

Review of A-level Chemistry Content

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Chemistry

University of Southampton

**Includes: AQA, Edexcel, OCR A, OCR B (Salters), WJEC and CCEA
2015- specifications**

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Note on Version 1.2: Thanks to Daniele Gibney (OCR) for helpful guidance and discussion in preparing this updated version of the original document. Some content descriptors have been updated, the original labelling of content as 'A2' has been changed to 'AL', clearer guidance on mathematical requirements is provided and an appendix on practical work has been added. Thanks also to Chris Holland (Univ of Bristol) for corrections to content statements.

Introduction (from the point of view of the authors)

This review is a follow up to the documents produced in June 2007 and August 2010, which outlined the content of the different UK A-level chemistry specifications taught at those times. From September 2015, A-level chemistry students in England and Wales will be following new specifications that are different to those studied previously. This review is based around these new A-levels and is intended to give teachers, university academics and other interested parties a clear indication of what is to be covered at A-level from this time. In order to keep the document as simple as possible, we have focussed on detailing those topics that are dealt with by all or most of the specifications. Remarks on less common topics are added in notes rather than being detailed in the tables. It should also be noted that **CCEA** (Northern Ireland) have not updated their specification this year, and as such all information relates to the 2008 specification. To find out more about the precise detail of what is covered, the specifications can be accessed online at the links below:

AQA specification:

<http://filestore.aqa.org.uk/resources/chemistry/specifications/AQA-7404-7405-SP-2015-V1-0.PDF>

Edexcel specification:

http://qualifications.pearson.com/content/dam/pdf/A_Level/Chemistry/2015/Specification_and_sample_assessments/A_level_Chemistry_2015_Specification.pdf

OCR A specification:

<http://www.ocr.org.uk/Images/171720-specification-accredited-a-level-gce-chemistry-a-h432.pdf>

OCR B (Salters) specification:

<http://www.ocr.org.uk/Images/171723-specification-accredited-a-level-gce-chemistry-b-salters-h433.pdf>

WJEC specification:

<http://www.eduqas.co.uk/qualifications/chemistry/as-a-level/eduqas-a-chemistry-spec-from-2015.pdf>

CCEA specification:

http://www.rewardinglearning.org.uk/common/includes/microsite_doc_link.aspx?docid=1273-11

The first assessment of the new A-level specifications will be undertaken in 2017. For a preview of what the papers are likely to look like, links to specimen papers can be found below. It should be noted that specimen papers have not always been an accurate representation of the 'real' papers which subsequently appeared, but the awarding bodies have stressed that these papers have been designed with great care and they are therefore likely to be fair guide to the sorts of examinations that students will sit at the end of their studies.

AQA specimen papers:

<http://www.aqa.org.uk/subjects/science/as-and-a-level/chemistry-7404-7405/assessment-resources>

Edexcel specimen papers:

http://qualifications.pearson.com/en/qualifications/edexcel-a-levels/chemistry-2015_coursematerials.html -filterQuery=category:Pearson-UK:Category%2FSpecification-and-sample-assessments

OCR A specimen papers:

<http://www.ocr.org.uk/qualifications/as-a-level-gce-chemistry-a-h032-h432-from-2015/>

OCR B (Salters) specimen papers:

<http://www.ocr.org.uk/qualifications/as-a-level-gce-chemistry-b-salters-h033-h433-from-2015/>

WJEC specimen papers:

<http://eduqas.co.uk/qualifications/chemistry/as-a-level/>

CCEA specimen papers:

<http://ccea.org.uk/chemistry/>

Note that this review does not consider other qualifications beyond 'mainstream' A-levels. There are many schools around the UK delivering IB, which has much in common with A-level, but takes a different approach in some areas. Pre-U is another qualification which is taught in a relatively small number of schools, and evidently goes into much more depth than is found at A-level. Due to the limited uptake of these qualifications, we have been unable to devote the time to their inclusion in this review. Similarly, we have not been able to consider the content of Scottish Highers at this time. We would be very keen to work with anybody with inside knowledge of these other qualifications to add them to the review and would be happy to be contacted on the matter.

One feature of A-levels is the fact that different topics are taught in slightly different orders in different specifications, and there is no longer categorisation under traditional sub-divisions 'Inorganic', 'Organic' and 'Physical' (except for in the **AQA** specification). To make the document easier to follow, we have tried to group topics together under these traditional headings, while including topics like atomic structure, types of bonding and spectroscopy under 'General chemistry'. The contents page should allow for relatively easy navigation.

The tables should be straightforward to follow, with '**AS**' and '**AL**' indicating which part of the course the topic is found in (**AS** effectively represents the first year of the full A-level), and '**X**' indicating that the topic is not explicitly covered in a particular specification. Since there is technically no longer an 'AL' part of A-level, students will either end their studies with an AS-level, or they will undertake the full A-level with assessment at the end of the full two years of study. For the purposes of this review document, the label '**AL**' has been used to denote content which is not covered in the '**AS** part of the specification, and could be termed 'A-level only' content'. Teachers are free to teach content in any order they wish to.

If a content item is marked with an '**X**', this doesn't necessarily mean that students studying that specification haven't been exposed to that particular topic. However, it is probably a safe bet to assume this as many teachers report difficulties in getting through all of the content in an A-level and it is unlikely that time will be spent teaching topics that are not on their specification.

In terms of the significant changes in the new specifications, there is now a greater emphasis on mathematics in chemistry, with numerous equations (e.g. $pV=nRT$, $k=Ae^{-E_a/RT}$) being added. This is a result of a stipulation from OFQUAL that 20% of the marks on chemistry A-level examinations associated with the new specifications should be devoted to maths at Level 2 or above. Level 2 maths is defined in this case as (thanks to Daniele Gibney at OCR for clarification):

- 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 ways in which the maths will be assessed will only truly be realised upon first assessment in 2017. Whilst the 'inorganic' content hasn't changed much (if at all), there have been a few changes to the 'organic'

content. This is most notable in the case of the **OCR A** specification, where carbon-carbon bond forming reactions have returned, and substituent directing effects in relation to electrophilic aromatic substitution have been introduced. Overall the emphasis on crude oil, cracking, and fractional distillation has been reduced compared to the previous iteration, along with material relating to global warming and the greenhouse effect.

Despite the changes, the new A-level specifications appear to be more similar to each other in terms of content than they have been in previous years, which for those of us in universities will hopefully mean that the September 2017 intake of undergraduates have a more uniform grounding in the subject than we have seen previously. The awarding bodies have stated that exams will include more problem solving, an aspect that will not only challenge students but also allow them to be more prepared when they undertake exams at university. At first glance, it is our judgement that the 2015 reforms represent a positive change for A-level chemistry in terms of content and potential for skills development, but we will need to wait until the first assessments are undertaken in Summer 2017 to get a fuller picture. That is not to say that we are unconcerned by the potential detrimental impacts of changes to practical assessment, which many in the community feel will lead to a decline in the levels of practical work carried out in many schools and colleges, and may be compounded by changes to funding and the priorities of management teams. However, it should be noted that the system of practical assessment that has been in place since 2008 has itself had a detrimental effect on students' experience of practical work, based on anecdotal evidence from our discussions with teachers and students (a notable exception being the **OCR B Salters** extended investigation) and there may be positive outcomes depending on the approaches adopted by individual teachers towards the implementation of practical work in the classroom.

Another defining feature of the new A-levels will be the fact that they are to be terminally assessed, with students sitting all of their exams at the end of Year 13. Since chemistry is a subject which depends on a solid synoptic understanding, this will be deemed by many to be a positive development, but it is clear that there are potential negative impacts on the students themselves, of which we need to be mindful.

As always, the proof of the pudding will be in the eating. We are planning to stay in touch with our network of teachers locally over the next few years to gauge the impact of the changes on teaching and the student experience. This, along with work being done by colleagues across the country, will feed into an updated version of this document to be produced in 2017 to provide a preview of the '2017 1st Year Chemistry Undergraduate' in advance of their arrival at university that autumn.

Please report any errors/omissions to us at: d.read@soton.ac.uk

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Labelling of DfE core/non-core content: Topics written in *italics* are those which map to the core content, as specified by the Department for Education. The DfE criteria are very concise and it is not always clear what is demanded e.g. point 31. mentions 'properties of elements...within these groups', but not which properties are required. We have therefore made some assumptions in our attribution e.g. that "*The electronegativity of the halogens decreases down the group.*" and "*The reducing power of halide ions increases down the group.*" are considered as core content in that they are properties typically covered in the specifications.

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General chemistry - atomic structure (NOTE: italicised content is that which is specified as core content by the Dept for Education)

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Atoms (and ions & isotopes) are made from protons, neutrons and electrons. Atomic symbols in the periodic table can be used to work out how many of each particle is present.</i> Students should be able to draw representations of atoms, define ions, isotopes etc.	AS	AS	AS	AS	AS	AS
<i>Electron shells are made up of sub-shells and orbitals.</i> Students should be able to work out electron configurations.	AS	AS	AS	AS	AS	AS
Atomic orbitals have different shapes. Students should be able to describe the shapes of s & p orbitals (+ d orbitals for WJEC).	X	AS	AS	AS	AS	AS
<i>Electronic structure influences the chemical properties of an element (ions typically formed with noble gas configuration).</i> O: $1s^2 2s^2 2p^6 3s^2 3p^4$ (or $[Ne] 3s^2 3p^4$). They can also draw 'electrons (arrows) in boxes'.	AS	AS	AS	AS	AS	AS
<i>Ionisation is the removal of one or more electrons, and ionisation energy is affected by atomic radius, nuclear charge, and electron shielding.</i> Students should be able to explain the role of atomic radius, nuclear charge and electron shielding in magnitudes of IE values, & describe evidence for the existence of sub-shells.	AS	AS	AS	AS	AS	AS
<i>Ionisation energies decrease down a group (e.g. Group 2).</i> Students should be able to use similar arguments to those above to explain this.	AS	AS	AS	AS	AS	AS
<i>Successive ionisation energies of elements provide evidence for the existence of sub-shells.</i> Students should be able to explain the trend in successive ionisation energies for an element (e.g. Na) using ideas about the charge on the ion and sub-shells.	AS	AS	AS	AS	AS	AS

OCR Salters requires knowledge of ideas about nuclear fusion forming elements in stars, and also covers nuclear fission. Radioactive decay and nuclear equations are also covered by **WJEC**. Atomic spectra are covered briefly by **Edexcel** and in some detail by **Salters, WJEC**, and **CCEA**, incorporating absorption/emission of quantised energy, with the precise wavelengths being characteristic of the element. Lyman, Balmer and Paschen series are covered.

General chemistry - moles and equations

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p>Definitions of relative atomic, formula, isotopic and molecular mass on C-12 scale.</p> <p>Students should be able to calculate relative atomic mass from % abundances/masses in a simple mass spectrum.</p>	AS	AS	AS	AS	AS	AS
<p>Relative masses and abundances of ions can be measured using a mass spectrometer.</p> <p>Students can derive R.A.M. (or R.F.M.) and % isotopic abundance from spectra. AQA requires knowledge of the operation of a TOF spectrometer, while other specifications do not mention a requirement for similar knowledge.</p>	AS	AS	AS	AS	AS	AS
<p>Students should be able to interpret simple mass spectra of elements and compounds, and appreciate that elements and compounds can be identified using mass spectrometry. Edexcel requires students to predict mass spectra for diatomic molecules.</p>	AS	AS	AS	AS	AS	AS
<p>Fragmentation occurs in mass spectrometry leading to peaks in the spectrum at lower m/z values.</p> <p>Students should recognise that fragmentation patterns give information regarding structure (e.g. loss of CH₃, C₂H₅ etc.).</p>	X	AS	AS	AS	X	AS
<p>The mole is a measure of the amount of a substance.</p> <p>Students should be able to calculate amount of substance (moles), no. of particles, concentration of solutions, and moles from gas volumes (at RTP), rearranging equations where appropriate.</p>	AS	AS	AS	AS	AS	AS
<p>Empirical formulae can be calculated from information regarding masses of elements in compounds, experimental results (e.g. from combustion analysis) or % compositions.</p> <p>Students should be able to carry out the appropriate calculations.</p>	AS	AS	AS	AS	AS	AS
<p>Molecular formulae can be calculated using the empirical formula/R.F.M.</p> <p>Students should be able to carry out the appropriate calculations.</p>	AS	AS	AS	AS	AS	AS

General chemistry - moles and equations cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Chemical equations can be used to show what happens in a reaction.</i></p> <p>Students should be able to balance equations (inc. state symbols), and use balanced equations to work out reacting masses/gas volumes.</p>	AS	AS	AS	AS	AS	AS
<p><i>Acid base titrations are used in quantitative analysis (note that CCEA specifies a requirement for knowledge of back titrations).</i></p> <p>Students should be able to perform appropriate calculations.</p>	AS	AS	AS	AS	AS	AS
<p><i>The theoretical yield of a reaction is the maximum amount that could be obtained in a reaction, while the % yield is the actual amount obtained.</i></p> <p>Students should be able to calculate theoretical and percentage yields.</p>	AS	AS	AS	AS	AS	AS
<p>Students should be able to explain what is meant by the term atom economy and carry out associated calculations.</p>	AS	AS	AS	AS	AS	AS
<p><i>Ionic equations only show the reacting particles, and the charges on both sides must balance.</i></p> <p>Students should be able to write ionic equations for relevant reactions (although they often find it very difficult).</p>	AS	AS	AS	AS	AS	AS
<p>The ideal gas equation is $pV = nRT$.</p> <p>Students should be able to use the equation in calculations.</p>	AS	AS	AS	AS	AS	X

General chemistry - covalent bonding and shapes of molecules

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Molecules are groups of atoms held together by covalent bonds (shared pairs of electrons).</i></p> <p>Students should be able to represent molecules using dot + cross diagrams (Lewis structures normally not taught).</p>	AS	AS	AS	AS	AS	AS

General chemistry - covalent bonding and shapes of molecules cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>π bonds are formed by overlap of two p orbitals (see also p.23 and p.24).</i> AQA spec doesn't cover the shape of p-orbitals, so understanding of π bonding may be limited. Generally, students should be able to describe the bonding in ethene and represent that molecule using a dot-and-cross diagram or rough sketches of the molecular orbitals. Note: knowledge of σ and π bonding may be patchy across the cohort.	(AS)	AS	AS	AS	AS	AS
<i>Dative (coordinate) covalent bonding is where both electrons come from one atom (e.g. NH_4^+).</i>	AS	AS	AS	AS	AS	AS
<i>The shape of a molecule is determined by the no. of electron pairs around the central atom.</i> Students should be able to explain that lone pairs repel more than bonding pairs.	AS	AS	AS	AS	AS	AS
<i>VSEPR theory can be used to work out the shapes of molecules and ions.</i> Students should be able to derive the shapes of species up to 6 coordinate species	AS	AS	AS	AS	AS	AS

General chemistry – intermolecular forces

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>The ability of an atom of an element to attract bonding electrons in a covalent bond is its electronegativity, measured on the Pauling scale.</i>	AS	AS	AS	AS	AS	AS
<i>Polar covalent bonds arise when the two atoms involved have differing electronegativities.</i>	AS	AS	AS	AS	AS	AS
<i>Polar bonds may lead to a polar molecule, except in cases where the polar bonds point in opposite directions, so the dipoles cancel each other out.</i> Students may or may not have been taught this with reference to symmetry.	AS	AS	AS	AS	AS	AS
<i>Intermolecular forces are much weaker than bonds between atoms.</i>	AS	AS	AS	AS	AS	AS

Note that **Salters** uses 'Intermolecular bond' rather than 'force', which may present some confusion to students when they were taught about 'forces between molecules' at GCSE level, rather than 'bonds'.

General chemistry – intermolecular forces cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Polar molecules experience attractive permanent dipole-dipole forces.</i> Students should be able to explain the influence of these forces on melting and boiling pts.	AS	AS	AS	AS	AS	AS
<i>Induced dipole-dipole forces are another type of intermolecular force.</i> Students should be able to explain the effect of the size and shape of a molecule on the strength of intermolecular forces, and the consequent effect on boiling & melting points.	AS	AS	AS	AS	AS	AS
<i>Hydrogen bonding arises when H is bonded to highly electronegative atoms.</i> Students can show H-bonding in water/ammonia by drawing diagrams showing lone pairs, dipoles and dashed lines representing H-bonds.	AS	AS	AS	AS	AS	AS
<i>Hydrogen bonding leads to higher melting points and boiling points, and makes compounds soluble in water.</i> Students should be able to explain why ice floats on water using ideas about H-bonds.	AS	AS	AS	AS	AS	AS

General chemistry – ionic, metallic and giant covalent substances

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Ionic bonding arises from the strong electrostatic attraction between ions of opposite charge.</i>	AS	AS	AS	AS	AS	AS
<i>Ions are formed when atoms gain/lose electrons to obtain a noble gas configuration.</i> Students should be able to represent ions using dot-and-cross diagrams, and derive the formula of an ionic compound using information about ionic charges.	AS	AS	AS	AS	AS	AS
<i>Sodium chloride has a giant ionic lattice structure (cube shaped) with many strong ionic bonds.</i> Students should be able to describe/explain properties of ionic cpds (high m.pt/b.pt, conductivity) in terms of energy required to break bonds/ion mobility in different states.	AS	AS	AS	AS	AS	AS

General chemistry – ionic, metallic and giant covalent substances cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Metals have giant structures with positive ions in a lattice surrounded by a sea of delocalised e⁻. Students should be able to describe and explain the properties (m.pt, b.pt, conductivity, and ductility/malleability) with reference to structure.</i>	AS	AS	AS	AS	AS	AS
<i>Diamond, graphite (allotropes of C) and SiO₂ have giant covalent (macromolecular) structures. Students should be able to describe/explain properties of substances (type of bonding).</i>	AS	AS	AS	AS	AS	AS

Edexcel is the only specification to go into any detail on polarisation/polarisability, but teaching of the topic is required for **AQA** to explain the covalent character of ionic compounds (p.29). **OCR Salters** requires knowledge of synthesis of soluble and insoluble salts, and the factors which determine the solubility of ionic compounds for a range of combinations of ions.

General chemistry – spectroscopy and chromatography

Note that coverage of mass spectrometry was discussed on p.7.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>IR radiation causes bonds in molecules to vibrate, and this is the basis for IR spectroscopy. Students should be able to interpret spectra of compounds such as alcohols and carbonyl compounds. OCR A and Edexcel are more detailed than the others.</i>	AS	AS	AS	AS	AS	AS
Students should be able to relate global warming to the absorption of IR radiation by greenhouse gases in the atmosphere. OCR Salters is more detailed than others.	AS	X	AS	AS	X	AS
<i>NMR spectroscopy can be used to gain information about the structure of organic molecules. Students should be able to interpret simple spectra to identify the number of protons in different environments with reference to given data on chemical shift values.</i>	AL	AL	AL	AL	AS	AL

General chemistry – spectroscopy and chromatography cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Peaks in NMR spectra can be split by spin-spin coupling.</i> Students should be able to use the n+1 rule to deduce the number of protons on an adjacent carbon atom from the splitting pattern in an N.M.R. spectrum. OCR A requires explanation of the identification of labile protons using D₂O.	AL	AL	AL	AL	AL	AL
<i>Carbon-13 NMR spectroscopy can provide further information regarding structure</i>	AL	AL	AL	AL	AS	X
<i>Chromatography can be used to separate mixtures (details below).</i>	AL	AL	AL	AL	AL	AL
TLC and paper chromatography (AQA requires knowledge of developing agents such as ninhydrin and UV light, and CCEA discusses 2 way chromatography).	AL	AL	AL	AS	AL	AL
Gas (or gas-liquid) chromatography.	AL	AL	AL	AL	AL	AL
Column chromatography. Edexcel and WJEC explicitly mention high performance liquid chromatography (HPLC).	AL	AL	X	X	AL	X
Chromatography combined with MS (e.g. GC-MS).	AL	AL	X	AL	X	AL

The level of N.M.R. theory taught will vary. Theory will not be examined, so many teachers will have kept it simple.

Aspects of green chemistry are still included in some of the new specifications, although there are no longer discrete units of teaching with the title 'Green Chemistry'. Topics that students may have covered include biofuels and other alternatives, the importance of catalysts and catalytic converters, waste reduction and use of renewable materials/energy sources. In some cases these are listed in specifications, in others they may be utilised as contexts for teaching other content.

Inorganic chemistry - the periodic table and ionisation energies

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Atomic radii, ionic radii, electronegativity, and thermal/electrical conductivity change as you go across a period. The topic is only mentioned vaguely in Salters, WJEC and Edexcel.</i></p> <p>Students should be able to describe & explain trends in these properties across a period.</p>	AS	AS	AS	AS	AS	AS
<p><i>Melting and boiling points across a period depend on the type of bonding/structure present.</i></p> <p>Students should be able to explain the trends in melting points of the elements across a period using ideas from the previous sections (Bonding and Structure).</p>	AS	AS	AS	AS	AS	AS
<p><i>Ionisation energy generally increases across a period.</i></p> <p>Students can explain the trend in IE across Period 3 using ideas about nuclear charge, s/p subshells, spin pairing, and electron repulsion (see also below).</p>	AS	AS	AS	AS	AS	AS
<p><i>There is a drop in ionisation energy from Group 2 to Group 3.</i></p> <p>Students should be able to explain this in terms of the orbitals the electrons are found in and the shielding by other electrons.</p>	AS	AS	AS	AS	AS	AS

Inorganic chemistry – redox processes

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Reduction and oxidation occur simultaneously in redox reactions. Oxidising agents accept electrons, and reducing agents donate electrons.</i></p> <p>Students should be able to write half-equations to show redox reactions.</p>	AS	AS	AS	AS	AS	AS
<p><i>Oxidation numbers or oxidation states (note that the two terms are often used interchangeably) can be assigned using a set of simple rules.</i></p> <p>Students should be able to work out the oxidation state of an element in a compound/ion.</p>	AS	AS	AS	AS	AS	AS
<p><i>The oxidation state increases when electrons are lost (oxidation), and decreases when electrons are gained (reduction).</i></p> <p>Students should recognise that disproportionation can occur e.g. $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{HCl}$</p>	AS	AS	AS	AS	AS	AS

AQA specifies knowledge of extraction of metals such as titanium.

Inorganic chemistry – s-block elements

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Key trends of s-block elements.</i></p> <p>Students should be able to describe and explain the trends of the following properties down groups 1 and 2: atomic and ionic radii, reactivity, electronegativity, and m.pt/b.pt.</p>	AS	AS	AS	AS	AS	AS
<p>Ions of s-block metals have distinctive flame colours (due to electronic transitions etc.).</p> <p>Students should recall that using a spectroscope gives a line emission spectrum.</p>	X	AS	X	AS	AS	AS
<p><i>Group 1 metals are the most reactive metals, which are easily oxidised to M^+ ions.</i></p> <p>Students should be able to explain the trend in reactivity down the group.</p>	AS	AS	AS	AS	AS	AS
<p><i>Group 2 metals react with water to produce hydroxides $M(\text{OH})_2$</i></p> <p>Students can write balanced symbol equations to show these reactions. Note that some specifications require knowledge of other reactions e.g. with chlorine, acid, oxygen.</p>	AS	AS	AS	AS	AS	AS

Inorganic chemistry – s-block elements cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>s</i> -block metal oxides and hydroxides are bases, forming alkaline solutions. Students should be able to recall approximate pH values of these solutions.	AS	AS	AS	AS	AS	AS
Group 2 metal carbonates decompose forming the oxide and carbon dioxide. Students should be able to describe and explain the trend in the stabilities of the Group 1 carbonates & nitrates as well as the Group 2 nitrates.	X	AS	X	AS	X	AS
Students should be able to describe & explain trends in the stabilities of Gp 2 carbonates.	X	AS	X	AS	AS	AS

Inorganic chemistry – halogens and halides

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>The halogens are reactive non-metals in Group 7 (or Group 17 in OCR specifications).</i> Students should be able to describe trends in boiling point and explain the reactivities in displacement reactions in terms of oxidising power. They can link this to size & attraction of electrons. Appearance in aqueous and organic solutions is also discussed.	AS	AS	AS	AS	AS	AS
<i>The electronegativity of the halogens decreases down the group.</i> Students should be able to describe this trend using converse arguments to those above.	AS	X	AS	X	X	AS
<i>Chlorine reacts with water and alkalis in disproportionation reactions to give useful products.</i> Students should be able to explain why these reactions are useful, write balanced equations and assign oxidation states appropriately.	AS	AS	AS	AS	AL	AS
<i>Salts of different halides react differently with sulphuric acid.</i> Students should be able to write equations for these reactions and assign oxidation states to identify oxidation and reduction.	AS	AS	X	AS	AL	AS

Inorganic chemistry – halogens and halides cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Silver nitrate and ammonia can be used to identify halide ions present in salts.</i></p> <p>Students should be able to describe the appearance of precipitates and the effect of adding dil./conc. ammonia solution. Students should be able to write ionic/full equations.</p>	AS	AS	AS	AS	AS	AS
<p>Hydrogen halides are colourless, acidic gases.</p> <p>Students should know the trends in thermal stability of hydrogen halides.</p>	X	AS	X	AS	X	AS
<p>Hydrogen halides can be prepared by reacting a halide salt and phosphoric acid.</p>	X	X	X	AS	X	X
<p>Chlorine can be used in water treatment.</p> <p>Students should be able to discuss the advantages and disadvantages in deciding whether chemicals should be added to water supplies.</p>	AS	X	AS	AS	AS	X

OCR Salters require a description of the extraction of chlorine by electrolysis of brine, and also requires knowledge of the risks of storage and transport and the recall of uses. **CCEA** includes reactivity towards hydrogen, phosphorous and sodium as well as NaOH and Fe^{II} and Fe^{III}. **OCR A** includes reactivity towards NaOH.

Inorganic chemistry – transition metals, complex ions and metal-aqua ions

WJEC is unique in its extensive coverage of p-block elements including: inert pair effect, expansion of the octet, general properties of p-block chlorides and general trends down each group. See the specification for details.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Transition metals are found in the d-block and can form one or more stable ions with a partially filled d-subshell.</i></p> <p>Students should be able to deduce electron configurations on atoms and ions and show them using standard notation and electrons (arrows) in boxes.</p>	AL	AL	AL	AL	AL	AL

Inorganic chemistry – transition metals, complex ions and metal-aqua ions cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Transition metals have similar chemical properties, and a range of special chemical properties (complex ion formation, coloured ions, catalysis, and variable [O] state).</i>	AL	AL	AL	AL	AL	AL
<i>Transition metals and their compounds make good catalysts because they can change oxidation states by gaining and/or losing electrons.</i>	AL	AL	AL	AL	AL	AL
<i>Complex ions are metal ions surrounded by ligands.</i> Students should be able to use the term coordination number in relation to octahedral, tetrahedral and linear complexes. They should also be able to draw complexes showing coordinate bonds with wedges/dashes. They should also be able to work out the charge on the complex from the [O] state of the metal and the charge(s) on the ligand(s).	AL	AL	AL	AL	AL	AL
<i>Ligands donate one or more lone pairs to form coordinate bonds.</i>	AL	AL	AL	AL	AL	AL
Complexes of transition metals sometimes exhibit stereoisomerism.	AL	AL	AL	X	X	AL
<i>Transition metal complexes are typically coloured.</i>	AL	AL	AL	AL	AL	AL
Students should be able to explain why transition metal complexes have colour including knowledge of partially filled d orbitals.	AL	AL	X	AL	AL	X
Colorimetry is a technique that can be used in experiments where measurements involving coloured solutions are required (e.g. in the investigation of reaction rates).	AL	X	AL	AL	AL	AL
<i>Ligand substitution reactions can occur.</i> Students should be able to write equations for a range of ligand exchange reactions, noting colour changes, coordination number/shape changes and instances of partial exchange.	AL	AL	AL	AL	AL	AL
Complex ions can have different stabilities. Students should be able to explain/predict the stability of complex ions in terms of the entropy changes that would occur during ligand exchange reactions. (AQA explicitly mentions the chelate effect).	AL	X	X	X	X	AL

Inorganic chemistry – transition metals, complex ions and metal-aqua ions cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Haemoglobin is a complex of iron with the multidentate ligand haem. Ligand substitution reactions are important in the transportation of oxygen.	AL	AL	AL	X	X	AL
EDTA is a commonly used hexadentate ligand.	AL	AL	X	AL	X	AL
<i>Metal aqua ions are formed by the coordination of water molecules to transition metals.</i> Students should be able to represent aqua ions e.g. $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ using 3D diagrams.	AL	AL	AL	AL	AL	AL
Metal-aqua ions react with hydroxide to form uncharged metal hydroxides, which are coloured solids and precipitate out of solution, and... Students should be able to describe observations and write balanced equations to explain the outcome of these reactions.	AL	AL	AL	AL	AL	AL
...the addition of ammonia in small quantities, and in excess, can lead to further reactions. Students should be able to describe observations and write balanced equations to explain the outcome of these reactions.	AL	AL	AL	AL	X	X
Redox titrations can be performed using oxidants (MnO_4^- , $\text{Cr}_2\text{O}_7^{2-}$). Students should be able to perform redox titrations and associated calculations.	AL	AL	AL	AL	AL	AL
Students should have an awareness of the ability of transition metals to undergo redox reactions.	AL	AL	AL	AL	AL	AL
Students should be able to perform iodine-thiosulphate titrations and appropriate calculations.	X	AL	AL	AS	AL	AL
<i>Transition metal ions undergo characteristic reactions with aqueous hydroxide.</i>	AL	AL	AL	AL	AL	AL
Students should be able to rationalise precipitation reactions as acid-base equilibria.	AL	AL	X	X	X	AL

Coverage is diverse in the new specifications, so we haven't included a full breakdown. Details can be found in the specifications. Students will have studied examples of transition metals and their chemistry, but which ones will depend on the specification and the teacher.

Inorganic chemistry – the elements of period 3

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
The elements of Period 3 react with oxygen to form oxides. Students should be able to recall the formulae and describe trends in oxidation state, bonding and structure of the period 3 oxides.	AL	X	X	X	X	AL
The properties of Period 3 oxides are related to their bonding and structure. Students should be able to describe trends in melting point and acidity/alkalinity of the oxides in solution explaining these trends using ideas about bonding and structure.	AL	X	X	X	X	AL
The elements of Period 3 react with chlorine to form chlorides. Students should be able to relate properties to trends in bonding/structure.	X	X	X	X	X	AL

Organic chemistry – reactions covered throughout A-level

Reaction	AQA	Ed	OCR A	Salter's	WJEC	CCEA
Acyl Chlorides:						
+ water → carboxylic acid	AL*	AL	AL	X	X	AL
+ alcohols → esters	AL*	AL	AL	AL	AL	AL
+ conc. ammonia → amides	AL*	AL	AL	AL	AL	AL
+ primary amines → amides	AL*	AL	AL	AL	AL	AL
Addition Polymerisation	AS	AS	AS	AS	AS	AS
Alcohols:						
+ [O] → aldehydes/ketones/carboxylic acids	AS	AS	AS	AS	AS	AS
+ HCl → chloroalkane	X	X	X	AS	AL	AS
+ PCl ₅ → chloroalkane	X	AS	X	X	X	AS
+ NaBr/H ₂ SO ₄ → bromoalkane	X	X	AS	X	X	X
dehydration → alkenes	AS	X	AS	AS	AS	AS
+ carboxylic acids → esters	AL	AL	AL	AS	AS	AS
+ sodium → sodium ethoxide	X	X	X	X	X	AS
Amide Hydrolysis	AL ¹	X	AL ¹	AL	AL	X
Amine Formation:						
alkyl halide + ethanolic ammonia	AL	AS	AL	AS	AL	AL
reduction of aromatic nitro compounds	X	AL	AL	X	AL	AL
reduction of nitrile	AL	AL	AL	X	AL	AL
Amines:						
+ acid → salt	AL	AL	AL	AL	AL	AL
+ acyl chloride → amide	AL	AL	X	AL	AL	AL
+ halogenoalkane → secondary amine	AL	AL	AL	X	AL	AL
+ P ₂ O ₅ → nitrile	X	X	X	X	X	AL
Azo Dye Formation	X	X	X	AL	AL	AL
Carbonyl Compounds (Aldehydes+Ketones):						
formation from alcohols	AS	AS	AS	AS	AS	AL
oxidation of aldehydes to carboxylic acids	AS	AS	AS	AL	AL	AL
+ HCN → cyanohydrin (hydroxynitrile)	AL*	AL*	AL*	AL*	AL*	AL*
+ hydride → alcohol	AL*	AL	AL*	X	AL	AL
+ 2,4-DNP	X	AL	AL	X	AL	AL
Carboxylic Acids:						
+ alkalis/carbonates	AL	AL	AL	AL	AS	AL
+ metals	X	X	AL	AL	X	X
+ alcohols → esters	AL	AL	AL	AL	AS	AL
+ LiAlH ₄ → alcohol	X	AL	X	X	AL	AL
+ PCl ₅ (SOCl ₂ on OCR A) → acyl chloride	X	AL	AL	X	AL	AL
Decarboxylation	X	X	X	X	AL	X
Carboxylic acid (aromatic) formation by [O] of methyl side chains with Mn (VII)/H ⁺	X	X	X	X	AL	X
Combustion of Alkanes	AS	AS	AS	AS	AS	AS
Condensation Polymerisation	AL	AL	AL	AL	AL	AS

¹ In the context of hydrolysis of proteins (AQA) and polyamides (AQA and OCR A).

Organic chemistry – reactions covered throughout A-level cont.

Reaction	AQA	Ed	OCR A	Salters	WJEC	CCEA
Cracking/Reforming	AS	AS	X	AS	X	AS
<i>Electrophilic Addition Reactions of Alkenes:</i>						
+ bromine	AS*	AS*	AS*	AS*	AS*	AS
+ hydrogen bromide	AS*	AS*	AS*	AS*	AS*	AS*
+ hydrogen (Ni or Pt cat)	X	AS	AS	AS	AS	AL
+ water (H ₂ SO ₄ or H ₃ PO ₄)	AS*	AS	AS	AS	AS	AS
+ permanganate → diols	X	AS	X	X	X	X
<i>Electrophilic Substitution of Aromatics:</i>						
halogenation	X	AL*	AL*	AL*	AL*	AL*
nitration	AL*	AL*	AL*	AL*	AL*	AL*
sulfonation	X	X	X	AL	X	X
Friedel-Crafts alkylation	X	AL*	AL	AL	AL	X
Friedel-Crafts acylation	AL*	AL*	AL	AL	X	X
Elimination	AS* ²	AS	AS	AS	AS	AS
Ester Formation – also see alcohols/acids	AL	AL	AL	AS	AS	AL
Ester <i>Hydrolysis</i>	AL	AL	AL	AL	X	AL
Fermentation	AS	X	X	X	AS	AS
Halogenoalkanes:						
+ H ₂ O/OH ⁻ → alcohol	AS*	AS*	AS*	AS*	AS*	AS*
+ ethanolic OH ⁻ → alkene	AS*	AS	X	X	AS	AS
+ ethanolic ammonia → amine	AS	AS*	AL	AS	AL	X
+ amines → secondary amines	AL*	X	AL	X	AL	AS
+ CN ⁻	AS	AS	AL	X	AL	AL
Halogenation of Alkanes (<i>Radical Substitution</i>)	AS*	AS*	AS*	AS*	AS*	AS*
<i>Hydrolysis</i> of Nitriles	X	X	AL	X	AL	X
<i>Nucleophilic Addition (see carbonyl cpds):</i>						
+ HCN → cyanohydrin (hydroxynitrile)	AL*	AL*	AL*	AL	AL*	AL*
+ hydride → alcohol	AL*	AL	AL*	X	X	AL
<i>Nucleophilic Substitution</i>	AS*	AS*	AS*	AS*	AS*	AS
Ozone Depletion	AS*	X	AS*	AS	X	X
Phenols:						
+ alkalis (not carbonates)	X	X	AL	AS	AL	X
test with iron (III) chloride	X	X	X	AS	AL	X
+ acyl chlorides/acid anhydrides → esters	X	X	X	AS	AL	X
+ bromine → 2,4,6-tribromophenol	X	AL	AL	X	AL	X
+ dilute nitric acid → 2-nitrophenol	X	X	AL	X	X	X
Transesterification	AL	X	X	X	X	X

Note: ‘*’ indicates that the specification requires knowledge of the mechanism for that reaction. As is mentioned elsewhere in this review, Edexcel and CCEA are the only specs to require S_N1 & S_N2. The generic ‘nucleophilic substitution’ reaction they all learn about is actually the S_N2 mechanism, although few of them will use the term.

² The mechanism for base-catalysed elimination is needed, but not for acid-catalysed elimination.

Organic chemistry – functional groups and nomenclature

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Students should be able to recognise and demonstrate the ability to name compounds in the following homologous series: alkanes, branched alkanes, cycloalkanes, halogenoalkanes, alkenes, alcohols, carboxylic acids, and esters.</i>	AS	AS	AS	AS	AS	AS
<i>Students should be able to recognise and demonstrate the ability to name compounds in the following homologous series: aldehydes and ketones.</i>	AS	AL	AS	AS	AL	AS
Students should have knowledge of tests for aldehydes and ketones.	AL	AL	AL	AL	AL	AL
Students should be able to describe a test for a methyl carbonyl group.	X	AL	X	X	AL	X
Students should be aware of the structure and properties of fats and oils (CCEA requires knowledge of their iodine value).	AL	X	X	AL	X	AL
Students should be aware of the positive and negative implications for Biodiesel use.	AL	AS	X	AS	X	X
Students should be able to recognise and demonstrate the ability to name compounds in the following homologous series: acyl chlorides.	AL	AL	X	AL	AL	AL
Students should be able to recognise and demonstrate the ability to name compounds in the following homologous series: acid anhydrides.	AL	X	AL	AS	X	X

Individual specifications can be referred to for further clarification on the requirements for recognising/naming homologous series. Generally, molecules with more than 6 C atoms will not be tested. The naming of ethers is only specified by **OCR Salters**, however may still be taught by teachers on other specifications. Students will have varying levels of confidence with nomenclature with many being unfamiliar with non-IUPAC names such as acetone or acetic acid.

Organic Chemistry – isomerism

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Representing organic compounds:</i></p> <p>Students should be able to represent organic compounds using the following:</p> <p>Molecular formulae, structural formulae, displayed formulae and skeletal formulae (they should also be able to use general formulae and empirical formulae).</p> <p>CCEA do not specify skeletal formulae, however many teachers will still teach them. Some students will be able to draw different representations without understanding what is meant by terms such as 'displayed formula'.</p>	AS	AS	AS	AS	AS	AS
<p><i>Structural isomers have the same molecular formula, but their atoms are arranged in a different way (to include chain isomers e.g. butane vs methyl propane and positional isomers e.g. propan-1-ol vs propan-2-ol).</i></p> <p>Students should be able to recognise, name, and predict the existence of isomers within the homologous series encountered at this level.</p>	AS	AS	AS	AS	AS	AS
<p><i>Geometric isomers are found in alkenes which have two different groups attached to each carbon of the C=C (see also p.9 and p.24).</i></p> <p>E/Z nomenclature is taught in favour of traditional cis/trans, although they may still be taught in parallel. OCR A and AQA require the application of Cahn-Ingold-Prelog rules.</p>	AS	AS	AS	AS	AS	AS
<p><i>Optical isomers are mirror images of each other.</i></p> <p>Students should be able to describe the optical activity of enantiomers.</p>	AL	AL	AL	AL	AL	AL
<p><i>Most optical isomers are produced as racemic mixtures in the lab.</i></p> <p>Students should be able to identify chiral centres in molecules. Note that Edexcel, WJEC, and CCEA cover this in great detail.</p>	AL	AL	AL	AL	AL	AL
<p><i>Optical isomers can rotate plane-polarised light (racemic mixtures do not).</i></p>	AL	AL	X	X	AL	AL

Organic chemistry – hydrocarbons

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Alkanes are saturated hydrocarbons that are useful as fuels. Students should be able to write a balanced symbol equation to represent combustion.	AS	AS	AS	AS	AS	AS
Alkenes are unsaturated hydrocarbons which exhibit geometric isomerism due to restricted rotation around the C=C bond (see also p.9 and p.23). Students should be able to explain restricted rotation in terms of the formation of a π-bond when the two p-orbitals overlap. Students should also recognise that the reactivity of alkenes is due to the double bond being a region of high e- density.	AS	AS	AS	AS	AS	AS
Crude oil can be separated into fractions containing hydrocarbons of different chain lengths by using fractional distillation. Students should be able to explain varying boiling points of alkanes (branched and straight chain) in terms of intermolecular forces and packing. (Although AQA doesn't specify this, intermolecular forces are covered elsewhere in the spec, so students should reasonably be expected to make the link).	AS	AS	X	X	X	AS
Branched chain alkanes and cycloalkanes can be added to petrol to improve the efficiency of combustion and eliminate knocking.	AS	X	X	X	X	AS
Straight chain alkanes can be isomerised to create branched chain isomers and reformed into cycloalkanes, which can be used as fuel additives.	AS	X	X	X	X	AS
Long chain hydrocarbons can be cracked to make smaller, more useful molecules. Shorter chain alkanes (used in fuels) and alkenes (used in polymers) are produced. Students should be able to describe the reaction using an equation and with reference to the use of a catalyst (as well as discussing economic considerations). Thermal cracking is explicitly mentioned in the AQA spec, and may be covered elsewhere.	AS	AS	X	AS	X	AS

Organic chemistry – polymers

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Amino acids can act as acids and bases and can form zwitterions.</i>	AL	AL	AL	AL	AL	AL
Proteins are condensation polymers of amino acids, which can undergo hydrolysis. Students should be able to give details of the reaction (reagents, conditions), including the identification of peptide bonds in structures.	AL	X	X	AL	AL	X
Proteins have different levels of structure. More detailed structural knowledge required by CCEA and Salters. AQA and Salters also require knowledge of the structure of DNA, with AQA and WJEC also requiring knowledge of enzymes. Many students will be able to describe primary, secondary and tertiary structure in terms of the intermolecular forces involved.	AL	X	X	AL	AL	AL
<i>Addition polymers are formed when many alkene monomers join together.</i> Students should be able to draw the polymer made from a specified monomer and vice versa. They should also be able to discuss the uses of polymers. CCEA needs LDPE and HDPE, as well as branching crystallinity and properties.	AL	AS	AS	AL	AS	AL
Polymers with different properties have different uses. Students should be able to relate the properties of polymers (e.g. LDPE, HDPE, PVC, PTFE, PS) to their uses.	AL	AL	X	X	X	AL
There are environmental consequences of the disposal of plastics.	AL	AL	AL	AL	X	AL
<i>Condensation polymers are usually made from two different types of monomer.</i> Students should be able to describe the formation of polyamides (e.g. nylon) and polyesters (e.g. terylene) and give details of the reactions (reagents, conditions, mechanism). They should be able to represent the polymers by showing repeat units.	AL	AL	AL	AL	AL	AL
Polyesters and polyamides are biodegradable because of the ease of hydrolysis of the links.	AL	AL	AL	AL	AL	AL

Organic chemistry – halogenoalkanes

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Alkanes that contain halogen atoms are called halogenoalkanes (or haloalkanes). Students should be able to name simple primary, secondary and tertiary halogenoalkanes and represent them using the different types of formulae discussed earlier.	AS	AS	AS	AS	AS	AS
The rate of hydrolysis of halogenoalkanes depends on the halogen present. Students should be able to describe the use of silver nitrate in the experiment and explain the results in terms of C-X bond strength.	AS	AS	AS	AS	AS	X

Organic chemistry – alcohols

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Alcohols are organic molecules that contain –OH groups. Students should be able to explain the high boiling points and water solubility of alcohols in terms of H-bonding, and name & represent a range of primary, secondary, and tertiary alcohols.	AS	AS	AS	AS	AS	AS

Organic chemistry – aromatic compounds

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Benzene and its derivatives are known as aromatic compounds. Students should be able to recognise and name examples of aromatic compounds.	AL	AL	AL	AL	AL	AL
Benzene is a planar molecule with 6 delocalised π -electrons. Students should be able to describe the structure/bonding in aromatic rings.	AL	AL	AL	AL	AL	AL
The delocalised model of benzene is supported by experimental evidence. Evidence includes bond lengths, enthalpy of hydrogenation and resistance to reaction.	AL	AL	AL	AL	AL	AL

Organic chemistry – aromatic compounds cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Electron-donating groups (-OH, -NH ₂) have a 2- (ortho) and 4- (para) directing effect, and electron-withdrawing groups (-NO ₂) have a 3- (meta) directing effect in electrophilic substitution of aromatic compounds. Students should be able to predict substitution products of aromatic compounds using directing effects.	X	X	AL	X	X	X
Phenols are a class of aromatic compound with -OH groups attached to the ring.	X	AL	AL	AS	AL	X
Phenols are acidic and have a range of useful applications. Students should be able to explain the properties of phenol as an acid in terms of the stabilisation of the anion.	X	X	X	AS	AL	X

Organic chemistry – amines and amides

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Amines contain the functional groups -NH₂, -NHR or NR₂.</i> Students should be able to recognise and name amines (including the use of primary, secondary, and tertiary).	AL	AL	AL	AS	AL	AL
<i>Amines are basic.</i> Students should also be able to explain the basicity of amines due to their ability to accept a proton.	AL	AL	AL	AL	AL	AL
Azo dyes can be produced from amines in multi-step organic syntheses. Students should be able to outline a synthesis and explain the colour of azo dyes.	X	X	X	AL	AL	AL
<i>Amides contain a carbonyl group bonded to a nitrogen atom.</i> Students should be aware of amides and their chemistry.	AL	AL	AL	AL	AL	AL

Organic chemistry – more advanced principles

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Students should be able to use reactions in the specification to devise a synthesis for an organic compound.</i>	AL	AL	AL	AL	AL	AL
The synthesis of drugs often requires the production of a single enantiomer. Students should be aware of the issues involved in chiral synthesis.	X	AL	X	X	X	X
Combinatorial chemistry has been used industrially to produce large numbers of compounds. Students should be aware of the basic principles of combinatorial chemistry	X	AL	X	X	X	X
Bonding and structure affect the pharmacological activity of a compound. Students should be able to describe and explain the structure and action of a given pharmacologically active compound.	X	X	X	AL	X	X
The length of a carbon chain in a molecule can be increased through the use of magnesium to form Grignard reagents.	X	AL	X	X	X	X

Physical chemistry – energetics and entropy

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Most chemical reactions have an enthalpy change associated with them. Exothermic reactions give out heat energy; endothermic reactions take heat energy in.</i></p> <p>Students should be able to draw enthalpy profile diagrams with labels to illustrate exo- and endothermic reactions, showing ΔH and E_a. (Note that understanding of the term enthalpy is often unclear).</p>	AS	AS	AS	AS	AS	AS
<p><i>Enthalpy changes can be worked out using $q = mc\Delta T$ and $\Delta H = -q / n$.</i></p> <p>Students should be able to describe/plan experimental techniques to work out enthalpy changes.</p>	AS	AS	AS	AS	AS	AS
<p><i>Enthalpy changes can be worked out indirectly by applying Hess's Law.</i></p> <p>Students should be able to draw enthalpy cycles to illustrate how they use enthalpy values to calculate enthalpy changes.</p>	AS	AS	AS	AS	AS	AS
<p><i>Breaking bonds is an endothermic process while making bonds is exothermic.</i></p> <p>Students <u>may</u> be aware of the link between bond length and bond strength.</p>	AS	AS	AS	AS	AS	AS
<p>Born-Haber cycles can be used to show the relationship between the following enthalpy changes: formation, atomisation, ionisation (1st, 2nd etc), electron affinity (1st, 2nd etc), and lattice enthalpy.</p> <p>Students should be able to define each enthalpy change and write an appropriate equation.</p> <p>OCR Salters students know about lattice enthalpies, but Born-Haber cycles aren't covered.</p>	AL	AL	AL	X	AL	AL
<p>Students can construct and use Born-Haber cycles (e.g. to calculate lattice enthalpy).</p>	AL	AL	AL	X	X	AL
<p>Students should be able to explain why theoretical lattice enthalpies differ from experimental values using ideas about polarised ions.</p>	AL	AL	X	X	X	X
<p>Students should be able to define enthalpy of solution and perform calculations.</p>	AL	AL	AL	AL	AL	AL
<p>Students should be able to define enthalpy of hydration and perform calculations.</p>	AL	AL	AL	AL	AL	X

Physical chemistry – energetics and entropy cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
Ionic charge and size affect the magnitude of lattice enthalpy.	AL	AL	AL	AL	AL	AL
Thermal decomposition of carbonates is affected by charge density.	X	AS	X	AS	AS	AS
<i>Entropy is a measure of the disorder of a system.</i> Students should be able to give a qualitative description of the trend in entropy on going from solid → liquid → gas.	AL	AL	AL	AL	AL	AL
Entropy changes can be calculated using the expression $\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$	X	AL	X	AL	X	X
<i>The entropy change of the system, ΔS_{system}, (or the standard entropy change ΔS) can be calculated from the appropriate data.</i>	AL	AL	AL	AL	AL	AL
The entropy change of the surroundings can be calculated using the expression $\Delta S_{surr} = -\Delta H/T$.	X	AL	X	AL	X	X
Spontaneous change occurs when the total entropy change is positive. Students should be able to calculate entropy changes given appropriate data, explaining why some endothermic reactions can occur spontaneously. Note that AQA, Edexcel, OCR A, WJEC & CCEA use Gibbs Free Energy (see below).	X	AL	X	AL	X	X
The expression $\Delta G = \Delta H - T\Delta S$ is used to calculate free energy changes.	AL	AL	AL	X	AL	AL
The expression $\Delta G = -RT \ln K$ is used to show that feasible reactions have a large value for the equilibrium constant and vice versa.	X	AL	X	X	X	X
Processes are spontaneous (feasible) when the free energy change is negative.	AL	AL	AL	X	AL	AL

AQA requires a discussion of why mean bond enthalpies may be unreliable in predicting ΔH of reactions. **Edexcel** requires a rationalisation of the solubilities of hydroxides and sulphates of group 2 metals in terms of lattice and hydration enthalpies (only **WJEC** requires the trends in solubility of group 2 hydroxides and sulphates). **Edexcel** and **Salters** require an explanation of the solubilities of ionic and covalent substances in solvents of differing polarity.

Physical chemistry - kinetics

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Particles must collide to react.</i></p> <p>Students should be able to describe and explain the effect on rate of reaction of changing concentration, pressure and surface area. They should be able to explain what is meant by activation energy using an enthalpy profile diagram & making reference to bond breaking.</p>	AS	AS	AS	AS	AS	AS
<p><i>Molecules in a gas possess a range of different kinetic energies and increasing the temperature leads to an increase in average KE and the proportion of molecules with $\geq E_a$.</i></p> <p>Students should be able to sketch a Boltzmann distribution and use this to help explain the effect of increasing temperature on the reaction rate.</p>	AS	AS	AS	AS	AS	AS
<p><i>Catalysts increase the rate of reaction by providing an alternative reaction pathway with lower activation energy, while remaining unchanged at the end of the reaction.</i></p> <p>Students should be able to use enthalpy profile diagrams and Boltzmann distributions to explain how catalysts speed up reactions.</p>	AS	AS	AS	AS	AS	AS
<p>Students should be able to define and use the following terms: rate of reaction, rate constant and order of reaction.</p>	AL	AL	AL	AL	AL	AL
<p>Students should be able to define and use the term half-life.</p>	X	AL	AL	AL	AL	X
<p><i>Initial rates can be taken using tangents in graphs of concentration vs time.</i></p> <p>Students should be able to deduce the rate equation $rate = k[A]^m[B]^n$ using initial rate data (limited to $m/n = 0, 1$ or 2) and calculate the rate constant from given data.</p>	AL	AL	AL	AL	AL	AL
<p>Students should be able to explain qualitatively the effect of changes in temperature on the rate constant.</p>	AL	AL	AL	AL	AL	AL

Physical chemistry – kinetics cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
The rate constant k varies with temperature as given by the Arrhenius equation, $k = Ae^{-E_a/RT}$. Students should be able to perform calculations using the Arrhenius equation, understand that the equation can be rearranged into the form $\ln k = -E_a/RT + \ln A$, and know how to use the rearranged form with experimental data to plot a straight line graph. Students will be given the equation and constants when required.	AL	AL	AL	AL	AL	X
Students should be able to use kinetic data to propose steps in reaction mechanisms. Note that only Edexcel and CCEA cover S_N1 and S_N2 specifically.	X	AL	AL	AL	AL	AL
<i>The slowest step in a multi-step reaction is the rate-determining step.</i> Students should be able to propose a rate equation that is consistent with the rate-determining step.	AL	AL	AL	AL	AL	AL
Homogeneous catalysts are in the same phase as reactants and work by forming intermediates.	AL	AL	AS	AS	AL	X
Homogeneous catalysis is demonstrated by the breakdown of atmospheric ozone as catalysed by Cl formed during the breakdown of CFCs by UV light. Students should be able to write equations to show the breakdown of ozone.	AS	X	AS	AS	X	X
Catalysts can be poisoned which prevents them from working.	AL	X	X	AS	X	AS
Heterogeneous catalysts are in a different phase from the reactants. Bonds in reactants are weakened when they are adsorbed on the surface. OCR A only touches on the subject mentioning catalytic converters at AS level. Students should be able to explain the application of a heterogeneous catalyst e.g. Fe in Haber process, Pt/Rh in catalytic converter.	AL	AL	AS	AS	AL	AL

CCEA doesn't make any mention of the term homogeneous with regard to catalysis. They do however cover the concept of heterogeneous catalysis, and examples of both forms are likely to be taught.

Physical chemistry - equilibria

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p>Many reversible reactions can reach a state of dynamic equilibrium.</p> <p>Students should be able to state the features of a dynamic equilibrium and predict the effect on equilibrium position of changing c, P and T, as well as recalling that catalysts have no effect on equilibrium position (expanded on at AL – see below).</p>	AS	AS	AS	AS	AS	AS
<p>Careful consideration is given to the conditions used for industrial processes involving equilibria.</p> <p>Students should be able to explain the compromises that are made regarding temperature and pressure with reference to yield and rate of reaction.</p>	AS	AS	AS	AL	(X)	AS
<p>K_c is the equilibrium constant in terms of concentration.</p> <p>Students should be able to write an expression for K_c from the balanced symbol equation and give the units (AL) and carry out calculations using given data.</p>	AS	AS	AS	AS	AS	AL
<p>The total pressure is equal to the sum of the partial pressures.</p>	AL	AL	AL	X	AL	AL
<p>Partial pressures can be calculated from the total pressure and mole fractions.</p>	AL	AL	AL	X	AL	AL
<p>K_p is the equilibrium constant in terms of partial pressure.</p> <p>Students should be able to write an expression for K_p from the balanced symbol equation and give the units and carry out calculations using given data.</p>	AL	AL	AL	X	AL	AL
<p><i>Le Chatelier's Principle</i> helps predict the effect of changing the conditions of equilibrium.</p> <p>Students should be able to explain the shift in equilibrium position resulting from changes in macroscopic properties (from AS) <u>and</u> explain the effect of temperature changes on the value of K_c / K_p in relation to the sign of ΔH.</p>	AL	AL	AL	(AL)	AL	AL
<p>Students should recall that although changes in concentration (pressure) will affect the equilibrium position, they have no effect on the value of K_c (K_p).</p>	AS	AL	AL	X	X	AL

Edexcel requires the ability to deal with heterogeneous equilibria. **CCEA** requires knowledge of partition coefficients. **OCR Salters** doesn't explicitly mention term 'Le Chatelier's Principle' (concept of 'opposing change' is still covered), and also requires solubility product calculations.

Physical chemistry - acids & bases

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<p><i>Acids are proton donors and bases are proton acceptors. Note that OCR and WJEC cover some of this material at AS level. Overall, however, the subject is spread over both levels.</i></p> <p>Students should be able to identify acid-base reactions from symbol equations and describe the reaction of acids with metals, carbonates and alkalis.</p>	AL	AL	AS	AL	AS	AL
<p><i>Strong acids/bases are fully dissociated in aqueous solutions while weak acids/bases are only partially dissociated.</i></p> <p>Students should be able to explain the difference between strong acids and concentrated acids.</p>	AL	AL	AS	AL	AS	AL
<p><i>Acids and bases form conjugate acid-base pairs.</i></p> <p>Students should be able to identify conjugate acids and bases.</p>	AL	AL	AL	AL	AL	AL
<p><i>The pH scale can be used as a measure of $[H^+]$ concentration.</i></p> <p>Students should be able to calculate the pH of a strong acid from its concentration.</p>	AL	AL	AL	AL	AS	AL
<p><i>K_a is the acid dissociation constant.</i></p> <p>Students should be able to:</p> <p>write an expression for K_a.</p> <p>calculate K_a or $[HA]$ from given data.</p> <p>work out $[H^+]$ and consequently estimate pH of a weak acid (without using quadratic equations)</p>	AL	AL	AL	AL	AL	AL
<p><i>pK_a is $-\log_{10}K_a$.</i></p> <p>Students should be able to work out pK_a values and explain their significance.</p>	AL	AL	AL	AL	AL	AL
<p><i>K_w is the ionic product of water and can be used to calculate $[H^+]$ and pH of alkaline solutions.</i></p>	AL	AL	AL	AL	AL	AL

K_b is not specified by any of the exam boards however may still be taught as a legacy of former content.

Physical chemistry - acids & bases cont.

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
pH curves show how pH changes in the course of a titration. Students should be able to sketch approximate pH curves for a given acid-base titration and select an appropriate indicator with reference to the curve.	AL	AL	AL	X	AL	AL
Students should be able to work out pK_a from the half-equivalence point in a pH curve.	X	AL	X	X	X	X
<i>Buffers are solutions that minimise changes in pH when small amounts of acid/alkali are added.</i> Students should be able to give examples of acidic and basic buffers and explain in terms of equilibria shifts how they minimise changes in pH. Students should also be able to calculate the pH of a buffer solution.	AL	AL	AL	AL	AL	AL
<i>Buffers play an important role in biological and non-biological systems.</i> Examples could include shampoo and blood.	AL	AL	AL	AL	AL	X

AQA requires this knowledge to be applied to diprotic/dibasic acids and bases. **Edexcel** and **OCR A** require knowledge of the enthalpy of neutralisation. Both **CCEA** and **WJEC** require students to be able to predict the pH of a solution of a salt.

Physical chemistry - electrochemistry

Topic	AQA	Ed	OCR	OCR Salters	WJEC	CCEA
<i>Electrochemical cells are made from two different metals in salt solutions of their own ions. Students should be able to draw labelled diagrams to show electrochemical cells and use E° values to indicate which metal is oxidised.</i>	AL	AL	AL	AL	AL	AL
The standard hydrogen electrode can be used as a reference electrode to measure standard potentials of other half-cells.	AL	AL	AL	AL	AL	AL
The electrochemical series can be used to explain the reactivity of metals in terms of oxidising/reducing powers of elements/ions. Students should be able to predict whether or not a reaction will occur on the basis of E° values and explain why there may be exceptions to these predictions.	AL	AL	AL	AL	AL	AL
The redox potential for a transition metal ion changing from a higher to a lower oxidation state is influenced by pH and by the ligand.	AL	X	X	X	X	X
Rusting is due to electrochemical processes involving iron, water and oxygen. Students should be able to write relevant equations, as well as describing methods of preventing rust (giving appropriate electrochemical explanations).	X	X	X	AL	X	X
Electrochemical cells can be used as a potential energy source.	AL	AL	AL	AL	AL	X
The hydrogen fuel cell can be used as an energy source Students should be able to describe the electrochemical processes occurring in the fuel cell. Coverage in the different specifications is variable.	AL	AL	X	X	AL	X
The simplified electrode reactions in a lithium cell.	AL	X	X	X	X	X
Standard electrode potentials can be used to make predictions regarding the feasibility of chemical reactions. There are limitations in the application of this approach.	AL	AL	AL	AL	AL	AL

Edexcel requires knowledge of E_{cell} , ΔS and equilibrium constants. **OCR Salters** need to know about redox processes in the nitrogen cycle.

Note: This doesn't apply to CCEA, since Northern Ireland is continuing with the previous arrangements. There is some confusion regarding the requirements for practical work in the new A-level science specifications. The DfE guidance* states that:

“Specifications in biology, chemistry and physics must encourage the development of the skills, knowledge and understanding in science through teaching and learning opportunities for regular hands-on practical work.

“In order to develop the necessary skills, knowledge and understanding, students studying A-levels in biology, chemistry and physics will be required to have carried out a minimum of 12 practical activities, which will contribute towards the Practical Endorsement. These skills, knowledge and understanding will also be assessed in A-level written examinations in the context of these, and other, practical activities. The written examinations for AS will also assess students in relation to their practical skills, knowledge and understanding.”

Indirectly assessed practical skills

Question papers for AS- and A-level qualifications will assess a range of skills (see below), with a requirement that 15% of the marks on any paper will relate to such skills. It should be noted that there have always been questions on exam papers which were based on a practical context, although this will have been variable over time. There are some concerns in the community that the stipulation that 15% of the marks should be related to practical skills will lead to an increase 'in teaching to the test', and also that these questions will favour students who are good at exams over those who are good at practical work. No doubt the examination authors will be putting their creativity to good use to ensure that the assessments mitigate against these concerns.

According to the DfE documentation, examinations will test students' abilities to:

Independent thinking

- solve problems set in practical contexts
- apply scientific knowledge to practical contexts

Use and application of scientific methods and practices

- comment on experimental design and evaluate scientific methods
- present data in appropriate ways
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled

Numeracy and the application of mathematical concepts in a practical context

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
- consider margins of error, accuracy and precision of data

Instruments and equipment

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

* Source: GCE AS and A level subject content for biology, chemistry, physics and psychology (Apr 2014), downloaded from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446829/A_level_science_subject_content.pdf

Directly assessed practical skills

DfE have state that “*Specifications for chemistry must give students opportunities to use relevant apparatus to develop and demonstrate these techniques.*” A list of techniques have been stipulated which should be assessed through a minimum of 12 identified practical activities within each specification (see below). Each of the A-level specifications lists 12 ‘core’ practicals (apart from the Edexcel document, which lists 16) which provide students with the opportunity to demonstrate all of the required practical skills.

The required practicals are defined in each specification and the assessment arrangements will be the same across all of them. Students will keep a record of all of their practical activities (e.g. in some sort of log book or practical portfolio) and will be assessed by their teachers against common practical assessment criteria (CPAC). Students who demonstrate the required standard across all requirements of the CPAC will be awarded a ‘Pass’ which will be report separately from their grade on their A-level certificate.

Note that this will only apply to the full A-level, since there will be no separate direct assessment of practical skills as part of the standalone AS-level. However, all papers, including those taken by students just sitting an AS-level, will include questions which assess practical skills, so it will be important that all students undertake the required practicals as outlined in their specification. Teachers will have the flexibility to design their own practical activities, although they will be required to ensure that these meet requirements of the CPAC.*

Practical techniques to be gained by candidates:

- use appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)
- use water bath or electric heater or sand bath for heating
- measure pH using pH charts, or pH meter, or pH probe on a data logger
- use laboratory apparatus for a variety of experimental techniques including:
 - titration, using burette and pipette
 - distillation and heating under reflux, including setting up glassware using retort stand and clamps
- qualitative tests for ions and organic functional groups
- filtration, including use of fluted filter paper, or filtration under reduced pressure
- use volumetric flask, including accurate technique for making up a standard solution
- use acid-base indicators in titrations of weak/strong acids with weak/strong alkalis
- purify:
 - a solid product by recrystallization
 - a liquid product, including use of separating funnel
- use melting point apparatus
- use thin-layer or paper chromatography
- set up electrochemical cells and measuring voltages
- safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances
- measure rates of reaction by at least two different methods, for example:
 - an initial rate method such as a clock reaction
 - a continuous monitoring method

* The OCR specification provided guidance here.

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Disclaimer: Whilst every effort has been made to ensure the accuracy of the content reported in this document, the analysis of 6 large specifications is a complex task, and the consolidation of the material into a relatively concise form, as contained in the tables herein, does mean there are likely to be some inconsistencies. Please report any concerns you have to us, and if in doubt, refer to the original specifications for full exemplification.

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