The specification has been designed to be co-teachable with the standalone AS Level in Chemistry A qualification. The first four modules comprise the AS Level in Chemistry A course and learners studying the A Level continue with the content of modules 5 and 6. The internally assessed Practical Endorsement skills also form part of the full A level (see Module 1.2).

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

Module 1 – Development of practical skills in chemistry

- Practical skills assessed in a written examination
- Practical skills assessed in the practical endorsement

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)

Module 5 – Physical chemistry and transition elements

- Reaction rates and equilibrium (quantitative)
- pH and buffers
- Enthalpy, entropy and free energy
- Redox and electrode potentials
- Transition elements

Module 6 – Organic chemistry and analysis

- Aromatic compounds
- Carbonyl compounds
- Carboxylic acids and esters
- Nitrogen compounds
- Polymers
- Organic synthesis
- Chromatography and spectroscopy (NMR)

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Assessment of practical skills and the Practical Endorsement

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 and also through the Practical Endorsement (see Section 5).

Practical activities are embedded within the learning outcomes of the course to encourage practical activities in the classroom which contribute to the achievement of the Practical Endorsement (Section 5) as well as enhancing learners' understanding of chemical theory and practical skills.

Opportunities for carrying out activities that could count towards the Practical Endorsement are indicated throughout the specification. These are shown in the Additional guidance column as **PAG1** to **PAG11** (Practical Activity Group, see Section 5). There are a wide variety of opportunities to assess **PAG12** throughout the specification.

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2c. Content of modules 1 to 6

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.

2

1.1 Practical skills assessed in a written examination

Practical skills are embedded throughout all the content of 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 and the skills required for the Practical Endorsement. HSW4
(b)	appropriate units for measurements	*M0.0*
(c)	presenting observations and data in an appropriate format.	HSW8

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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: **(i)** selection and labelling of axes with appropriate scales, quantities and units **(ii)** measurement of gradients and intercepts.	*M3.2, 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

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1.2 Practical skills assessed in the practical endorsement

A range of practical experiences is a vital part of a learner's development as part of this course.

Learners should develop and practise a wide range of practical skills throughout the course as preparation for the Practical Endorsement, as well as for the written examinations.

The experiments and skills required for the Practical Endorsement will allow learners to develop and practise their practical skills, preparing learners for the written examinations.

Please refer to Section 5 (the Practical Endorsement) of this specification to see the list of practical experiences all learners should cover during the course. Further advice and guidance on the Practical Endorsement can be found in the Practical Skills Handbook support booklet.

2

1.2.1 Practical skills

	Learning outcomes	Additional guidance
	Practical work carried out throughout the course will enable learners to develop the following skills:	
	Independent thinking	
(a)	apply investigative approaches and methods to practical work	Including how to solve problems in a practical context. HSW3
	Use and application of scientific methods and practices	
(b)	safely and correctly use a range of practical equipment and materials	See Section 5. Including identification of potential hazards. Learners should understand how to minimise the risks involved. HSW4
(c)	follow written instructions	
(d)	make and record observations/measurements	HSW8
(e)	keep appropriate records of experimental activities	See Section 5.
(f)	present information and data in a scientific way	
(g)	use appropriate software and tools to process data, carry out research and report findings	*M3.1* HSW3
	Research and referencing	
(h)	use online and offline research skills including websites, textbooks and other printed scientific sources of information	
(i)	correctly cite sources of information	The Practical Skills Handbook provides guidance on appropriate methods for citing information.

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Instruments and equipment

(j)	use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.	See Section 5. HSW4

1.2.2 Use of apparatus and techniques

	Learning outcomes	Additional guidance
	*Through use of the apparatus and techniques listed below, and a minimum of 12 assessed practicals (see Section 5), learners should be able to demonstrate all of the practical skills listed within 1.2.1 and CPAC (Section 5, **Table 2**) as exemplified through:*	
(a)	use of appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)	HSW4
(b)	use of a water bath or electric heater or sand bath for heating	HSW4
(c)	measurement of pH using pH charts, or pH meter, or pH probe on a data logger	HSW4
(d)	use of laboratory apparatus for a variety of experimental techniques including: **(i)** titration, using burette and pipette **(ii)** distillation and heating under reflux, including setting up glassware using retort stand and clamps **(iii)** qualitative tests for ions and organic functional groups **(iv)** filtration, including use of fluted filter paper, or filtration under reduced pressure	HSW4
(e)	use of a volumetric flask, including accurate technique for making up a standard solution	HSW4
(f)	use of acid–base indicators in titrations of weak/strong acids with weak/strong alkalis	HSW4
(g)	purification of: **(i)** a solid product by recrystallisation **(ii)** a liquid product, including use of a separating funnel	HSW4
(h)	use of melting point apparatus	HSW4
(i)	use of thin layer or paper chromatography	HSW4

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(j)	setting up of electrochemical cells and measuring voltages	HSW4
(k)	safely and carefully handling solids and liquids, including corrosive, irritant, flammable and toxic substances	HSW4
(l)	measurement of rates of reaction by at least two different methods, for example: **(i)** an initial rate method such as a clock reaction **(ii)** a continuous monitoring method.	HSW4

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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 A Level 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.

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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*

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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, 6.02×10^{23} mol^{-1}) **(iv)** *molar mass* (mass per mole, units g mol^{-1}), **(v)** *molar gas volume* (gas volume per mole, units 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 NaCl; amount of O_2. 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 **(see also 6.3.2 e)**.
(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 mol dm^{-3} and 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*

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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 (HC*l*, 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*

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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*

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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

2.2.1 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: $1s^2 2s^2 2p^4$.

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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. Na*Cl*	
(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°).

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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.	

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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.

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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.

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(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.	

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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 (see also 3.1.4 a)** HSW4 Qualitative analysis.

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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 learn about 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: ΔH of reaction, formation, combustion and neutralisation	
(a)	explanation that some chemical reactions are accompanied by enthalpy changes that are exothermic (ΔH, negative) or endothermic (ΔH, positive)	
(b)	construction of enthalpy profile diagrams to show the difference in the enthalpy of reactants compared with products	*M3.1*

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(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* (breaking of 1 mol of bonds in gaseous molecules)	*M0.0, M0.2, M2.2, M2.3, M2.4* Definition of average bond enthalpy **not** required.
(ii)	explanation of exothermic and endothermic reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds	Learners are expected to understand that an actual bond enthalpy may differ from the average value.
(iii)	use of average bond enthalpies to calculate enthalpy changes and related quantities **(see also 2.2.2 f)**	
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 To include the enthalpy changes covered in **5.2.1 c**. **PAG3** HSW4 Opportunities for carrying out experimental and investigative work.

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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.

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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.

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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.

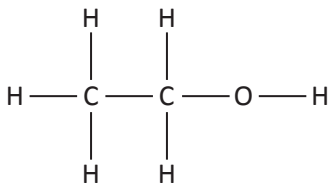
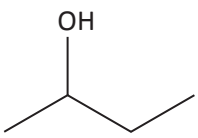
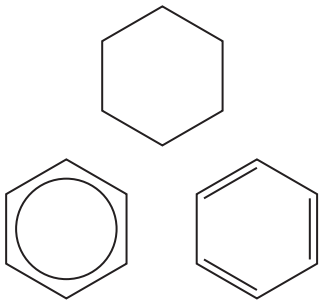
4.1 Basic concepts and hydrocarbons

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.

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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)

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(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• and CH_3•). 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.

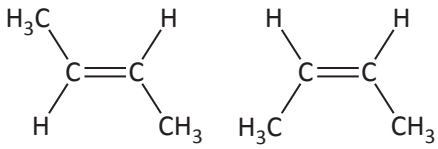
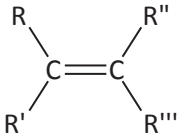
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4.1.2 Alkanes

	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.	

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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 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)	*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.
(ii)	use of Cahn–Ingold–Prelog (CIP) priority rules to identify the *E* and *Z* stereoisomers	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*

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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

PAG7 (see also 6.3.1 c)

(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

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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 HC*l* formed during disposal by combustion of halogenated plastics (e.g. PVC)	HSW9,10 Benefits of cheap oil-derived plastics counteracted by problems for environment of landfill; the move to re-using waste, improving 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	

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(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:	Equations should use [O] to represent the oxidising agent.
	(i) the oxidation of primary alcohols to form aldehydes and carboxylic acids; the control of the oxidation product using different reaction conditions	**PAG7 (see also 6.3.1 c)**
	(ii) the oxidation of secondary alcohols to form ketones	
	(iii) the resistance to oxidation of tertiary alcohols	
(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:	**PAG7 (see also 6.3.1 c)**
	(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	
(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–C*l*, C–Br and C–I)	

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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 the functional groups encountered in Module 4. 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 encountered up to this point of the specification. Extra information may be provided on exam papers to extend the learner's toolkit of organic reactions. HSW3 Development of synthetic routes.

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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. H_2O, CO_2 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:	*M3.1*
	(i) an alcohol from an absorption peak of the O–H bond	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.
	(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	
(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 **(see also 6.3.2 e)**. 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. Learners will **not** be expected to interpret mass spectra of organic halogen compounds. Limited to organic compounds encountered in this specification **(see also 6.3.2 e)**. 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.

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(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 2.1.3c)** **(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.

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Module 5: Physical chemistry and transition elements

The content within this module assumes knowledge and understanding of the chemical concepts developed in Module 2: Foundations in chemistry and Module 3: Periodic table and energy.

This module extends the study of energy, reaction rates and equilibria, and the periodic table.

The main areas of physical chemistry studied include:

- rate equations, orders of reaction, the rate-determining step
- equilibrium constants, K_c and K_p
- acid–base equilibria including pH, K_a and buffer solutions
- lattice enthalpy and Born–Haber cycles
- entropy and free energy
- electrochemical cells.

The main areas of inorganic chemistry studied include:

- redox chemistry
- transition elements.

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 and Module 3: Periodic table and energy.

- Atoms, moles and stoichiometry
- Acid and redox reactions
- Bonding and structure
- Periodicity, Group 2 and the halogens
- Enthalpy changes
- Reaction rates
- Chemical equilibrium

Knowledge and understanding of Module 2 and Module 3 will be assumed and examination questions will be set that link their content with this module and other areas of chemistry.

5.1 Rates, equilibrium and pH

The largely qualitative treatment of reaction rates and equilibria encountered in Module 3 is developed within a quantitative and graphical context.

This section also allows learners to develop practical quantitative techniques involved in the determination of reaction rates and pH.

There are many opportunities for developing mathematical skills, including use of logarithms and exponents, when studying the content of this section and when carrying out quantitative practical work.

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5.1.1 How fast?

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Orders, rate equations and rate constants	
(a)	explanation and use of the terms: *rate of reaction*, *order*, *overall order, rate constant*, *half-life*, *rate-determining step*	
(b)	deduction of:	*M0.2*
	(i) orders from experimental data	Learners are expected to interpret initial rates data to determine orders with respect to reactants. Integrated forms of rate equations are **not** required.
	(ii) a rate equation from orders of the form: rate = $k[A]^m[B]^n$, where m and n are 0, 1 or 2	**PAG10** HSW8 Use of rate equations.
(c)	calculation of the rate constant, k, and related quantities, from a rate equation including determination of units	*M0.0, M0.1, M0.4, M1.1, M2.2, M2.3, M2.4*
	Rate graphs and orders	
(d)	from a concentration–time graph:	*M0.1, M0.4, M1.1, M3.1, M3.2, M3.3, M3.4, M3.5*
	(i) deduction of the order (0 or 1) with respect to a reactant from the shape of the graph	Concentration–time graphs can be plotted from continuous measurements taken during the course of a reaction (continuous monitoring).
	(ii) calculation of reaction rates from the measurement of gradients **(see also 3.2.2 b)**	
(e)	from a concentration–time graph of a first order reaction, measurement of constant half-life, $t_{1/2}$	*M3.1, M3.2* Learners should be aware of the constancy of half-life for a first order reaction.
(f)	for a first order reaction, determination of the rate constant, k, from the constant half-life, $t_{1/2}$, using the relationship: $k = \ln 2/t_{1/2}$	*M0.1, M0.4, M1.1, M2.3, M2.4, M2.5* Learners will **not** be required to derive this equation from the exponential relationship between concentration and time, $[A] = [A_0]e^{-kt}$.
(g)	from a rate–concentration graph:	*M0.1, M0.4, M1.1, M3.1, M3.2, M3.3, M3.4, M3.5*
	(i) deduction of the order (0, 1 or 2) with respect to a reactant from the shape of the graph	Rate–concentration data can be obtained from initial rates investigations of separate experiments using different concentrations of one of the reactants. Clock reactions are an approximation of this method where the time measured is such that the reaction has not proceeded too far.
	(ii) determination of rate constant for a first order reaction from the gradient	HSW5 Link between order and rate.

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(h)	the techniques and procedures used to investigate reaction rates by the initial rates method and by continuous monitoring, including use of colorimetry **(see also 3.2.2 e)**	**PAG9,10** HSW4 Opportunities to carry out experimental and investigative work.
Rate-determining step		
(i)	for a multi-step reaction, prediction of, **(i)** a rate equation that is consistent with the rate-determining step **(ii)** possible steps in a reaction mechanism from the rate equation and the balanced equation for the overall reaction	HSW1 Use of experimental evidence for the proposal of reaction mechanisms.
Effect of temperature on rate constants		
(j)	a qualitative explanation of the effect of temperature change on the rate of a reaction and hence the rate constant **(see 3.2.2 f–g)**	*M0.3*
(k)	the Arrhenius equation: **(i)** the exponential relationship between the rate constant, k and temperature, T given by the Arrhenius equation, $k = Ae^{-Ea/RT}$ **(ii)** determination of E_a and A graphically using: $\ln k = -E_a/RT + \ln A$ derived from the Arrhenius equation.	*M0.1, M0.4, M2.2, M2.3, M2.4, M2.5, M3.1, M3.2, M3.3, M3.4* E_a = activation energy, A = pre-exponential factor, R = gas constant (provided on the *Data Sheet*) Explanation of A is **not** required. Equations provided on the *Data Sheet.* HSW5 Link between k and T.

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5.1.2 How far?

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Equilibrium		
(a)	use of the terms *mole fraction* and *partial pressure*	**See also 3.2.3 Chemical Equilibrium**.
(b)	calculation of quantities present at equilibrium, given appropriate data	*M0.2*
(c)	the techniques and procedures used to determine quantities present at equilibrium	**Not** for K_p. HSW4 Opportunities to carry out experimental and investigative work.
(d)	expressions for K_c and K_p for homogeneous and heterogeneous equilibria **(see also 3.2.3 f)**	*M0.2* Note: liquid and solid concentrations are constant and are omitted in heterogeneous K_c and K_p expressions.
(e)	calculations of K_c and K_p, or related quantities, including determination of units **(see also 3.2.3 f)**	*M0.0, M0.1, M0.2, M0.4, M2.2, M2.3, M2.4* Learners will **not** be required to solve quadratic equations.
(f)	**(i)** the qualitative effect on equilibrium constants of changing temperature for exothermic and endothermic reactions	*M0.3*
	(ii) the constancy of equilibrium constants with changes in concentration, pressure or in the presence of a catalyst	
(g)	explanation of how an equilibrium constant controls the position of equilibrium on changing concentration, pressure and temperature	*M0.3*
(h)	application of the above principles in **5.1.2 How far?** for K_c, K_p to other equilibrium constants, where appropriate **(see also 5.1.3 c etc.)**.	

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5.1.3 Acids, bases and buffers

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Brønsted–Lowry acids and bases	
(a)	**(i)** a Brønsted–Lowry acid as a species that donates a proton and a Brønsted–Lowry base as a species that accepts a proton **(see also 2.1.4 Acids)**	Learners should be able to identify acid–base pairs in equations for acid–base equilibria. HSW1,7 Development of different models over time to explain acid–base behaviour.
	(ii) use of the term *conjugate acid–base pairs*	
	(iii) monobasic, dibasic and tribasic acids	
(b)	the role of H^+ in the reactions of acids with metals and bases (including carbonates, metal oxides and alkalis), using ionic equations **(see also 2.1.4 c, 2.1.5 e)**	
(c)	**(i)** the acid dissociation constant, K_a, for the extent of acid dissociation **(see also 2.1.4 b)**	*M0.1, M0.2, M0.4, M2.3, M2.4, M2.5*
	(ii) the relationship between K_a and pK_a	
	pH and $[H^+(aq)]$	
(d)	use of the expression for pH as: $pH = -\log[H^+]$ $[H^+] = 10^{-pH}$	*M0.1, M0.4, M2.2, M2.3, M2.4, M2.5* HSW8 pH as convenient terminology for communicating $[H^+]$.
(e)	use of the expression for the ionic product of water, K_w	*M0.1, M0.4, M2.2, M2.3, M2.4*
(f)	calculations of pH, or related quantities, for: **(i)** strong monobasic acids **(ii)** strong bases, using K_w	*M0.1, M0.4, M2.2, M2.3, M2.4, M2.5*
(g)	calculations of pH, K_a or related quantities, for a weak monobasic acid using approximations	*M0.1, M0.4, M2.1, M2.2, M2.3, M2.4, M2.5* Approximations for weak acid calculations: $[HA]_{equilibrium} \sim [HA]_{undissociated}$ i.e. $[HA] >> [H^+]$ $[H^+]_{equilibrium} \sim [A^-]_{equilibrium}$ i.e. negligible dissociation of H_2O. Learners will **not** be required to solve quadratic equations.

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(h) limitations of using approximations to K_a related calculations for 'stronger' weak acids

M0.3

Including reasons why

$[HA]_{equilibrium} \sim [HA]_{undissociated}$ may no longer be valid.

HSW6 Understanding of the circumstances under which K_a approximations break down.

2

Buffers: action, uses and calculations

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

(j) formation of a buffer solution from:

- **(i)** a weak acid and a salt of the weak acid, e.g. CH_3COOH/CH_3COONa
- **(ii)** excess of a weak acid and a strong alkali, e.g. excess $CH_3COOH/NaOH$

(k) explanation of the role of the conjugate acid–base pair in an acid buffer solution, e.g. CH_3COOH/CH_3COO^-, in the control of pH

(l) calculation of the pH of a buffer solution, from the K_a value of a weak acid and the equilibrium concentrations of the conjugate acid–base pair; calculations of related quantities

M0.1, M0.4, M2.2, M2.3, M2.4, M2.5

(m) explanation of the control of blood pH by the carbonic acid–hydrogencarbonate buffer system

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

Neutralisation

(n) pH titration curves for combinations of strong and weak acids with strong and weak bases, including:

M3.1

- **(i)** sketch and interpretation of their shapes
- **(ii)** explanation of the choice of suitable indicators, given the pH range of the indicator

No indicator is suitable for a weak acid/weak base titration.
The indicator should be considered as a weak acid, HA.

- **(iii)** explanation of indicator colour changes in terms of equilibrium shift between the HA and A^- forms of the indicator

(o) the techniques and procedures used when measuring pH with a pH meter.

PAG11
HSW4 Opportunities to carry out experimental and investigative work.

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5.2 Energy

Born–Haber cycles are used as a theoretical model to illustrate the energy changes associated with ionic bonding.

Entropy and free energy are then introduced as concepts used to predict quantitatively the feasibility of chemical change.

Redox chemistry permeates chemistry and the introductory work in Module 2 is developed further within this section, including use of volumetric analysis for redox titrations and an introduction of electrochemistry in the context of electrode potentials.

5.2.1 Lattice enthalpy

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Lattice enthalpy	
(a)	explanation of the term *lattice enthalpy* (formation of 1 mol of ionic lattice from gaseous ions, $\Delta_{LE}H$) and use as a measure of the strength of ionic bonding in a giant ionic lattice **(see also 2.2.2 b–c)**	Definition required.
	Born–Haber and related enthalpy cycles	
(b)	use of the lattice enthalpy of a simple ionic solid (e.g. NaCl, $MgCl_2$) and relevant energy terms for: **(i)** the construction of Born–Haber cycles **(ii)** related calculations	*M2.2, M2.3, M2.4, M3.1* Relevant energy terms: *enthalpy change of formation, ionisation energy, enthalpy change of atomisation* and *electron affinity.* Definition required for first ionisation energy **(see also 3.1.1 c)** and enthalpy change of formation **(see also 3.2.1 d)** only. HSW2 Application of conservation of energy to determine enthalpy changes.
(c)	explanation and use of the terms: **(i)** *enthalpy change of solution* (dissolving of 1 mol of solute, $\Delta_{sol}H$) **(ii)** *enthalpy change of hydration* (dissolving of 1 mol of gaseous ions in water, $\Delta_{hyd}H$)	Definitions required. Details of infinite dilution **not** required.
(d)	use of the enthalpy change of solution of a simple ionic solid (e.g. NaCl, $MgCl_2$) and relevant energy terms (*enthalpy change of hydration* and *lattice enthalpy*) for: **(i)** the construction of enthalpy cycles **(ii)** related calculations	*M2.2, M2.3, M2.4, M3.1* HSW2 Application of conservation of energy to determine enthalpy changes.

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

5.2.2 Enthalpy and entropy

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Entropy	
(a)	explanation that entropy is a measure of the dispersal of energy in a system which is greater, the more disordered a system	HSW1 The model of entropy to explain thermodynamic stability.
(b)	explanation of the difference in magnitude of the entropy of a system: **(i)** of solids, liquids and gases **(ii)** for a reaction in which there is a change in the number of gaseous molecules	
(c)	calculation of the entropy change of a system, ΔS, and related quantities for a reaction given the entropies of the reactants and products	*M2.2, M2.3, M2.4*
	Free energy	
(d)	explanation that the feasibility of a process depends upon the entropy change and temperature in the system, $T\Delta S$, and the enthalpy change of the system, ΔH	HSW1,5,6 Use of entropy, enthalpy and temperature for predicting feasibility.
(e)	explanation, and related calculations, of the free energy change, ΔG, as: $\Delta G = \Delta H - T\Delta S$ (the Gibbs' equation) and that a process is feasible when ΔG has a negative value	*M0.0, M2.2, M2.3, M2.4* HSW5 Link between ΔG and feasibility.
(f)	the limitations of predictions made by ΔG about feasibility, in terms of kinetics.	*M0.3* HSW6 The relative effects of entropy and rate in determining feasibility of processes.

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5.2.3 Redox and electrode potentials

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Redox		
(a)	explanation and use of the terms *oxidising agent* and *reducing agent* **(see also 2.1.5 Redox)**	
(b)	construction of redox equations using half-equations and oxidation numbers	*M0.2*
(c)	interpretation and prediction of reactions involving electron transfer	
Redox titrations		
(d)	the techniques and procedures used when carrying out redox titrations including those involving Fe^{2+}/MnO_4^- and $I_2/S_2O_3^{2-}$ **(see also 2.1.5 e–f)**	HSW4 Opportunities to carry out experimental and investigative work.
(e)	structured and non-structured titration calculations, based on experimental results of redox titrations involving: **(i)** Fe^{2+}/MnO_4^- and $I_2/S_2O_3^{2-}$ **(ii)** non-familiar redox systems	*M0.1, M0.2, M0.4, M1.1, M1.2, M2.2, M2.3, M2.4* Non-structured titration calculations could be examined in the context of both acid–base and redox titrations **(see also 2.1.4 d–e)**.
Electrode potentials		
(f)	use of the term *standard electrode (redox) potential*, $E^{\ominus}$ including its measurement using a hydrogen electrode	$E^{\ominus}$ data will be provided on examination papers.
(g)	the techniques and procedures used for the measurement of cell potentials of: **(i)** metals or non-metals in contact with their ions in aqueous solution **(ii)** ions of the same element in different oxidation states in contact with a Pt electrode	For measurement of standard cell potentials, ions of the same element can have concentrations of 1 mol dm^{-3} or be equimolar. **PAG8** HSW4 Opportunities to carry out experimental and investigative work.
(h)	calculation of a standard cell potential by combining two standard electrode potentials	
(i)	prediction of the feasibility of a reaction using standard cell potentials and the limitations of such predictions in terms of kinetics and concentration	*M0.3* HSW6 The relative effects of standard electrode potential, rate and concentration in determining feasibility of processes.

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Storage and fuel cells

(j)	application of principles of electrode potentials to modern storage cells	Details of storage cells and required equations will be provided. Relevant electrode potentials and other data will be supplied. HSW9 Benefits of electrochemical cells counteracted by risks from toxicity and fire from Li-based cells.
(k)	explanation that a fuel cell uses the energy from the reaction of a fuel with oxygen to create a voltage and the changes that take place at each electrode.	Recall of fuel cells and equations will **not** be required. Relevant electrode potentials and other data will be supplied.

5.3 Transition elements

This section provides learners with a deeper knowledge and understanding of the periodic table within the context of the transition elements.

This section includes the role of ligands in complex ions, stereochemistry, precipitation, ligand substitution and redox reactions. The colour changes and observations in these reactions increase the toolkit of qualitative inorganic tests for identifying unknown ionic compounds.

5.3.1 Transition elements

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Properties		
(a)	the electron configuration of atoms and ions of the d-block elements of Period 4 (Sc–Zn), given the atomic number and charge **(see also 2.2.1 d)**	Learners should use sub-shell notation e.g. for Fe: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$.
(b)	the elements Ti–Cu as transition elements i.e. d-block elements that have an ion with an incomplete d-sub-shell	
(c)	illustration, using at least two transition elements, of:	No detail of how colour arises required.
	(i) the existence of more than one oxidation state for each element in its compounds **(see also 5.3.1 k)**	Practical examples of catalytic behaviour include: Cu^{2+} for reaction of Zn with acids; MnO_2 for decomposition of H_2O_2.
	(ii) the formation of coloured ions **(see also 5.3.1 h, j–k)**	No detail of catalytic processes required.
	(iii) the catalytic behaviour of the elements and their compounds and their importance in the manufacture of chemicals by industry **(see 3.2.2 d)**	HSW9 Benefits of reduced energy usage; risks from toxicity of many transition metals.

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Ligands and complex ions

(d)	explanation and use of the term *ligand* in terms of coordinate (dative covalent) bonding to a metal ion or metal, including bidentate ligands	Examples should include: monodentate: H_2O, Cl^- and NH_3 bidentate: $NH_2CH_2CH_2NH_2$ ('en'). In exams, other ligands could be introduced.
(e)	use of the terms *complex ion* and *coordination number* and examples of complexes with: **(i)** six-fold coordination with an octahedral shape **(ii)** four-fold coordination with either a planar or tetrahedral shape **(see also 2.2.2 g–h)**	*M4.1, M4.2* Examples: Octahedral: many hexaaqua complexes, e.g. $[Cu(H_2O)_6]^{2+}$, $[Fe(H_2O)_6]^{3+}$ Tetrahedral: many tetrachloro complexes, e.g. $CuCl_4^{2-}$ and $CoCl_4^{2-}$ Square planar: complexes of Pt, e.g. platin: $Pt(NH_3)_2Cl_2$ **(see also 5.3.1 g)**.
(f)	types of stereoisomerism shown by complexes, including those associated with bidentate and multidentate ligands: **(i)** *cis–trans* isomerism e.g. $Pt(NH_3)_2Cl_2$ **(see also 4.1.3 c–d)** **(ii)** optical isomerism e.g. $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$ **(see also 6.2.2 c)**	*M4.1, M4.2, M4.3* Learners should be able to draw 3-D diagrams to illustrate stereoisomerism. HSW8
(g)	use of *cis*-platin as an anti-cancer drug and its action by binding to DNA preventing cell division	HSW9 Benefits of chemotherapy; risks from unpleasant side effects.

Ligand substitution

(h)	ligand substitution reactions and the accompanying colour changes in the formation of: **(i)** $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[CuCl_4]^{2-}$ from $[Cu(H_2O)_6]^{2+}$ **(ii)** $[Cr(NH_3)_6]^{3+}$ from $[Cr(H_2O)_6]^{3+}$ **(see also 5.3.1 j)**	Complexed formulae should be used in ligand substitution equations.
(i)	explanation of the biochemical importance of iron in haemoglobin, including ligand substitution involving O_2 and CO	

Precipitation reactions

(j)	reactions, including ionic equations, and the accompanying colour changes of aqueous Cu^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+} and Cr^{3+} with aqueous sodium hydroxide and aqueous ammonia, including: **(i)** precipitation reactions **(ii)** complex formation with excess aqueous sodium hydroxide and aqueous ammonia	For precipitation, non-complexed formulae or complexed formulae, are acceptable e.g. $Cu^{2+}(aq)$ or $[Cu(H_2O)_6]^{2+}$; $Cu(OH)_2(s)$ or $Cu(OH)_2(H_2O)_4$. With excess NaOH, only $Cr(OH)_3$ reacts further forming $[Cr(OH)_6]^{3-}$. With excess NH_3, only $Cr(OH)_3$ and $Cu(OH)_2$ react forming $[Cr(NH_3)_6]^{3+}$ and $[Cu(NH_3)_4(H_2O)_2]^{2+}$ respectively **(see also 5.3.1 h)**.

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Redox reactions

(k)	redox reactions and accompanying colour changes for: **(i)** interconversions between Fe^{2+} and Fe^{3+} **(ii)** interconversions between Cr^{3+} and $Cr_2O_7^{2-}$ **(iii)** reduction of Cu^{2+} to Cu^+ and disproportionation of Cu^+ to Cu^{2+} and Cu	Fe^{2+} can be oxidised with H^+/MnO_4^- and Fe^{3+} reduced with I^-, Cr^{3+} can be oxidised with H_2O_2/OH^- and $Cr_2O_7^{2-}$ reduced with Zn/H^+, Cu^{2+} can be reduced with I^-. In aqueous conditions, Cu^+ readily disproportionates. Learners will **not** be required to recall equations but may be required to construct and interpret redox equations using relevant half-equations and oxidation numbers **(see 5.2.3 b–c)**.
(l)	interpretation and prediction of unfamiliar reactions including ligand substitution, precipitation, redox.	

5.3.2 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-}, Cl^-, Br^-, I^-, SO_4^{2-} **(see 3.1.4 a)** **(ii)** cations: NH_4^+; Cu^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+}, Cr^{3+} **(see 3.1.4 a, 5.3.1 j)**.	**PAG4** HSW4 Qualitative analysis.

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Module 6: Organic chemistry and analysis

The content within this module assumes knowledge and understanding of the chemical concepts developed in Module 2: Foundations in chemistry and Module 4: Core organic chemistry.

This module introduces several new functional groups and emphasises the importance of organic synthesis. This module also adds NMR spectroscopy to the instrumentation techniques used in organic and forensic analysis.

The main areas of organic chemistry studied include:

- aromatic compounds
- carboxylic acids and esters
- organic nitrogen compounds: amines and amino acids
- polymerisation: addition polymers and condensation polymers
- synthetic organic chemistry and further development of practical skills
- the importance of modern analytical techniques in organic analysis.

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 and Module 4: Core organic chemistry.

- Atoms, moles and stoichiometry
- Acid and redox reactions
- Bonding and structure
- Organic nomenclature and structures
- Hydrocarbons
- Alcohols and haloalkanes
- Synthesis and analysis

Knowledge and understanding of Module 2 and Module 4 will be assumed and examination questions will be set that link their content with this module and other areas of chemistry.

6.1 Aromatic compounds, carbonyls and acids

This section extends the range of functional groups encountered in Module 4.

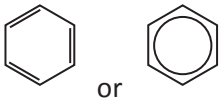
Aromatic compounds are first introduced, including the central role of delocalisation within the chemistry of arenes and phenols. Directing groups are also introduced, including their importance to organic synthesis.

The important carbonyl compounds, aldehydes and ketones, are then studied.

Finally, carboxylic acids and their related functional groups, acyl chlorides and esters, are studied. The importance of acyl chlorides in organic synthesis is emphasised.

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6.1.1 Aromatic compounds

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Benzene and aromatic compounds	
(a)	the comparison of the Kekulé model of benzene with the subsequent delocalised models for benzene in terms of p-orbital overlap forming a delocalised π-system	Learners may represent the structure of benzene in equations and mechanisms as:  or HSW1,7 Development of the model for benzene over time.
(b)	the experimental evidence for a delocalised, rather than Kekulé, model for benzene in terms of bond lengths, enthalpy change of hydrogenation and resistance to reaction **(see also 6.1.1 f)**	HSW11 Acceptance of the delocalised benzene model by the scientific community in light of supporting experimental evidence.
(c)	use of IUPAC rules of nomenclature for systematically naming substituted aromatic compounds	Use of locant numbers to identify positions of substitution e.g. 2,4-dinitromethylbenzene. HSW8 Introduction of systematic nomenclature.
	Electrophilic substitution	
(d)	the electrophilic substitution of aromatic compounds with: **(i)** concentrated nitric acid in the presence of concentrated sulfuric acid **(ii)** a halogen in the presence of a halogen carrier **(iii)** a haloalkane or acyl chloride in the presence of a halogen carrier (Friedel–Crafts reaction) and its importance to synthesis by formation of a C–C bond to an aromatic ring **(see also 6.2.4 d)**	Halogen carriers include iron, iron halides and aluminium halides.
(e)	the mechanism of electrophilic substitution in arenes for nitration and halogenation **(see also 4.1.1 h–i)**	For nitration mechanism, learners should include equations for formation of NO_2^+. Halogen carriers include iron, iron halides and aluminium halides. For the halogenation mechanism, the electrophile can be assumed to be X^+. HSW1,2,8 Use of reaction mechanisms to explain organic reactions.

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(f)	the explanation of the relative resistance to bromination of benzene, compared with alkenes, in terms of the delocalised electron density of the π-system in benzene compared with the localised electron density of the π-bond in alkenes **(see also 4.1.3 a, 6.1.1 a)**	HSW2,5 Use of delocalised benzene model to explain reactivity.
(g)	the interpretation of unfamiliar electrophilic substitution reactions of aromatic compounds, including prediction of mechanisms	Extra information may be provided on exam papers.

Phenols

(h)	the weak acidity of phenols shown by the neutralisation reaction with NaOH but absence of reaction with carbonates **(see also 5.1.3 b)**	**PAG7 (see also 6.3.1 c)**
(i)	the electrophilic substitution reactions of phenol: **(i)** with bromine to form 2,4,6-tribromophenol **(ii)** with dilute nitric acid to form 2-nitrophenol	Note that nitration with phenol does not require concentrated HNO_3 or the presence of a concentrated H_2SO_4 catalyst.
(j)	the relative ease of electrophilic substitution of phenol compared with benzene, in terms of electron pair donation to the π-system from an oxygen p-orbital in phenol **(see also 4.1.3 a)**	Illustrated by reactions with bromine and with nitric acid. Explanation is only in terms of susceptibility of ring to 'attack' and not in terms of stability of intermediate. HSW2,5 Use of delocalised benzene model to explain reactivity.
(k)	the 2- and 4-directing effect of electron-donating groups (OH, NH_2) and the 3-directing effect of electron-withdrawing groups (NO_2) in electrophilic substitution of aromatic compounds	Learners will **not** be expected to know further electron-donating or electron-withdrawing groups; relevant additional data will be supplied in examinations. HSW5 Correlation between substituted group and position of reaction.
(l)	the prediction of substitution products of aromatic compounds by directing effects and the importance to organic synthesis **(see also 6.2.5 Organic Synthesis)**.	

6.1.2 Carbonyl compounds

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	

Reactions of carbonyl compounds

(a)	oxidation of aldehydes using $Cr_2O_7^{2-}/H^+$ (i.e. $K_2Cr_2O_7/H_2SO_4$) to form carboxylic acids	In equations for organic redox reactions, [O] and [H] should be used. **PAG7 (see also 6.3.1 c)**

(b)	nucleophilic addition reactions of carbonyl compounds with: **(i)** $NaBH_4$ to form alcohols **(ii)** HCN [i.e. $NaCN(aq)/H^+(aq)$], to form hydroxynitriles **(see also 6.2.4 b)**	
(c)	the mechanism for nucleophilic addition reactions of aldehydes and ketones with $NaBH_4$ and HCN	For $NaBH_4$, the nucleophile can be considered as being the hydride ion, H^-, with subsequent protonation of the organic intermediate from H_2O. For HCN, initial nucleophilic attack is from CN^- ions; subsequent protonation stage can be shown using H_2O or H^+. HSW1,2,8 Use of reaction mechanisms to explain organic reactions.
Characteristic tests for carbonyl compounds		
(d)	use of 2,4-dinitrophenylhydrazine to: **(i)** detect the presence of a carbonyl group in an organic compound **(ii)** identify a carbonyl compound from the melting point of the derivative	The equation for this reaction is **not** required. Structure of derivative **not** required. **PAG7 (see also 6.3.1 c)** HSW4 Qualitative analysis.
(e)	use of Tollens' reagent (ammoniacal silver nitrate) to: **(i)** detect the presence of an aldehyde group **(ii)** distinguish between aldehydes and ketones, explained in terms of the oxidation of aldehydes to carboxylic acids with reduction of silver ions to silver.	In equations involving Tollens' reagent, [O] is acceptable. **PAG7 (see also 6.3.1 c)** HSW4 Qualitative analysis.

6.1.3 Carboxylic acids and esters

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
Properties of carboxylic acids		
(a)	explanation of the water solubility of carboxylic acids in terms of hydrogen bonding	
(b)	reactions in aqueous conditions of carboxylic acids with metals and bases (including carbonates, metal oxides and alkalis)	Comparison of acidity of different carboxylic acids **not** required. **PAG7 (see 6.3.1 c)**

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Esters

(c) esterification of:

- **(i)** carboxylic acids with alcohols in the presence of an acid catalyst (e.g. concentrated H_2SO_4)
- **(ii)** acid anhydrides with alcohols

(d) hydrolysis of esters:

- **(i)** in hot aqueous acid to form carboxylic acids and alcohols
- **(ii)** in hot aqueous alkali to form carboxylate salts and alcohols

Acyl chlorides

(e) the formation of acyl chlorides from carboxylic acids using $SOCl_2$

(f) use of acyl chlorides in synthesis in formation of esters, carboxylic acids and primary and secondary amides.

Including esterification of phenol, which is not readily esterified by carboxylic acids.

6.2 Nitrogen compounds, polymers and synthesis

This section focuses on organic nitrogen compounds, including amines, amides and amino acids. Chirality and optical isomerism is also introduced.

Condensation polymerisation is also introduced and compared with addition polymerisation.

The importance of carbon–carbon bond formation in organic synthesis is stressed. Learners are also able to consider multi-stage synthetic routes towards an organic product.

This module allows learners many opportunities to further develop their organic practical skills, especially in preparing and purifying organic solids, including recrystallisation and determination of melting points.

6.2.1 Amines

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Basicity and preparation of amines	
(a)	the basicity of amines in terms of proton acceptance by the nitrogen lone pair and the reactions of amines with dilute acids, e.g. HCl(aq), to form salts	Comparison of basicity of different amines **not** required. Restricted to inorganic acids.

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(b)	the preparation of: **(i)** aliphatic amines by substitution of haloalkanes with excess ethanolic ammonia and amines **(ii)** aromatic amines by reduction of nitroarenes using tin and concentrated hydrochloric acid.	Including formation of primary amines from ammonia and secondary/tertiary amines from amines. See also reduction of nitriles **(see 6.2.4 c)**.

2

6.2.2 Amino acids, amides and chirality

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Reactions of amino acids	
(a)	the general formula for an α-amino acid as $RCH(NH_2)COOH$ and the following reactions of amino acids: **(i)** reaction of the carboxylic acid group with alkalis and in the formation of esters **(see also 6.1.3 c)** **(ii)** reaction of the amine group with acids	
	Amides	
(b)	structures of primary and secondary amides **(see also 6.1.3 f, 6.2.3 a–b)**	
	Chirality	
(c)	optical isomerism (an example of stereoisomerism, in terms of non-superimposable mirror images about a chiral centre) **(see also 4.1.3 c–d)**	*M4.2, M4.3* Learners should be able to draw 3-D diagrams to illustrate stereoisomerism. HSW1,8
(d)	identification of chiral centres in a molecule of any organic compound.	*M4.2, M4.3*

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6.2.3 Polyesters and polyamides

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Condensation polymers	
(a)	condensation polymerisation to form: **(i)** polyesters **(ii)** polyamides	Formation from carboxylic acids/dicarboxylic acids (or respective acyl chlorides) and from alcohols/diols or amines/diamines. Learners will **not** be expected to recall the structures of synthetic polyesters and polyamides or their monomers.
(b)	the acid and base hydrolysis of: **(i)** the ester groups in polyesters **(ii)** the amide groups in polyamides	
(c)	prediction from addition and condensation polymerisation of: **(i)** the repeat unit from a given monomer(s) **(ii)** the monomer(s) required for a given section of a polymer molecule **(iii)** the type of polymerisation.	**See also 4.1.3 j.**

6.2.4 Carbon–carbon bond formation

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Extending carbon chain length	
(a)	the use of C–C bond formation in synthesis to increase the length of a carbon chain **(see also 6.1.1 d, 6.1.2 b)**	
(b)	formation of C–C≡N by reaction of: **(i)** haloalkanes with CN^- and ethanol, including nucleophilic substitution mechanism **(see also 4.2.2 c)** **(ii)** carbonyl compounds with HCN, including nucleophilic addition mechanism **(see also 6.1.2 b–c)**	
(c)	reaction of nitriles from **(b)**: **(i)** by reduction (e.g. with H_2/Ni) to form amines **(ii)** by acid hydrolysis to form carboxylic acids	

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(d) formation of a substituted aromatic C–C by alkylation (using a haloalkane) and acylation (using an acyl chloride) in the presence of a halogen carrier (Friedel–Crafts reaction) **(see also 6.1.1 d)**.

6.2.5 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 used for the preparation and purification of organic solids involving use of a range of techniques **(see also 4.2.3 a)** including: **(i)** organic preparation • use of Quickfit apparatus • distillation and heating under reflux **(ii)** purification of an organic solid • filtration under reduced pressure • recrystallisation • measurement of melting points	**PAG6** 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 Module 6 **(see also 4.2.3 b)**. HSW3 Development of synthetic routes.
(c) multi-stage synthetic routes for preparing organic compounds.	Learners will be expected to be able to devise multi-stage synthetic routes by applying transformations between all functional groups studied throughout the specification. Extra information may be provided on exam papers to extend the learner's toolkit of organic reactions. HSW3 Development of synthetic routes.

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6.3 Analysis

This section develops and complements the spectroscopic areas of organic chemistry previously encountered (see Module 4: Core organic chemistry; 4.2.4 Analytical techniques).

This section demonstrates how analytical techniques introduced in Module 4 (infrared spectroscopy, mass spectrometry and elemental analysis) may be used in combination with NMR spectroscopy to provide evidence of structural features in molecules.

The instrumentation methods of analysis studied during the A level course provide learners with an important base of knowledge, understanding and awareness for further study in Higher Education and in many areas of employment in the broad scientific field.

This section also looks at how unknown organic functional groups can be analysed and identified using simple test-tube tests.

6.3.1 Chromatography and qualitative analysis

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
	Types of chromatography	
(a)	interpretation of one-way TLC chromatograms in terms of R_f values	*M3.1* **PAG6** HSW3 Interpretation of TLC to analyse organic compounds.
(b)	interpretation of gas chromatograms in terms of: **(i)** retention times **(ii)** the amounts and proportions of the components in a mixture.	*M3.1, M3.2* To include creation and use of external calibration curves to confirm concentrations of components. Peak integration values will be supplied. HSW3 Interpretation of GC to analyse organic compounds.
	Tests for organic functional groups	
(c)	qualitative analysis of organic functional groups on a test-tube scale; processes and techniques needed to identify the following functional groups in an unknown compound: **(i)** alkenes by reaction with bromine **(see also 4.1.3 f)** **(ii)** haloalkanes by reaction with aqueous silver nitrate in ethanol **(see also 4.2.2 a)** **(iii)** phenols by weak acidity but no reaction with CO_3^{2-} **(see also 6.1.1 h)** **(iv)** carbonyl compounds by reaction with 2,4-DNP **(see also 6.1.2 d)** **(v)** aldehydes by reaction with Tollens' reagent **(see also 6.1.2 e)**	**PAG7** HSW4 Qualitative analysis.

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(vi) primary and secondary alcohols and aldehydes by reaction with acidified dichromate **(see also 4.2.1 c, 6.1.2a)**

(vii) carboxylic acids by reaction with CO_3^{2-} **(see also 6.1.3 b)**.

6.3.2 Spectroscopy

2

Learning outcomes	Additional guidance
Learners should be able to demonstrate and apply their knowledge and understanding of:	
NMR Spectroscopy	
(a) analysis of a carbon-13 NMR spectrum of an organic molecule to make predictions about: **(i)** the number of carbon environments in the molecule **(ii)** the different types of carbon environment present, from chemical shift values **(iii)** possible structures for the molecule	*M3.1* All carbon-13 NMR spectra that are assessed will be proton decoupled. In examinations, NMR chemical shift values will be provided on the *Data Sheet*. Restricted to functional groups studied in the A level specification. HSW3,5 Interpretation of spectra to analyse organic compounds.
(b) analysis of a high resolution proton NMR spectrum of an organic molecule to make predictions about: **(i)** the number of proton environments in the molecule **(ii)** the different types of proton environment present, from chemical shift values **(iii)** the relative numbers of each type of proton present from relative peak areas, using integration traces or ratio numbers, when required **(iv)** the number of non-equivalent protons adjacent to a given proton from the spin–spin splitting pattern, using the $n + 1$ rule **(v)** possible structures for the molecule	*M3.1* In examinations, NMR chemical shift values will be provided on the *Data Sheet*. Restricted to functional groups studied in the A level specification. Learners will be expected to identify aromatic protons from chemical shift values but will **not** be expected to analyse their splitting patterns. HSW3,5 Interpretation of spectra to analyse organic compounds.
(c) prediction of a carbon-13 or proton NMR spectrum for a given molecule	*M3.1*
(d) **(i)** the use of tetramethylsilane, TMS, as the standard for chemical shift measurements **(ii)** the need for deuterated solvents, e.g. $CDCl_3$, when running an NMR spectrum **(iii)** the identification of O–H and N–H protons by proton exchange using D_2O	

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Combined techniques

(e)	deduction of the structures of organic compounds from different analytical data including:	*M3.1*
	(i) elemental analysis **(see also 2.1.3 c)**	Spectral reference data will be provided on the *Data Sheet*.
	(ii) mass spectra **(see also 4.2.4 f–g)**	Restricted to functional groups studied in the A level specification.
	(iii) IR spectra **(see also 4.2.4 d–e)**	Learners will **not** be expected to interpret mass spectra of organic halogen compounds.
	(iv) NMR spectra.	HSW3,5,6 Interpretation of a variety of different evidence to analyse organic compounds.

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2d. Prior knowledge, learning and progression

2

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 A level specification has been written to provide progression from GCSE Science, GCSE Additional Science, GCSE Further Additional Science, GCSE Chemistry or from AS Level 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 A 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.

The A Level Chemistry course will prepare learners for progression to undergraduate courses in Chemistry, Biochemistry, Medicine, Dentistry, Engineering, Pharmacy, one of the other sciences or related subjects. For learners wishing to follow an apprenticeship route or those seeking direct entry into chemical science careers, this A 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**

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3 Assessment of OCR A Level in Chemistry A

3a. Forms of assessment

All three externally assessed components (01–03) contain some synoptic assessment, some extended response questions and some stretch and challenge questions.

Stretch and challenge questions are designed to allow the most able learners the opportunity to demonstrate the full extent of their knowledge and skills.

Stretch and challenge questions will support the awarding of the A* grade at A level, addressing the need for greater differentiation between the most able learners.

Periodic table, elements and physical chemistry (Component 01)

This component is worth 100 marks and is split into two sections and assesses content from teaching modules 1, 2, 3 and 5. Learners answer all questions.

Section A contains multiple choice questions. This section of the paper is worth 15 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 85 marks.

Synthesis and analytical techniques (Component 02)

This component is worth 100 marks and is split into two sections and assesses content from teaching modules 1, 2, 4 and 6. Learners answer all questions.

Section A contains multiple choice questions. This section of the paper is worth 15 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 85 marks.

Unified chemistry (Component 03)

This component assesses content from across all teaching modules 1 to 6. 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.

Practical Endorsement in chemistry (Component 04)

Performance in this component is reported separately to the performance in the A level as measured through externally assessed components 01 to 03. This non-exam assessment component rewards the development of practical competency in chemistry and is teacher assessed. Learners demonstrate competence in the range of skills and techniques specified in Section 1.2 of the specification by carrying out a minimum of 12 assessed practical activities. The Practical Endorsement is teacher assessed against the Common Practical Assessment Criteria as specified in Section 5g.

Learners may work in groups but must demonstrate and record independent evidence of their competency. Teachers who award a pass to their learners must be confident that each learner consistently and routinely exhibits the competencies listed in Section 5g and has demonstrated competence in all the skills detailed in section 1.2.1 and in all the apparatus and techniques detailed in Section 1.2.2 before completion of the A level course. The practical activities provided by OCR are all mapped against the specification and assessment criteria.

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3b. Assessment objectives (AO)

There are three assessment objectives in OCR's A 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 A Level in Chemistry A

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

Component	% of A Level in Chemistry A (H432)		
	AO1	AO2	AO3
Periodic table, elements and physical chemistry (H432/01)	13–14	15–16	8–9
Synthesis and analytical techniques (H432/02)	13–14	15–16	8–9
Unified chemistry (H432/03)	5–6	10–12	9–10
Practical endorsement in chemistry (H432/04)*	N/A	N/A	N/A
Total	**31–34**	**40–44**	**25–28**

* The Practical Endorsement is assessed and reported separately from the overall A level grade (see Section 5).

3c. 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 2017 examination series onwards.

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3d. Retaking the qualification

Candidates can retake the qualification as many times as they wish. They retake all examined components of the qualification. Candidates can choose either to retake the Practical Endorsement or to carry forward their result for the Practical Endorsement by using the carry forward entry option (see Section 4a). The result for the Practical Endorsement may be carried forward for the lifetime of the specification.

A candidate who is retaking A Level Chemistry A may re-use a previous result for the Practical Endorsement, even if it was awarded by another awarding organisation or if it was awarded for an alternative suite [e.g. a Practical Endorsement pass result from A Level Chemistry A could be re-used for retaking A Level Chemistry B (Salters)].

3e. Assessment of extended response

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 all externally assessed components, including two questions in each component 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.

3f. 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 A level course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. All 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.

3g. Calculating qualification results

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

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

A learner's result for their Practical Endorsement in chemistry component will not contribute to their overall qualification grade.

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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. These do not incur a cost and do not commit your centre in any way.

Registration for the Practical Endorsement

From autumn 2015 (and each autumn thereafter) JCQ will ask each centre to indicate which awarding organisation it intends to use for its entries in A level Chemistry and to provide the name of the lead teacher. JCQ will allocate centres to awarding organisations for the purpose of the monitoring visits. Centres will receive communications concerning the visits from awarding organisations, not from JCQ.

Lead teachers are required to undertake the free on-line training provided (available at: **https://practicalendorsement.ocr.org.uk**) on the implementation of the Practical Endorsement and must then disseminate this information to all other teachers of that science within the centre so that each teacher can apply the standards appropriately. Your registration is not communicated to any organisation other than the awarding organisation responsible for your monitoring visit, and then only at the time you are selected for monitoring.

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 A Level in Chemistry A must be entered for one of the entry options shown on the following table:

Entry option		Component		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
H432	Chemistry A	01	Periodic table, elements and physical chemistry	External assessment
		02	Synthesis and analytical techniques	External assessment
		03	Unified chemistry	External assessment
		04	Practical Endorsement in chemistry	Non-exam assessment (Visiting monitoring)

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Entry option		Component		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
H432C	Chemistry A	01	Periodic table, elements and physical chemistry	External assessment
		02	Synthesis and analytical techniques	External assessment
		03	Unified chemistry	External assessment
		80	Practical Endorsement in chemistry – Carried Forward*	Non-exam assessment (Carried Forward)

*The carry forward option will be available for the first time from June 2018.

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.

The A Level Chemistry A qualification requires learners to complete a Practical Endorsement incorporating a minimum of 12 practical activities, allowing them to demonstrate a range of practical skills, use of apparatus and techniques to fulfil the Common Practical Assessment Criteria.

The Practical Endorsement is an essential part of the course and will allow learners to develop skills for further study or employment, as well as imparting important knowledge that is part of the specification.

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 candidates at the centre have had the opportunity to undertake the prescribed practical activities.

Please see the JCQ publication *Instructions for conducting non-examination assessments* for further information.

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.

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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* and JCQ *Reasonable Adjustments for GCE A-level sciences – Endorsement of practical skills.*

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 components 01, 02 and 03. Calculators are subject to the rules in the document *Instructions for Conducting Examinations* published annually by JCQ **(www.jcq.co.uk).**

4d. Admin of non-exam assessment

Regulations governing arrangements for internal assessments are contained in the JCQ *Instructions for conducting non-examination assessments*. Appendix 1 of this document gives specific details for the Practical Skills Endorsement for A Level sciences designed for use in England.

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

4e. Results and certificates

Grade scale

A level qualifications are graded on the scale: A*, 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 for the A Level Sciences Practical Endorsements will be shown independently of the qualification grade on the certificate. Candidates who fulfil the requirements and reach the minimum standard will be awarded a Pass grade. Candidates who fail to reach the minimum standard will be recorded as 'Not Classified' and this will also be reported on the certificate.

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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 each entry option.

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 GCE in Chemistry A'.

4f. Post-results services

A number of post-results services are available:

- **Enquiries about results** – If you are not happy with the outcome of a learner's results, centres may submit an enquiry about results.
- **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.
- **Practical Endorsement** – As monitoring and any potential request for further visits take place throughout the period of the qualification, there is no post-results service provided.

4g. 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.

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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 A 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.

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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).

Copies of this sheet may be used for teaching.

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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}

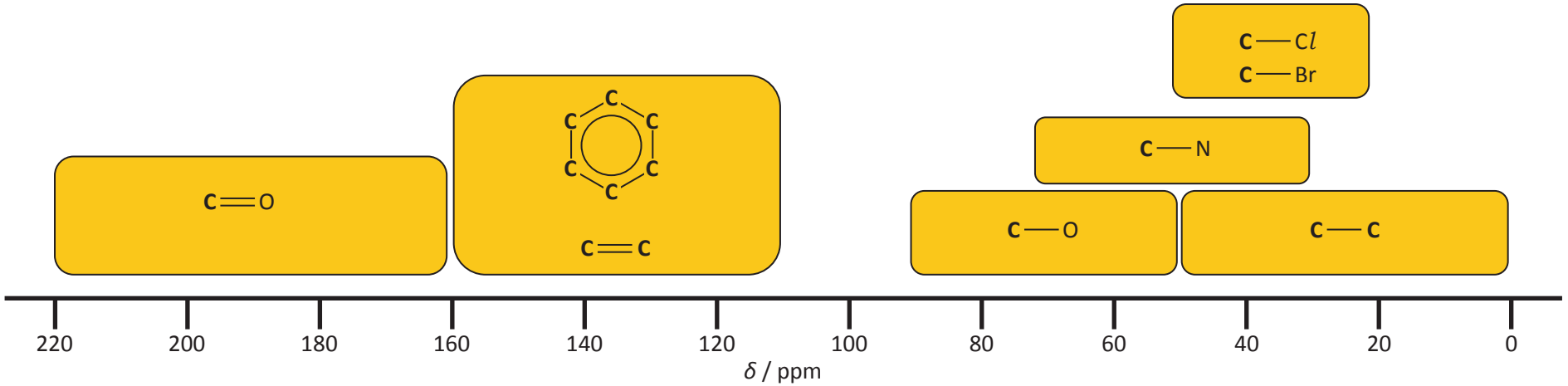
Characteristic infrared absorptions in organic molecules

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

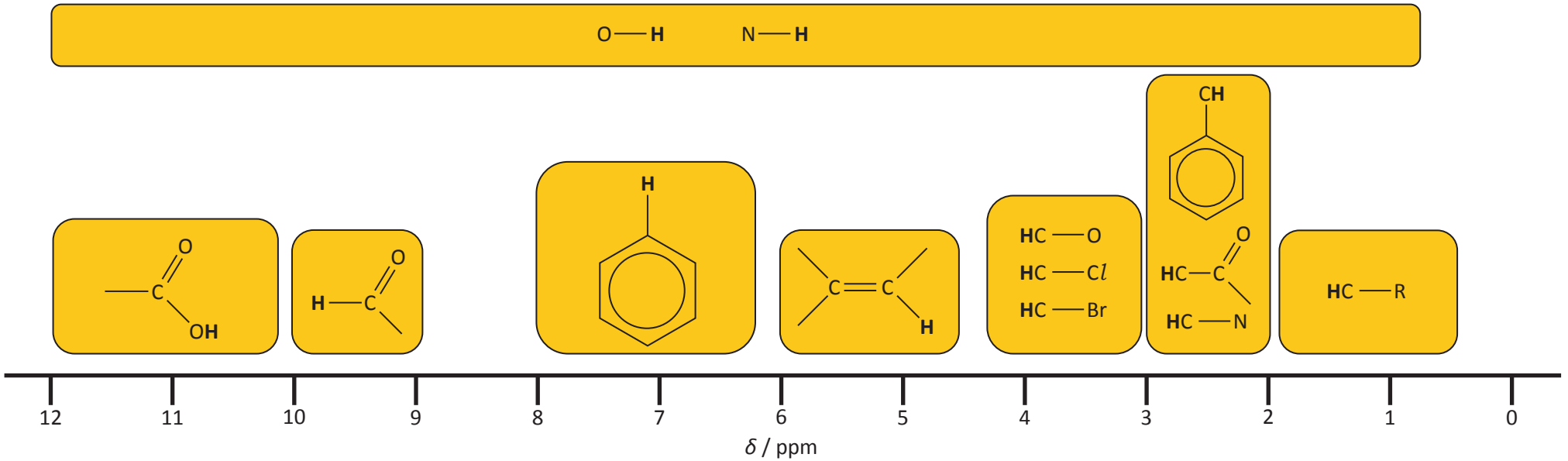
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A Level in Chemistry A

^{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–C**H**$_2$–C=O, may be shifted more than indicated above.

The Periodic Table of the Elements

(1)	(2)											(3)	(4)	(5)	(6)	(7)	(0)
1																	**18**
1 **H** hydrogen 1.0	**2**											**13**	**14**	**15**	**16**	**17**	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	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	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		

Key
atomic number
Symbol
name
relative atomic mass

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

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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 terminology.

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.

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5e. Mathematical requirements

In order to be able to develop their skills, knowledge and understanding in A 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. Skills shown in **bold** type will only be tested in the full A level course, not the standalone AS level course.

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.

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A 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 • **give units for an equilibrium constant or a rate constant** • understand that different units are used in similar topic areas, so that conversions may be necessary e.g. entropy in J mol^{-1} K^{-1} and enthalpy changes in kJ mol^{-1}.	1.1.2(b), 2.1.3(a,e), 3.2.1(e,f,g), 5.1.1(c), 5.1.2(e), 5.2.2(e)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A 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)
M0.1	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 Avogadro constant • **understand standard form when applied to areas such as (but not limited to) K_w** • 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), 5.1.1(c,d,f,g,k), 5.1.2(e), 5.1.3(c,d,e,f,g,l), 5.2.3(e)
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), 5.1.1(b), 5.1.2(b,d,e), 5.1.3(c), 5.2.3(b,e)
M0.3	Estimate results	Learners may be tested on their ability to: • **evaluate the effect of changing experimental parameters on measurable values e.g. how the value of K_c would change with temperature given different specified conditions.**	3.2.3(g), 5.1.1(j), 5.1.2(f,g), 5.1.3(h), 5.2.2(f), 5.2.3(i)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A 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)
M0.4	Use calculators to find and use power, **exponential and logarithmic functions**	Learners may be tested on their ability to: • carry out calculations using the Avogadro constant • **carry out pH and pK_a calculations** • **make appropriate mathematical approximations in buffer calculations.**	2.1.3(a,e,f), 5.1.1(c,d,f,g,k), 5.1.2(e), 5.1.3(c,d,e,f,g,l)
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), 2.1.4(e), 3.2.1(g), 3.2.3(f), 5.1.1(c,d,f,g), 5.2.3(e)
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), 5.2.3(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)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A 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 – Algebra			
M2.1	Understand and use the symbols: =, <, ≪, ≫, >, ∝, ~, ⇌	No exemplification required.	
M2.2	Change the subject of an equation	Learners may be tested on their ability to: • carry out structured and unstructured mole calculations • **calculate a rate constant, *k* from a rate equation.**	2.1.3(c,d,e,f), 2.1.4(e), 3.2.1(e,f,g), 5.1.1(c,k), 5.1.2(e), 5.1.3(d,e,f,g,l), 5.2.1(b,d), 5.2.2(c,e), 5.2.3(e)
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 • **carry out rate calculations.**	2.1.3(c,d,e,f), 2.1.4(e), 3.2.1(e,f,g), 3.2.3(f), 5.1.1(c,f,k), 5.1.2(e), 5.1.3(c,d,e,f,g,l), 5.2.1(b,d), 5.2.2(c,e), 5.2.3(e)
M2.4	Solve algebraic equations	Learners may be tested on their ability to: • carry out Hess' law calculations • **calculate a rate constant, *k* from a rate equation.**	2.1.3(c,d,e,f), 2.1.4(e), 3.2.1(e,f,g), 3.2.3(f), 5.1.1(c,f,k), 5.1.2(e), 5.1.3(c,d,e,f,g,l), 5.2.1(b,d), 5.2.2(c,e), 5.2.3(e)
M2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	Learners may be tested on their ability to: • **carry out pH and pK_a calculations.**	5.1.1(f,k), 5.1.3(c,d,f,g,l)
M3 – Graphs			
M3.1	Translate information between graphical, numerical and algebraic forms	Learners may be tested on their ability to: • interpret and analyse spectra • **determine the order of a reaction from a graph and derive rate expression.**	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), 5.1.1(d,e,g,k), 5.1.3(n), 5.2.1(b,d), 6.3.1(a,b), 6.3.2(a,b,c,e)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A 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)
M3.2	Plot two variables from experimental or other data	Learners may be tested on their ability to: • plot graphs from collected or supplied data to follow the course of a reaction • draw lines of best fit • extrapolate and interpolate • **construct calibration curves.**	1.1.3(d), 3.2.1(h), 3.2.2(b), 5.1.1(d,e,g,k), 6.3.1(b)
M3.3	**Determine the slope and intercept of a linear graph**	Learners may be tested on their ability to: • **calculate values for E_a and *A* from the gradient and intercept of a graph using the Arrhenius equation.**	1.1.3(d), 5.1.1(d,k)
M3.4	**Calculate rate of change from a graph showing a linear relationship**	Learners may be tested on their ability to: • **calculate the rate constant of a first-order reaction by determination of the gradient of a rate–concentration graph.**	1.1.3(d), 5.1.1(d,g,k)
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), 5.1.1(d,g)
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), 5.3.1(e,f)

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	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A 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)
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 • **identify chiral centres from a 2-D or 3-D representation.**	2.2.2(g), 4.1.1(b,e), 4.1.2(b), 4.1.3(c,d), 5.3.1(e,f), 6.2.2(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 • **identify chiral centres from a 2-D or 3-D representation.**	4.1.3(b,c,d), 5.3.1(f), 6.2.2(c,d)

Definition of Level 2 mathematics

Within A 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.

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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 learners 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®.

[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**.

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5g. Practical endorsement

The Practical Endorsement is common across Chemistry A and Chemistry B (Salters). It requires a minimum of 12 practical activities to be completed from the Practical Activity Groups (PAGs) defined below (**Fig. 1**).

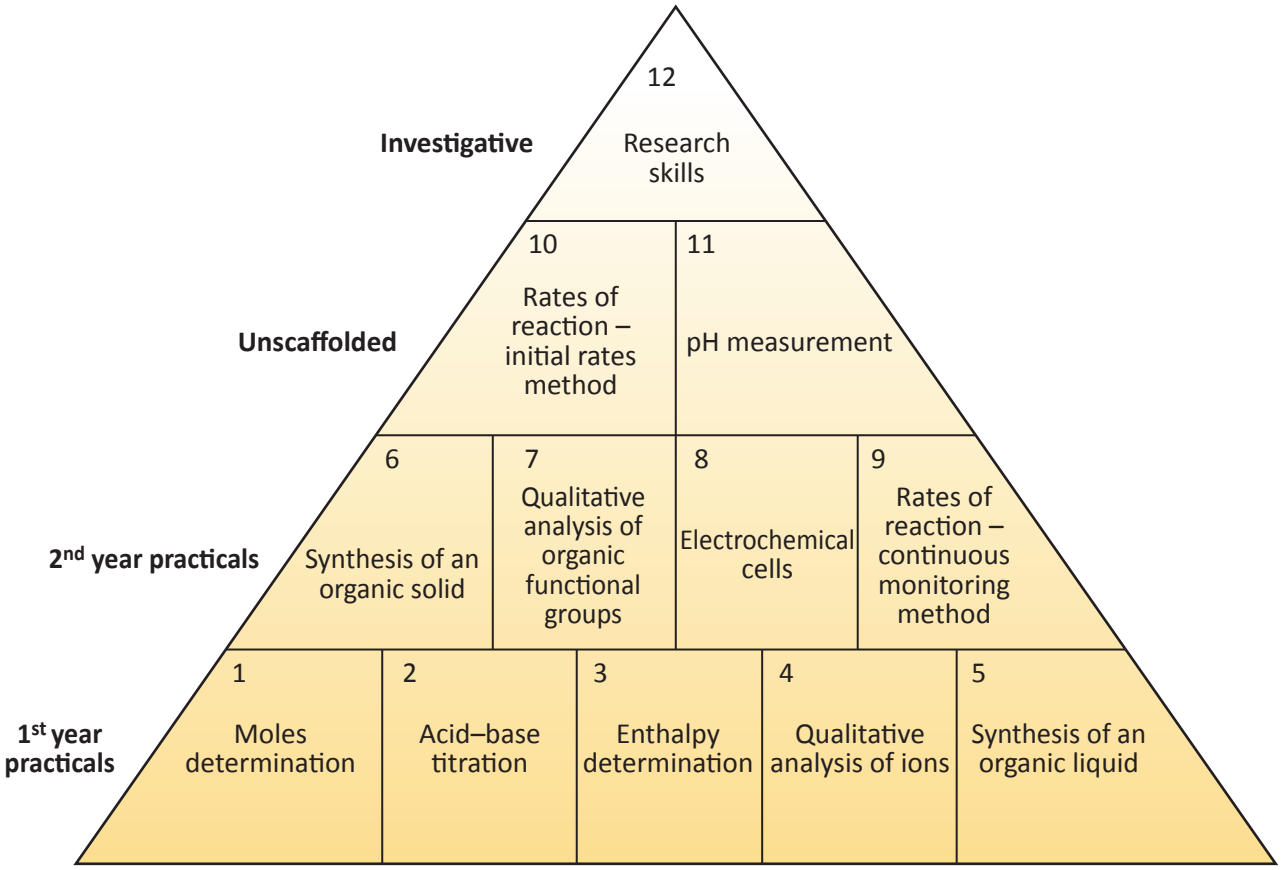


Fig. 1 OCR's Practical Activity Groups (PAGs), also see **Table 1**

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Table 1 Practical activity requirements for the OCR Chemistry Practical Endorsement

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be available from the OCR website and centres can devise their own activity)	Specification reference (examples)
1 Moles determination	• Measurement of mass • Measurement of volume of gas	Determination of the composition of copper(II) carbonate	2.1.3(d), 2.1.3(h)
2 Acid–base titration	• Measurement of volume of a liquid • Use of volumetric flask, including accurate technique for making up a standard solution • Titration, using burette and pipette • Use of acid–base indicators in titrations of weak/strong acids with weak/strong bases	Titration of sodium hydrogencarbonate against hydrochloric acid	2.1.4(d)
3 Enthalpy determination	• Measurement of temperature	Determination of the enthalpy change of neutralisation	3.2.1(e), 3.2.1(h)
4 Qualitative analysis of ions	• Use of apparatus for qualitative tests for ions • Make and record qualitative observations	Identification of the anions and cations present in a mixture of Group 2 salts	3.1.3(g), 3.1.4(a), 5.3.2(a)
5 Synthesis of an organic liquid	• Heating under reflux[1] • Purification using a separating funnel • Distillation • Risk assessment	Synthesis of a haloalkane	4.2.3(a)
6 Synthesis of an organic solid	• Purification by recrystallisation • Use of melting point apparatus • Use of thin layer or paper chromatography • Filtration • Heating under reflux[1] • Risk assessment	Synthesis of aspirin	6.2.5(a), 6.3.1(a)
7 Qualitative analysis of organic functional groups	• Use of apparatus for qualitative tests for organic functional groups • Heating using water bath or electric heater • Make and record observations	Identifying functional groups in a series of unknown organic compounds	4.1.3(f), 4.2.1(c), 4.2.2(a), 6.1.1(h), 6.1.2(a), 6.1.2(d), 6.1.2(e), 6.1.3(b), 6.3.1(c)

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Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be available from the OCR website and centres can devise their own activity)	Specification reference (examples)
8 Electrochemical cells	• Set up of electrochemical cells and measurement of voltages	The effect of concentration on the cell potential of an electrochemical cell	5.2.3(g)
9 Rates of reaction – continuous monitoring method	• Measurement of rate of reaction by a continuous monitoring method • Measurement of time • Use of appropriate software to process data[2]	Finding the half-life of a reaction	3.2.2(e), 5.1.1(h)
10 Rates of reaction – initial rates method	• Measurement of rate of reaction by an initial rate method • Use of appropriate software to process data[2] • Identify and control variables	Finding the order and rate constant for a reaction	5.1.1(b), 5.1.1(h)
11 pH measurement	• Measurement of pH	Identifying unknown solutions via pH measurements	5.1.3(o)
12 Research skills	• Apply investigative approaches • Use online and offline research skills • Correctly cite sources of information	How long does it take iron tablets to break down in the stomach?	Opportunities throughout specification

[1,2] These techniques/skills may be covered in *either* of the groups indicated.

The technique, '*Safely and carefully handling solids and liquids, including corrosive, irritant, flammable and toxic substances* ***(1.2.2 k)***' needs to be covered across the selection of activities.

It is expected that the following skills will be developed across <u>all</u> activities, regardless of the exact selection of activities. The ability to:

- safely and correctly use a range of practical equipment and materials **(1.2.1 b)**
- follow written instructions **(1.2.1 c)**
- keep appropriate records of experimental activities **(1.2.1 e)**
- make and record observations/measurements **(1.2.1 d)**
- present information and data in a scientific way **(1.2.1 f)**
- use a wide range of experimental and practical instruments, equipment and techniques **(1.2.1 j)**.

The practical activities can be completed at any point during the two year A level course at the discretion of the centre. Candidates starting from a standalone AS can count A level practical activities carried out during the AS year towards the A level Practical Endorsement provided that they are appropriately recorded. It is recommended therefore that candidates starting AS maintain a record of practical activities carried out (e.g. this could be in the form of a 'log book' or 'practical portfolio') that could be counted towards the Practical Endorsement. For candidates who then decide to follow a full A level, having started from AS, they can carry this record with them into their A level study.

The assessment of practical skills is a compulsory requirement of the course of study for A level qualifications in chemistry. It will appear on all students' certificates as a separately reported result, alongside the overall grade for the qualification. The arrangements for the assessment of practical skills are common to all awarding organisations. These arrangements include:

- A minimum of 12 practical activities to be carried out by each student which, together, meet the requirements of Appendices 5b (*Practical skills identified for direct assessment and developed through teaching and learning,* covered in Section **1.2.1**) and 5c (*Use of apparatus and techniques*, covered in Section **1.2.2**) from the prescribed subject content, published by the Department for Education. The required practical activities are defined by each awarding organisation (see **Fig. 1** and **Table 1**)
- Teachers will assess students against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The CPAC (see **Table 2**) are based on the requirements of Appendices 5b and 5c of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass.
- Each student will keep an appropriate record of their practical work, including their assessed practical activities
- Students who demonstrate the required standard across all the requirements of the CPAC, incorporating all the skills, apparatus and techniques (as defined in Sections 1.2.1 and 1.2.2), will receive a 'Pass' grade (note that the practical activity tracker available from OCR allows confirmation that the activities selected cover all the requirements).
- There will be no direct assessment of practical skills for AS qualifications
- Students will answer questions in the AS and A level examination papers that assess the requirements of Appendix 5a (*Practical skills identified for indirect assessment and developed through teaching and learning*, covered in Section **1.1**) from the prescribed subject content, published by the Department for Education. These questions may draw on, or range beyond, the practical activities included in the specification.

In order to achieve a pass, students will need to:

- develop these competencies by carrying out a minimum of 12 practical activities (**PAG1** to **PAG12**), which allow acquisition of all the skills, apparatus and techniques outlined in the requirements of the specification (Sections 1.2.1 and 1.2.2)
- consistently and routinely exhibit the competencies listed in the CPAC (**Table 2**) before the completion of the A-level course
- keep an appropriate record of their practical work, including their assessed practical activities
- be able to demonstrate and/or record independent evidence of their competency, including evidence of independent application of investigative approaches and methods to practical work.

The practical activities prescribed in the subject specification (**PAG1** to **PAG12**) will provide opportunities for demonstrating competence in all the skills identified, together with the use of apparatus and techniques for each subject. However, students can also demonstrate these competencies in any additional practical activity undertaken throughout the course of study which covers the requirements of appendix 5b and 5c (covered in Sections 1.2.1 and 1.2.2).

Students may work in groups but teachers who award a pass to their students need to be confident of individual students' competence.

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Table 2 Common Practical Assessment Criteria (CPAC) for the assessment of practical competency in A Level sciences

Competency	Practical Mastery
	In order to be awarded a Pass a Learner must, by the end of the practical science assessment, consistently and routinely meet the criteria in respect of each competency listed below. A Learner may demonstrate the competencies in any practical activity undertaken as part of that assessment throughout the course of study. Learners may undertake practical activities in groups. However, the evidence generated by each Learner must demonstrate that he or she independently meets the criteria outlined below in respect of each competency. Such evidence – **a)** will comprise both the Learner's performance during each practical activity and his or her contemporaneous record of the work that he or she has undertaken during that activity, and **b)** must include evidence of independent application of investigative approaches and methods to practical work.
(1) Follows written procedures	**a)** Correctly follows instructions to carry out experimental techniques or procedures.
(2) Applies investigative approaches and methods when using instruments and equipment	**a)** Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. **b)** Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. **c)** Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. **d)** Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
(3) Safely uses a range of practical equipment and materials	**a)** Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field. **b)** Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.
(4) Makes and records observations	**a)** Makes accurate observations relevant to the experimental or investigative procedure. **b)** Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
(5) Researches, references and reports	**a)** Uses appropriate software and/or tools to process data, carry out research and report findings. **b)** Cites sources of information, demonstrating that research has taken place, supporting planning and conclusions.

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Choice of activity

Centres can include additional skills, apparatus and techniques within an activity (PAG) beyond those listed as the minimum in **Table 1** or in the published practical activities. They may also carry out more than the minimum 12 practical activities required to meet the Practical Endorsement.

To achieve a Pass within the Practical Endorsement, candidates must have demonstrated competence in all the skills, apparatus and techniques detailed in Sections 1.2.1 and 1.2.2 of the specification by carrying out a minimum of 12 assessed practical activities (covering all of **PAG1** to **PAG12**) and achieved the level of competence defined within the Common Practical Assessment Criteria (**Table 2**).

The minimum of 12 activities can be met by:

(i) using OCR suggested activities (provided as resources from Interchange, or by contacting **pass@ocr.org.uk** should you be unable to access Interchange)

(ii) modifying OCR suggested activities to match available equipment whilst fulfilling the same skills, apparatus and techniques and CPAC

(iii) using activities devised by the centre and mapped against Section 1.2 of the specification and the CPAC

(iv) using activities from external sources such as the learned societies, mapped against Section 1.2 of the specification and the CPAC

Centres can receive guidance on the suitability of their own practical activities or against any of the options within **(ii)** to **(iv)** above through our free practical assessment support service by emailing **pass@ocr.org.uk**.

Where centres devise their own practical activity or use an alternative activity, that practical activity must be of a level of demand appropriate for A level.

Practical Activity Groups 1 to 12 can be achieved through more than one centre devised practical activity, and centres are not limited to 12 practical activities such that a centre could, for instance, split **PAG6** into two activities of their own (rather than one) with the two activities fulfilling the requirements. Alternatively it could be possible that an extended activity may cover the requirements of more than one group, in which case the centre could then select an additional activity from another group to achieve the required minimum of 12 practical activities.

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5h. Revision of the requirements for practical work

OCR will review the Practical Endorsement detailed in Section 5g of this specification following any revision by the Secretary of State of the skills, apparatus or techniques specified in respect of A Level Chemistry A.

OCR will revise the Practical Endorsement if appropriate.

If any revision to the Practical Endorsement is made, OCR will produce an amended specification which will be published on the OCR website. OCR will then use the following methods to communicate the amendment to centres: subject information update emailed sent to all Examinations Officers, e-alerts to centres that have registered to teach the qualification and social media.

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Your checklist

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

- [ ] Bookmark **ocr.org.uk/alevelchemistrya** 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 at **ocr.org.uk/updates**
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Free resources and support for our A Level Chemistry qualification, developed through collaboration between our Chemistry Subject Specialists, teachers and other subject experts, are available from our website. You can also contact our Chemistry Subject Specialists for specialist advice, guidance and support, giving you individual service and assistance whenever you need it.

Meet the team at ocr.org.uk/scienceteam and contact them at:
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