

A Level

CHEMISTRY A

H432

For first teach in 2015

Student revision checklist

Version 1

CHEMISTRY A

Student revision checklist

A Level Chemistry A - H432

Revision checklists

The tables below can be used as a revision checklist.

For more information please see the [OCR A Level Chemistry A specification](#).

The table headings are explained below:

Assessable learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
Here is a list of the learning outcomes for this qualification and the content you need to cover and work on.	<p>You can use the tick boxes to show when you have revised an item and how confident you feel about it.</p> <p>R = RED means you are really unsure and lack confidence; you might want to focus your revision here and possibly talk to your teacher for help.</p> <p>A = AMBER means you are reasonably confident but need some extra practice.</p> <p>G = GREEN means you are very confident.</p> <p>As your revision progresses, you can concentrate on the RED and AMBER items in order to turn them into GREEN items.</p> <p>You might find it helpful to highlight each topic in red, orange or green to help you prioritise.</p>			<p>You can use the comments column to:</p> <ul style="list-style-type: none"> • add more information about the details for each point • add formulae or notes • include a reference to a useful resource • highlight areas of difficulty or things that you need to talk to your teacher about or look up in a textbook.

Module 1 Development of practical skills in chemistry				
1.1.1 Planning				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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.				
(b) identification of variables that must be controlled, where appropriate				
(c) evaluation that an experimental method is appropriate to meet the expected outcomes				

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1.1.2 Implementing				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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.				
(b) appropriate units for measurements.				
(c) presenting observations and data in an appropriate format				
1.1.3 Analysis				
(a) processing, analysing and interpreting qualitative and quantitative experimental results Including reaching valid conclusions, where appropriate.				

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1.1.3 Analysis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(b) use of appropriate mathematical skills for analysis of quantitative data Refer to Section 5d for a list of mathematical skills that learners should have acquired competence in as part of their course.				
(c) appropriate use of significant figures				
(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.				
1.1.4 Evaluation				
(a) how to evaluate results and draw conclusions				
(b) the identification of anomalies in experimental measurements				

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1.1.4 Evaluation				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(c) the limitations in experimental procedures				
(d) precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus				
(e) refining of experimental design by suggestion of improvements to the procedures and apparatus				
1.2.1 Practical skills				
Independent thinking (a) apply investigative approaches and methods to practical work Including how to solve problems in a practical context.				

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1.2.1 Practical skills				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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.				
(c) follow written instructions				
(d) make and record observations/measurements				
(e) keep appropriate records of experimental activities See Section 5.				
(f) present information and data in a scientific way				

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1.2.1 Practical skills				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(g) use appropriate software and tools to process data, carry out research and report findings				
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				
Instruments and equipment				
(j) use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding including in the specification. See Section 5.				

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1.2.2 Use of apparatus and techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(a) use of appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)				
(b) use of a water bath or electric heater or sand bath for heating				
(c) measurement of pH using pH charts, or pH meter, or pH probe on a data logger				
(d) use of laboratory apparatus for a variety of experimental techniques including: <ul style="list-style-type: none"> (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. 				

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1.2.2 Use of apparatus and techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(e) use of a volumetric flask, including accurate technique for making up a standard solution				
(f) use of acid-base indicators in titrations of weak/strong acids with weak/strong alkalis				
(g) purification of: (i) a solid product by recrystallisation (ii) a liquid product, including use of a separating funnel.				
(h) use of melting point apparatus				
(i) use of thin layer or paper chromatography				
(j) setting up of electrochemical cells and measuring voltages				
(k) safely and carefully handling solids and liquids, including corrosive, irritant, flammable and toxic substances				

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1.2.2 Use of apparatus and techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(I) 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.				

Module 2 Foundations in chemistry				
2.1.1 Atomic structure and isotopes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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 Different models for atomic structure can be used to explain different phenomena, e.g. the Bohr model explains periodic properties. The changing accepted models of atomic structure over time. The use of evidence to accept or reject particular models.				
Relative mass				
(c) explanation of the terms <i>relative isotopic mass</i> (mass compared with 1/12th mass of carbon-12) and <i>relative atomic mass</i> (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.				

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2.1.1 Atomic structure and isotopes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(d) use of mass spectrometry in:</p> <p>(i) the determination of relative isotopic masses and relative abundances of the isotope</p> <p>Knowledge of the mass spectrometer not required.</p> <p>(ii) calculation of the relative atomic mass of an element from the relative abundances of its isotopes.</p> <p>Limited to ions with single charges.</p>				
<p>(e) use of the terms <i>relative molecular mass</i>, M_r, and <i>relative formula mass</i> and their calculation from relative atomic masses</p> <p>For simple molecules, the term <i>relative molecular mass</i> will be used.</p> <p>For compounds with giant structures, the term <i>relative formula mass</i> will be used.</p> <p>Definitions of relative molecular mass and relative formula mass will not be required.</p>				

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2.1.2 Compounds, formulae and equations				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Formulae and equations</p> <p>(a) the writing of formulae of ionic compounds from ionic charges, including:</p> <p>(i) prediction of ionic charge from the position of an element in the periodic table</p> <p>(ii) recall of 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^+</p> <p>Note that 'nitrate' and 'sulfate' should be assumed to be NO_3^- and SO_4^{2-}.</p> <p>Charges on ions other than in (i) and (ii) will be provided.</p>				
<p>(b) construction of balanced chemical equations (including ionic equations), including state symbols, for reactions studied and for unfamiliar reactions given appropriate information</p>				

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2.1.3 Amount of substance				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>The mole</p> <p>(a) Explanation and use of the terms:</p> <p>(i) <i>amount of substance</i></p> <p>(ii) <i>mole</i> (symbol 'mol'), as the unit for amount of substance.</p> <p>(iii) the <i>Avogadro constant</i>, N_A (the number of particles per mole, $6.02 \times 10^{23} \text{ mol}^{-1}$)</p> <p>(iv) <i>molar mass</i> (mass per mole, units g mol^{-1})</p> <p>(v) <i>molar gas volume</i> (gas volume per mole, units $\text{dm}^3 \text{ mol}^{-1}$).</p> <p>Amount of substance will be used in exams using the formula of the substance, e.g. amount of an NaCl; amount of O₂.</p> <p>In recognition of IUPAC's review, we will accept both the classical (carbon-12 based) and revised (Avogadro constant based) definitions of the mole in examinations from June 2018 onwards (see https://iupac.org/new-definition-mole-arrived/)</p> <p>The value for N_A and the molar gas volume at RTP are provided on the <i>Data Sheet</i>.</p>				

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2.1.3 Amount of substance				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
Determination of formulae (b) use of the terms: (i) <i>empirical formula</i> (the simplest whole number ratio of atoms of each element present in a compound) (ii) <i>molecular formula</i> (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 To include calculating empirical formulae from elemental analysis data (see also 6.3.2 e).				
(d) the terms <i>anhydrous</i> , <i>hydrated</i> and <i>water of crystallisation</i> and calculation of the formula of a hydrated salt from given percentage composition, mass composition or based on experimental results				

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2.1.3 Amount of substance				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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. Learners will be expected to express concentration in mol dm ⁻³ and g dm ⁻³ .				
(f) the ideal gas equation: $pV = nRT$ The value for <i>R</i> is provided on the <i>Data Sheet</i> . Learners will be expected to express quantities in SI units.				
(g) use of stoichiometric relationships in calculations				
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.				

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2.1.3 Amount of substance				
Learning outcomes	R	A	G	Comments
You will be required to show and apply knowledge and understanding of:				
(i) the techniques and procedures required during experiments requiring the measurement of mass, volumes of solutions and gas volumes Many opportunities to carry out experimental and investigative work.				
(j) the benefits for sustainability of developing chemical processes with a high atom economy Use of processes with high atom economy in chemical industry and other areas.				
2.1.4 Acids				
Acids, bases, alkalis and neutralisation				
(a) the formulae of the common acids HCl, H ₂ SO ₄ , HNO ₃ and CH ₃ COOH) 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				

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2.1.4 Acids				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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 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				

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2.1.5 Redox				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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 Appropriate use of oxidation numbers in written communication.				

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2.1.5 Redox				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(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</p> <p>Examples should include, but not be limited to, iron (II) and iron (III).</p> <p>Learners will be expected to write formulae from names such as chlorate (I) and chlorate (III) and <i>vice versa</i>.</p> <p>Note that 'nitrate' and 'sulfate' with no shown oxidation number, are assumed to be NO_3^- and SO_4^{2-}</p> <p>Systematic and unambiguous nomenclature.</p>				
<p>Redox reactions</p> <p>(d) oxidation and reduction in terms of:</p> <p>(i) electron transfer</p> <p>(ii) changes in oxidation number</p> <p>Should include examples of s-, p- and d-block elements.</p>				

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2.1.5 Redox				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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, Al, 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				

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2.2.1 Electron structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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				
(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. Development of refined models for electron structure.				

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2.2.1 Electron structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(d) deduction of the electron configurations of; <ul style="list-style-type: none"> (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 $Z = 36$. <p>Learners should use sub-shell notation, i.e. for oxygen: $1s^2 2s^2 2p^4$.</p>				
2.2.2 Bonding and structure				
Ionic bonding <ul style="list-style-type: none"> (a) ionic bonding as electrostatic attraction between positive and negative ions, and the construction of '<i>dot-and-cross</i>' diagrams 				
<ul style="list-style-type: none"> (b) explanation of the solid structures of giant ionic lattices, resulting from oppositely charged ions strongly attracted in all directions e.g. NaCl 				

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2.2.2 Bonding and structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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 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 ' <i>dot-and-cross</i> ' diagrams of molecules and ions to describe: (i) single covalent bonding (ii) multiple covalent bonding (iii) dative covalent (coordinate) bonding. ' <i>Dot-and-cross</i> ' diagrams of up to six electron pairs (including lone pairs) surrounding a central atom.				

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2.2.2 Bonding and structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(f) use of the term <i>average bond enthalpy</i> as a measurement of covalent bond strength</p> <p>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.</p>				
<p>The shapes of simple molecules and ions</p> <p>(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</p> <p>Learners should be able to draw 3-D diagrams to illustrate shapes of molecules and ions. Using electron pair repulsion theory to predict molecular shapes.</p>				

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2.2.2 Bonding and structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(h) electron pair repulsion to explain the following shapes of molecules and ions: linear, non-linear, trigonal planar, pyramidal, tetrahedral and octahedral</p> <p>Learners are expected to know that lone pairs repel more than bonded pairs and the bond angles for common examples of each shape including CH₄ (109.5°), NH₃ (107°) and H₂O (104.5°).</p>				
<p>(j) explanation of:</p> <p>(i) a polar bond and permanent dipole within molecules containing covalently-bonded atoms with different electronegativities</p> <p>(ii) a polar molecule and overall dipole in terms of permanent dipole(s) and molecular shape.</p> <p>A polar molecule requires polar bonds with dipoles that do not cancel due to their direction. E.g. H₂O and CO₂ both have polar bonds but only H₂O has an overall dipole.</p>				

2.2.2 Bonding and structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Intermolecular forces</p> <p>(k) intermolecular forces based on permanent dipole–dipole interactions and induced dipole–dipole interactions</p> <p>Permanent dipole–dipole and induced dipole–dipole interactions can both be referred to as van der Waals' forces.</p> <p>Induced dipole–dipole interactions can also be referred to as London (dispersion) forces.</p> <p>Dipole interactions as a model to explain intermolecular bonding.</p>				
<p>(l) hydrogen bonding as intermolecular bonding between molecules containing N, O or F and the H atom of –NH, –OH or HF</p> <p>Including the role of lone pairs.</p>				

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2.2.2 Bonding and structure				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(m) explanation of anomalous properties of H ₂ O resulting from hydrogen bonding, e.g.: (i) the density of ice compared with water (ii) its relatively high melting and boiling points. Use of ideas about hydrogen bonding to explain macroscopic properties.				
(n) explanation of the solid structures of simple molecular lattices, as covalently bonded molecules attracted by intermolecular forces, e.g. I ₂ , ice				
(o) explanation of the effect of structure and bonding on the physical properties of covalent compounds with simple molecular lattice structures including melting and boiling points, solubility and electrical conductivity				

Module 3 Periodic table and energy				
3.1.1 Periodicity				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>The structure of the periodic table</p> <p>(a) the periodic table as the arrangement of elements:</p> <ul style="list-style-type: none"> (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. <p>The development of the Periodic Law and acceptance by the scientific community.</p> <p>The extension of the periodic table through discovery and confirmation of new elements.</p>				
<p>Periodic trend in electron configuration and ionisation energy</p> <p>(b) (i) the periodic trend in electron configurations across Periods 2 and 3 (see also 2.2.1 d)</p> <p>(ii) classification of elements into s-, p- and d-blocks.</p>				

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3.1.1 Periodicity				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(c) first ionisation energy (removal of 1 mol of electrons from 1 mol of gaseous atoms) and successive ionisation energy, and:</p> <p>(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</p> <p>(ii) prediction from successive ionisation energies of the number of electrons in each shell of an atom and the group of an element.</p> <p>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). Trends in ionisation energy support the Bohr model of the atom.</p>				

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3.1.1 Periodicity				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
Periodic trend in structure and melting point (d) explanation of: <ul style="list-style-type: none"> (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 Use of ideas about bonding to explain the strength and conductive properties of graphene, and its potential applications and benefits.				

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3.1.1 Periodicity				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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 variations in melting points across Periods 2 and 3 in terms of structure and bonding (see also 2.2.2 o). Trend in structure from giant metallic to giant covalent to simple molecular lattice.				

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3.1.2 Group 2				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
Redox reactions and reactivity of Group 2 metals (a) the outer shells 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 \rightarrow 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) Definition of second ionisation energy is not required, but learners should be able to write an equation for the change involved.				

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3.1.2 Group 2				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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) $\text{Ca}(\text{OH})_2$ in agriculture to neutralise acid soils (ii) $\text{Mg}(\text{OH})_2$ and CaCO_3 as 'antacids' in treating indigestion.				
3.1.3 The halogens				
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)				

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3.1.3 The halogens				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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.				
3.1.3 The halogens				
(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				

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3.1.3 The halogens				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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) 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.				

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3.1.3 The halogens				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Characteristic reactions of halide ions</p> <p>(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</p> <p>Complexes with ammonia are not required other than observations (see also 3.1.4 a). Qualitative analysis.</p>				

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3.1.4 Qualitative analysis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Tests for ions</p> <p>(a) qualitative analysis of ions on a test-tube scale; processes and techniques needed to identify the following ions in an unknown compound:</p> <p>(i) anions:</p> <ul style="list-style-type: none"> • CO_3^{2-}, by reaction with $\text{H}^+(\text{aq})$ forming $\text{CO}_2(\text{g})$ (see 2.1.4 c) • SO_4^{2-}, by precipitation with $\text{Ba}^{2+}(\text{aq})$ • Cl^-, Br^-, I^-, (see 3.1.3 g) <p>(ii) cations: NH_4^+, by reaction with warm $\text{NaOH}(\text{aq})$ forming NH_3.</p> <p>Sequence of tests required is carbonate, sulfate then halide. (BaCO_3 and Ag_2SO_4 are both insoluble). Qualitative analysis.</p>				

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3.2.1 Enthalpy changes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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				
(c) qualitative explanation of the term <i>activation energy</i> , including use of enthalpy profile diagrams Activation energy in terms of the minimum energy required for a reaction to take place.				

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3.2.1 Enthalpy changes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(d) explanation and use of the terms: <ul style="list-style-type: none"> (i) <i>standard conditions and standard states</i> (physical states under standard conditions) (ii) <i>enthalpy change of reaction</i> (enthalpy change associated with a stated equation, $\Delta_r H$) (iii) <i>enthalpy change of formation</i> (formation of 1 mol of a compound from its elements, $\Delta_f H$) (iv) <i>enthalpy change of combustion</i> (complete combustion of 1 mol of a substance, $\Delta_c H$) (v) <i>enthalpy change of neutralisation</i> (formation of 1 mol of water from neutralisation, $\Delta_{\text{neut}} H$). <p>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.</p>				
(e) determination of enthalpy changes directly from appropriate experimental results, including use of the relationship: $q = mc\Delta T$				

CHEMISTRY A

3.2.1 Enthalpy changes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(f) (i) explanation of the term <i>average bond enthalpy</i> (as the breaking of 1 mol of bonds in gaseous molecules) (ii) explanation of exothermic and endothermic reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds. (iii) use of average bond enthalpies to calculate enthalpy changes and related quantities (see also 2.2.2 f). Formal definition of average bond enthalpy not required. Learners are expected to understand that an actual bond enthalpy may differ from the average value.				

CHEMISTRY A

3.2.1 Enthalpy changes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Hess' law and enthalpy cycles</p> <p>(g) Hess' law for constructions of enthalpy cycles and calculations to determine indirectly:</p> <ul style="list-style-type: none"> (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. <p style="padding-left: 40px;">Definition of Hess' law not required. Unfamiliar enthalpy cycles will be provided. Application of the principle of conservation of energy to determine enthalpy changes.</p>				
<p>(h) the techniques and procedures used to determine enthalpy changes directly and indirectly</p> <p style="padding-left: 40px;">To include the enthalpy changes covered in 5.2.1 c</p> <p style="padding-left: 40px;">Opportunities for carrying out experimental and investigative work.</p>				

CHEMISTRY A

3.2.2 Reaction rates				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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				
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.				

CHEMISTRY A

3.2.2 Reaction rates				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(d) (i) explanation of the terms <i>homogeneous</i> and <i>heterogeneous</i> 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 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 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)				

CHEMISTRY A

3.2.2 Reaction rates				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(g) explanation, using Boltzmann distributions, of the qualitative effect on the proportion of molecules exceeding the activation energy and hence the reaction rate, for: <ul style="list-style-type: none"> (i) temperature changes (ii) catalytic behaviour (see also 3.2.2 c) <p style="text-align: center;">Use of Boltzmann distribution model to explain effect on reaction rates.</p>				
3.2.3 Chemical equilibrium				
(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 <p style="text-align: center;">Definition for le Chatelier's principle not required. Use of le Chatelier's principle to explain effect of factors on the position of equilibrium.</p>				

CHEMISTRY A

3.2.3 Chemical equilibrium				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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. 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 Balancing the effects of equilibrium, rate, safety and economics to determine the conditions used in industrial reactions e.g. Haber process.				

3.2.3 Chemical equilibrium				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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 Learners will not need to determine the units for K_c				
(g) estimation of the position of equilibrium from the magnitude of K_c A qualitative estimation only is required.				

Module 4 Core organic chemistry				
4.1.1 Basic concepts of organic chemistry				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Naming and representing the formulae of organic compounds</p> <p>(a) application of IUPAC rules of nomenclature for systematically naming organic compounds</p> <p>Nomenclature will be limited to the functional groups within this specification. E.g. $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$ has the systematic name: 2-methylbutan-1-ol.</p> <p>Learners will be expected to know the names of the first ten members of the alkanes homologous series and their corresponding alkyl groups.</p> <p>Use of systematic nomenclature to avoid ambiguity.</p> <p>The role of IUPAC in developing a systematic framework for chemical nomenclature.</p>				

4.1.1 Basic concepts of organic chemistry				
Learning outcomes	R	A	G	Comments
<p>You will be required to show and apply knowledge and understanding of:</p> <p>(b) interpretation and use of the terms:</p> <p>i) <i>general formula</i> (the simplest algebraic formula of a member of a homologous series) e.g. for an alkane: C_nH_{2n+2}</p> <p>(ii) <i>structural formula</i> (the minimal detail that shows the arrangement of atoms in a molecule) e.g. for butane: $CH_3CH_2CH_2CH_3$ or $CH_3(CH_2)_2CH_3$</p> <p>(iii) <i>displayed formula</i> (the relative positioning of atoms and the bonds between them) e.g. for ethanol:</p> $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $				

4.1.1 Basic concepts of organic chemistry

Learning outcomes

You will be required to show and apply knowledge and understanding of:

R

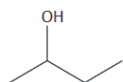
A

G

Comments

(b) interpretation and use of the terms:

- (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:

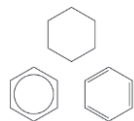


See also **2.1.3 b** for empirical formula and molecular formula.

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:



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

CHEMISTRY A

4.1.1 Basic concepts of organic chemistry				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Functional groups</p> <p>(c) interpretation and use of the terms:</p> <p>(i) <i>homologous series</i> (a series of organic compounds having the same functional group but with each successive member differing by CH₂)</p> <p>(ii) <i>functional group</i> (a group of atoms responsible for the characteristic reactions of a compound)</p> <p>(iii) <i>alkyl group</i> (of formula C_nH_{2n+1})</p> <p>(iv) <i>aliphatic</i> (a compound containing carbon and hydrogen joined together in straight chains, branched chains or non-aromatic rings)</p> <p>(v) <i>alicyclic</i> (an aliphatic compound arranged in non-aromatic rings with or without side chains)</p> <p>(vi) <i>aromatic</i> (a compound containing a benzene ring)</p>				

4.1.1 Basic concepts of organic chemistry				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Functional groups</p> <p>(c) interpretation and use of the terms:</p> <p>(vii) <i>saturated</i> (single carbon–carbon bonds only) and <i>unsaturated</i> (the presence of multiple carbon–carbon bonds, including C=C, CC/ and aromatic rings).</p> <p>Definition required for homologous series only.</p> <p>R may be used to represent alkyl groups, but also other fragments of organic compounds not involved in reactions.</p> <p>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.</p>				

CHEMISTRY A

4.1.1 Basic concepts of organic chemistry				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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 <i>structural isomers</i> (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula				
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).				

CHEMISTRY A

4.1.1 Basic concepts of organic chemistry				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(g) the term <i>radical</i> (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. $Cl\cdot$ and $CH_3\cdot$). 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. Use of the 'curly arrow' model to demonstrate electron flow in organic reactions.				

CHEMISTRY A

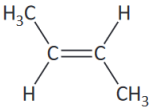
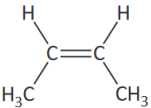
4.1.1 Basic concepts of organic chemistry				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles Any relevant dipoles should be included. Curly arrows should start from a bond, a lone pair of electrons or a negative charge. Use of reaction mechanisms to explain organic reactions.				
4.1.2 Alkanes				
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. Use of model of orbital overlap to explain covalent bonding in organic compounds.				

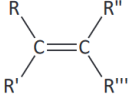
4.1.2 Alkanes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(b) explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion (see also 2.2.2 g–h) Learners should be able to draw 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)				
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) 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				

4.1.2 Alkanes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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				

CHEMISTRY A

4.1.3 Alkenes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Properties of alkenes</p> <p>(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</p> <p>Hybridisation is not required. Use of the model of orbital overlap to explain covalent bonding in organic compounds.</p>				
<p>(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)</p>				

4.1.3 Alkenes				
Learning outcomes	R	A	G	Comments
<p>You will be required to show and apply knowledge and understanding of:</p> <p>Stereoisomerism in alkenes</p> <p>(c) (i) explanation of the terms:</p> <ul style="list-style-type: none"> • <i>stereoisomers</i> (compounds with the same structural formula but with a different arrangement in space) • <i>E/Z isomerism</i> (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) • <i>cis-trans isomerism</i> (a special case of <i>E/Z isomerism</i> in which two of the substituent groups attached to each carbon atom of the C=C group are the same). <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p><i>E</i>-but-2-ene (<i>trans</i>)</p> </div> <div style="text-align: center;">  <p><i>Z</i>-but-2-ene (<i>cis</i>)</p> </div> </div> <p>Use of <i>E</i> as equivalent to <i>trans</i> and <i>Z</i> as equivalent to <i>cis</i> is only consistently correct when there is an H on each carbon atom of the C=C bond.</p>				

4.1.3 Alkenes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(c) (ii) use of Cahn–Ingold–Prelog (CIP) priority rules to identify the <i>E</i> and <i>Z</i> stereoisomers Assigning CIP priorities to double or triple bonds within R groups is not required: 				
(d) determination of possible <i>E/Z</i> or <i>cis-trans</i> stereoisomers of an organic molecule, given its structural formula				
Addition reactions of alkenes (e) the reactivity of alkenes in terms of the relatively low bond enthalpy of the π -bond				

CHEMISTRY A

4.1.3 Alkenes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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 ₃ PO ₄ , to form alcohols. (see also 6.3.1 c)				
(g) definition and use of the term <i>electrophile</i> (an electron pair of 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. Use of reaction mechanisms to explain organic reactions.				

CHEMISTRY A

4.1.3 Alkenes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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. 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 additional polymer deduced from a given monomer. (ii) Identification of the monomer that would produce a given section of an addition polymer.				

CHEMISTRY A

4.1.3 Alkenes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Waste polymers and alternatives</p> <p>(k) the benefits for sustainability of processing waste polymers by:</p> <ul style="list-style-type: none"> (i) combustion for energy production (ii) use as an organic feedstock for the production of plastics and other organic chemicals (iii) removal of toxic waste products, e.g. removal of HCl formed during disposal by combustion of halogenated plastics (e.g. PVC). <p style="padding-left: 40px;">Benefits of cheap oil-derived plastics counteracted by problems for the environment of landfill; the move to re-using waste, improving the use of resources.</p>				
<p>(l) the benefits to the environment of development of biodegradable and photodegradable polymers</p> <p style="padding-left: 40px;">Benefits of reduced dependency on finite resources and alleviating problems from disposal of persistent plastic waste.</p>				

4.2.1 Alcohols				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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 I and 4.1.2 c) (ii) classification of alcohols into primary, secondary and tertiary alcohols.				
(b) combustion of alcohols				
(c) oxidation of alcohols by an oxidising agent, e.g. $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (i.e. $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$), including: (i) the oxidation of primary alcohols to form aldehydes and carboxylic acids; the control of the oxidation product using different reaction conditions (ii) the oxidation of secondary alcohols to form ketones				
(iii) the resistance to oxidation of tertiary alcohols Equations should use [O] to represent the oxidising agent (see also 6.3.1 c).				

CHEMISTRY A

4.2.1 Alcohols				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(d) elimination of H ₂ O from alcohols in the presence of an acid catalyst (e.g. H ₃ PO ₄ or H ₂ SO ₄) and heat to form alkenes Mechanism not required.				
(e) substitution with halide ions in the presence of acid (e.g. NaBr/H ₂ SO ₄) to form haloalkanes Mechanism not required.				
4.2.2 Haloalkanes				
Substitution reactions of haloalkanes				
(a) hydrolysis of haloalkanes in a substitution reaction: (i) by aqueous alkali (ii) by water in the presence of AgNO ₃ and ethanol to compare experimentally the rates of hydrolysis of different carbon–halogen bonds. (see also 6.3.1 c).				

CHEMISTRY A

4.2.2 Haloalkanes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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) Use of reaction mechanisms to explain organic reactions.				
(d) explanation of the trend in rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon-halogen bonds (C-F, C-Cl, C-Br and C-I)				

CHEMISTRY A

4.2.2 Haloalkanes				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Environmental concerns from use of organohalogen compounds</p> <p>(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:</p> <p>(i) the production of halogen radicals (ii) the catalysed breakdown of ozone by $\text{Cl}\cdot$ and other radicals e.g. $\cdot\text{NO}$.</p> <p>Simple equations of the breakdown process are required, e.g. $\text{CF}_2\text{Cl}_2 \rightarrow \text{CF}_2\text{Cl}\cdot + \cdot\text{Cl}$ $\cdot\text{Cl} + \text{O}_3 \rightarrow \cdot\text{ClO} + \text{O}_2$ $\cdot\text{ClO} + \text{O} \rightarrow \cdot\text{Cl} + \text{O}_2$</p> <p>Learners could be expected to construct similar equations for other stated radicals.</p> <p>Benefits of CFCs; acceptance of scientific evidence explaining ozone depletion leading to government legislation against CFC use.</p>				

CHEMISTRY A

4.2.3 Organic synthesis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Practical skills</p> <p>(a) the techniques and procedures for:</p> <p>(i) use of Quickfit apparatus including for distillations and heating under reflux</p> <p>(ii) preparation and purification of an organic liquid including:</p> <ul style="list-style-type: none"> • 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. <p style="text-align: center;">Opportunities to carry out experimental and investigative work.</p>				
<p>Synthetic routes</p> <p>(b) for an organic molecule containing several functional groups:</p> <p>(i) identification of individual functional groups</p> <p>(ii) prediction of properties and reactions.</p> <p style="text-align: center;">Learners will be expected to identify the functional groups encountered in Module 4.</p> <p style="text-align: center;">Development of synthetic routes.</p>				

CHEMISTRY A

4.2.3 Organic synthesis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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. Development of synthetic routes.				
4.2.4 Analytical techniques				
Infrared spectroscopy (a) infrared (IR) radiation causes covalent bonds to vibrate more and absorb energy				

4.2.4 Analytical techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(b) absorption of infrared radiation by atmospheric gases containing C=O, O-H and C-H bonds (e.g. CO₂, H₂O and CH₄), the suspected link to global warming and resulting changes to energy usage</p> <p>Acceptance of scientific evidence explaining global warming has prompted governments towards policies to use renewable energy supplies.</p>				
<p>(c) use of an infrared spectrum of an organic compound to identify:</p> <p>(i) an alcohol from an absorption peak of the O-H bond</p> <p>(ii) an aldehyde or ketone from an absorption peak of the C=O bond</p> <p>(iii) a carboxylic acid from an absorption peak of the C=O bond and a broad absorption peak of the O-H bond.</p> <p>In examinations, infrared absorption data will be provided on the <i>Data Sheet</i>.</p> <p>Learners should be aware that most organic compounds produce a peak at approximately 3000 cm⁻¹ due to absorption by C-H bonds.</p>				

4.2.4 Analytical techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(d) interpretations and predictions of an infrared spectrum of familiar or unfamiliar substances using supplied data Restricted to functional groups studied in this specification (see also 6.3.2 e). 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 Use of analytical techniques to provide evidence for law courts, e.g. drink driving.				

CHEMISTRY A

4.2.4 Analytical techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Mass spectrometry</p> <p>(f) use of a mass spectrum of an organic compound to identify the molecular ion peak and hence to determine molecular mass</p> <p>Limited to ions with single charges. Learners will not be expected to interpret mass spectra of organic halogen compounds.</p> <p>Limited to organic compounds encountered in this specification (see also 6.3.2 e).</p> <p>Learners should be aware that mass spectra may contain a small M+1 peak from the small proportion of carbon-13.</p> <p>Analysis and interpretation of spectra.</p>				
<p>(g) analysis of fragmentation peaks in a mass spectrum to identify parts of structures</p> <p>Learners should be able to suggest the structures of fragment ions.</p> <p>Analysis and interpretation of spectra.</p>				

CHEMISTRY A

4.2.4 Analytical techniques				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Combined techniques</p> <p>(h) deduction of the structures of organic compounds from different analytical data including:</p> <p>(i) elemental analysis (see also 2.1.3 c)</p> <p>(ii) mass spectra</p> <p>(iii) IR spectra.</p> <p>Limited to functional groups encountered in this specification.</p> <p>Learners will not be expected to interpret mass spectra of organic halogen compounds.</p> <p>Analysis and interpretation of different analytical data.</p>				

Module 5 Physical chemistry and transition elements				
5.1.1 How fast?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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: <ul style="list-style-type: none"> (i) orders from experimental data (ii) a rate equation from orders of the form: rate = $k[A]^m[B]^n$, where m and n are 0, 1 or 2. <p>Learners are expected to interpret initial rates data to determine orders with respect to reactants. Integrated forms of rate equations are not required.</p> <p>Use of rate equations.</p>				

5.1.1 How fast?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
Orders, rate equations and rate constants (c) calculation of the rate constant, k , and related quantities, from a rate equation including determination of units				
Rate graphs and orders (d) from a concentration–time graph: (i) deduction of the order (0 or 1) with respect to a reactant from the shape of the graph (ii) calculation of reaction rates from the measurement of gradients (see also 3.2.2 b) Concentration–time graphs can be plotted from continuous measurements taken during the course of a reaction (continuous monitoring).				
(e) from a concentration-time graph of a first order reaction, measurement of constant half-life $t_{1/2}$ Learns should be aware of the constancy of half-life for a first order reaction.				

5.1.1 How fast?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(f) for a first order reaction, determination of the rate constant, k , from the constant half-life, $t_{1/2}$, using the relationship: $k = \ln 2/t_{1/2}$ 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: (i) deduction of the order (0 or 1) with respect to a reactant from the shape of the graph (ii) determination of rate constant for a first order reaction from the gradient 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. Link between order and rate.				

CHEMISTRY A

5.1.1 How fast?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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) 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. 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)				

CHEMISTRY A

5.1.1 How fast?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(k) the Arrhenius equation: (i) the exponential relationship between the rate constant, k and temperature, T given by the Arrhenius equation, $k = Ae^{-E_a/RT}$ (ii) determination of E_a and A graphically using $\ln k = -E_a/RT + \ln A$ derived from the Arrhenius equation. E_a = activation energy, A = pre-exponential factor, R = gas constant (provided on the <i>Data Sheet</i>) Explanation of A is not required. Equations provided on the <i>Data Sheet</i> . Link between k and T .				
5.1.2 How far?				
Equilibrium (a) use of the terms <i>mole fraction</i> and <i>partial pressure</i> See also 3.2.3 Chemical Equilibrium				

CHEMISTRY A

5.1.2 How far?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(b) calculation of quantities present at equilibrium, given appropriate data				
(c) the techniques and procedures used to determine quantities present at equilibrium Not for K_p . Opportunities to carry out experimental and investigative work.				
(d) expressions for or K_c and K_p for homogeneous and heterogeneous equilibria (see also 3.2.3 f) 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) Learners will not be required to solve quadratic equations.				

CHEMISTRY A

5.1.2 How far?				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(f) (i) the qualitative effect on equilibrium constants of changing temperature for exothermic and endothermic reactions (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				
(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.)				

CHEMISTRY A

5.1.3 Acids, bases and buffers				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Brønsted–Lowry acids and bases</p> <p>(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)</p> <p>(ii) use of the term conjugate acid–base pairs</p> <p>(iii) monobasic, dibasic and tribasic acids.</p> <p>Learners should be able to identify acid–base pairs in equations for acid–base equilibria.</p> <p>Development of different models over time to explain acid–base behaviour.</p>				
<p>(b) the role of H⁺ 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)</p>				
<p>(c) (i) the acid dissociation constant K_a for the extent of acid dissociation (see also 2.1.4 b)</p> <p>(ii) the relationship between K_a and pK_a.</p>				

CHEMISTRY A

5.1.3 Acids, bases and buffers				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>pH and [H+(aq)]</p> <p>(d) use of the expression for pH as:</p> $\text{pH} = -\log [\text{H}^+]$ $[\text{H}^+] = 10^{-\text{pH}}$				
<p>(e) use of the expression for the ionic product of water, K_w</p>				
<p>(f) calculations of pH, or related quantities, for:</p> <p>(i) strong monobasic acids</p> <p>(ii) strong bases, using K_w.</p>				
<p>(g) calculations of pH, K_a or related quantities, for a weak monobasic acid using approximations</p> <p>Approximations for weak acid calculations:</p> $[\text{HA}]_{\text{equilibrium}} \sim [\text{HA}]_{\text{undissociated}}$ <p>i.e. $[\text{HA}] \gg [\text{H}^+]$</p> $[\text{H}^+]_{\text{equilibrium}} \sim [\text{A}^-]_{\text{equilibrium}}$ <p>i.e. negligible dissociation of H_2O.</p> <p>Learners will not be required to solve quadratic equations</p>				

CHEMISTRY A

5.1.3 Acids, bases and buffers				
Learning outcomes	R	A	G	Comments
<p>You will be required to show and apply knowledge and understanding of:</p> <p>(h) limitations of using approximations to K_a related calculations for 'stronger' weak acids</p> <p style="padding-left: 40px;">Including reasons why</p> <p style="padding-left: 40px;">$[HA]_{\text{equilibrium}} \sim [HA]_{\text{undissociated}}$ may no longer be valid.</p> <p style="padding-left: 40px;">Understanding of the circumstances under which K_a approximations break down.</p>				
<p>Buffers: actions, uses and calculations</p> <p>(i) a buffer solution as a system that minimises pH changes on addition of small amounts of an acid or a base</p>				
<p>(j) formation of a buffer solution from:</p> <p>(i) a weak acid and a salt of the weak acid, e.g. $\text{CH}_3\text{COOH}/\text{CH}_3\text{COONa}$</p> <p>(ii) excess of a weak acid and a strong alkali, e.g. excess $\text{CH}_3\text{COOH}/\text{NaOH}$</p>				

CHEMISTRY A

5.1.3 Acids, bases and buffers				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(k) explanation of the role of the conjugate acid–base pair in an acid buffer solution, e.g. $\text{CH}_3\text{COOH}/\text{CH}_3\text{COO}^-$, 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				
(m) explanation of the control of blood pH by the carbonic acid–hydrogencarbonate buffer system The $\text{H}_2\text{CO}_3/\text{HCO}_3^-$ buffer is present in blood plasma, maintaining a pH between 7.35 and 7.45.				

CHEMISTRY A

5.1.3 Acids, bases and buffers				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(n) pH titration curves for combinations of strong and weak acids with strong and weak bases, including:</p> <p>(i) sketch and interpretation of their shapes</p> <p>(ii) explanation of the choice of suitable indicators, given the pH range of the indicator</p> <p>(iii) explanation of indicator colour changes in terms of equilibrium shift between the HA and A⁻ forms of the indicator.</p> <p>No indicator is suitable for a weak acid/weak base titration.</p> <p>The indicator should be considered as a weak acid, HA.</p>				
<p>(o) the techniques and procedures used when measuring pH with a pH meter</p> <p>Opportunities to carry out experimental and investigative work.</p>				

5.2 Energy				
5.2.1 Lattice enthalpy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(a) explanation of the term <i>lattice enthalpy</i> (formation of 1 mol of ionic lattice from gaseous ions, Δ_{LEH}) and use as a measure of the strength of ionic bonding in a giant ionic lattice (see also 2.2.2 b–c)</p> <p>Definition required.</p>				
<p>Born-Haber and related enthalpy cycles</p> <p>(b) use of the lattice enthalpy of a simple ionic solid (e.g. NaCl, MgCl₂) and relevant energy terms for:</p> <p>(i) the construction of Born–Haber cycles</p> <p>(ii) related calculations.</p> <p>Relevant energy terms: <i>enthalpy change of formation, ionisation energy, enthalpy change of atomisation and electron affinity.</i></p> <p>Definition required for first ionisation energy (see also 3.1.1 c) and enthalpy change of formation (see also 3.2.1 d) only.</p> <p>Application of conservation of energy to determine enthalpy changes.</p>				

5.2.1 Lattice enthalpy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(c) explanation and use of the terms: (i) <i>enthalpy change of solution</i> (dissolving of 1 mol of solute, $\Delta_{\text{sol}}H$) (ii) <i>enthalpy change of hydration</i> (dissolving of 1 mol of gaseous ions in water, $\Delta_{\text{hyd}}H$) 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 (<i>enthalpy change of hydration</i> and <i>lattice enthalpy</i>) for: (i) the construction of enthalpy cycles (ii) related calculations. Application of conservation of energy to determine enthalpy changes.				
(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				

CHEMISTRY A

5.2.2 Enthalpy and entropy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
Entropy (a) explanation that entropy is a measure of the dispersal of energy in a system which is greater, the more disordered a system 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 product				
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 Use of entropy, enthalpy and temperature for predicting feasibility.				

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5.2.2 Enthalpy and entropy				
Learning outcomes	R	A	G	Comments
You will be required to show and apply knowledge and understanding of:				
(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 Link between ΔG and feasibility.				
(f) the limitations of predictions made by ΔG about feasibility, in terms of kinetics The relative effects of entropy and rate in determining feasibility of processes.				
5.2.3 Redox and electrode potentials				
Redox				
(a) explanation and use of the terms <i>oxidising agent</i> and <i>reducing agent</i> (see also 2.1.5 Redox)				
(b) construction of redox equations using half-equations and oxidation numbers				
(c) interpretation and prediction of reactions involving electron transfer				

5.2.3 Redox and electrode potentials				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Redox titrations</p> <p>(d) the techniques and procedures used when carrying out redox titrations including those involving $\text{Fe}^{2+}/\text{MnO}_4^-$ and $\text{I}_2/\text{S}_2\text{O}_3^{2-}$ (see also 2.1.5 e–f).</p> <p>Opportunities to carry out experimental and investigative work.</p>				
<p>(e) structured and non-structured titration calculations, based on experimental results of redox titrations involving:</p> <p>(i) $\text{Fe}^{2+}/\text{MnO}_4^-$ and $\text{I}_2/\text{S}_2\text{O}_3^{2-}$</p> <p>(ii) non-familiar redox systems.</p> <p>Non-structured titration calculations could be examined in the context of both acid–base and redox titrations (see also 2.1.4 d–e).</p>				
<p>Electrode potentials</p> <p>(f) use of the of the term <i>standard electrode (redox) potential</i>, E^\ominus, including its measurement using a hydrogen electrode</p> <p>E^\ominus data will be provided on examination papers.</p>				

5.2.3 Redox and electrode potentials				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(g) the techniques and procedures used for the measurement of cell potentials of:</p> <p>(i) metals or non-metals in contact with their ions in aqueous solution</p> <p>(ii) ions of the same element in different oxidation states in contact with a Pt electrode.</p> <p>For measurement of standard cell potentials, ions of the same element can have concentrations of 1 mol dm^{-3} or be equimolar.</p> <p>Opportunities to carry out experimental and investigative work.</p>				
<p>(h) calculation of a standard cell potential by combining two standard electrode potentials</p>				
<p>(i) prediction of the feasibility of a reaction using standard cell potentials and the limitations of such predictions in terms of kinetics and concentration</p> <p>The relative effects of standard electrode potential, rate and concentration in determining feasibility of processes.</p>				

CHEMISTRY A

5.2.3 Redox and electrode potentials				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Storage and fuel cells</p> <p>(j) application of principles of electrode potentials to modern storage cells</p> <p>Details of storage cells and required equations will be provided. Relevant electrode potentials and other data will be supplied.</p> <p>Benefits of electrochemical cells counteracted by risks from toxicity and fire from Li-based cells.</p>				
<p>(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</p> <p>Recall of fuel cells and equations will not be required. Relevant electrode potentials and other data will be supplied.</p>				

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5.3 Transition elements				
5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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: $1s^22s^22p^63s^23p^63d^64s^2$.				
(b) the elements Ti-Cu as transition elements i.e. d-block elements that have an ion with an incomplete d-sub-shell				

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5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(c) illustration, using at least two transition elements, of:</p> <p>(i) the existence of more than one oxidation state for each element in its compounds (see also 5.3.1 k)</p> <p>(ii) the formation of coloured ions (see also 5.3.1 h, j–k).</p> <p>(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).</p> <p>No detail of how colour arises required.</p> <p>Practical examples of catalytic behaviour include: Cu^{2+} for reaction of Zn with acids; MnO_2 for decomposition of H_2O_2.</p> <p>No detail of catalytic processes required.</p>				

5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(d) explanation and use of the term <i>ligand</i> 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: $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$ ('en')</p> <p>In exams, other ligands could be introduced.</p>				
<p>(e) use of the terms <i>complex ion</i> and <i>coordination number</i> and examples of complexes with:</p> <p>(i) six-fold coordination with an octahedral shape</p> <p>(ii) four-fold coordination with either a planar or tetrahedral shape (see also 2.2.2 g–h)</p> <p>Examples: Octahedral: many hexaaqua complexes, e.g. $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ Tetrahedral: many tetrachloro complexes, e.g. Cu Cl_4^{2-} and Co Cl_4^{2-} Square planar: complexes of Pt, e.g. platinum: $\text{Pt}(\text{NH}_3)_2 \text{Cl}_2$ (see also 5.3.1 g).</p>				

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5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(f) types of stereoisomerism shown by complexes, including those associated with bidentate and multidentate ligands: (i) <i>cis-trans</i> isomerism e.g. $\text{Pt}(\text{NH}_3)_2 \text{Cl}_2$ (see also 4.1.3 c-d) (ii) optical isomerism e.g. $[\text{Ni}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$ (see also 6.2.2 c) Learners should be able to draw 3-D diagrams to illustrate stereoisomerism.				
(g) use of <i>cis</i> -platin as an anti-cancer drug and its action by binding to DNA preventing cell division Benefits of chemotherapy; risks from unpleasant side effects.				

5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Ligand substitution</p> <p>(h) ligand substitution reactions and the accompanying colour changes in the formation of:</p> <p>(i) $\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2^{2+}$ and $[\text{CuCl}_4]^{2-}$ from $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$</p> <p>(ii) $[\text{Cr}(\text{NH}_3)_6]^{3+}$ from $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ (see also 5.3.1 j).</p> <p>Complexed formulae should be used in ligand substitution equations.</p>				
<p>(i) explanation of the biochemical importance of iron in haemoglobin, including ligand substitution involving O_2 and CO</p>				

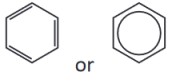
CHEMISTRY A

5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Precipitation reactions</p> <p>(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:</p> <p>(i) precipitation reactions</p> <p>(ii) complex formation with excess aqueous sodium hydroxide and aqueous ammonia.</p> <p>For precipitation, non-complexed formulae or complexed formulae, are acceptable e.g. $\text{Cu}^{2+}(\text{aq})$ or $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$; $\text{Cu}(\text{OH})_2(\text{s})$ or $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$. With excess NaOH, only $\text{Cr}(\text{OH})_3$ reacts further forming $[\text{Cr}(\text{OH})_6]^{3-}$.</p> <p>With excess NH_3, only $\text{Cr}(\text{OH})_3$ and $\text{Cu}(\text{OH})_2$ react forming $[\text{Cr}(\text{NH}_3)_6]^{3+}$ and $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ respectively (see also 5.3.1 h).</p>				

5.3.1 Transition elements				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Redox reactions</p> <p>(j) redox reactions and accompanying colour changes for:</p> <p>(i) interconversions between Fe^{2+} and Fe^{3+}</p> <p>(ii) interconversions between Cr^{3+} and $\text{Cr}_2\text{O}_7^{2-}$</p> <p>(iii) reduction of Cu^{2+} to Cu^+ and disproportionation of Cu^+ to Cu^{2+} and Cu.</p> <p>Fe^{2+} can be oxidised with $\text{H}^+/\text{MnO}_4^-$ and Fe^{3+} reduced with I^-, Cr^{3+} can be oxidised with $\text{H}_2\text{O}_2/\text{OH}^-$ and $\text{Cr}_2\text{O}_7^{2-}$ reduced with Zn/H^+, Cu^{2+} can be reduced with I^-. In aqueous conditions, Cu^+ readily disproportionates.</p> <p>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).</p>				
(l) interpretation and prediction of unfamiliar reactions including ligand substitution, precipitation, redox.				

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5.3.2 Qualitative analysis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Tests for ions</p> <p>(a) qualitative analysis of ions on a test-tube scale: processes and techniques needed to identify the following ions in an unknown compound:</p> <p>(i) anions: CO_3^{2-}, Cl^-, Br^-, I^-, SO_4^{2-} (see 3.1.4 a)</p> <p>(ii) cations: NH_4^+; Cu^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+}, Cr^{3+} (see 3.1.4 a, 5.3.1 j).</p> <p>Qualitative analysis.</p>				

Module 6 Organic chemistry and analysis				
6.1.1 Aromatic compounds				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Benzene and aromatic compounds</p> <p>(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</p> <p>Learners may represent the structure of benzene in equations and mechanisms as:</p>  <p>Development of the model for benzene over time.</p>				
<p>(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)</p> <p>Acceptance of the delocalised benzene model by the scientific community in light of supporting experimental evidence.</p>				

CHEMISTRY A

6.1.1 Aromatic compounds				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(c) use of IUPAC rules of nomenclature for systematically naming substituted aromatic compounds Use of locant number to identify positions of substitution e.g. 2,4-dinitromethylebenzene. Introduction of systematic nomenclature.				
Electrophilic substitution (d) the electrophilic substitution of aromatic compounds with: <ul style="list-style-type: none"> (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.				

6.1.1 Aromatic compounds				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(e) the mechanism of electrophilic substitution in arenes for nitration and halogenation (see also 4.1.1 h–i)</p> <p>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^+.</p> <p>Use of reaction mechanisms to explain organic reactions.</p>				
<p>(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)</p> <p>Use of delocalised benzene model to explain reactivity.</p>				

CHEMISTRY A

6.1.1 Aromatic compounds				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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) (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 a mixture of 2-nitrophenol and 4-nitrophenol. Note that nitration with phenol does not require concentrated HNO ₃ or the presence of a concentrated H ₂ SO ₄ catalyst.				

6.1.1 Aromatic compounds				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(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)</p> <p>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.</p> <p>Use of delocalised benzene model to explain reactivity.</p>				
<p>(k) the 2- and 4-directing effect of electron-donating groups (OH, NH₂) and the 3-directing effect of electron-withdrawing groups (NO₂) in electrophilic substitution of aromatic compounds</p> <p>Learners will not be expected to know further electron-donating or electron-withdrawing groups; relevant additional data will be supplied in examinations.</p> <p>Correlation between substituted group and position of reaction.</p>				

6.1.1 Aromatic compounds				
Learning outcomes	R	A	G	Comments
You will be required to show and apply knowledge and understanding of:				
(I) 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				
Reactions of carbonyl compounds				
(a) oxidation of aldehydes using $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (i.e. $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$) to form carboxylic acids In equations for organic redox reactions, [O] and [H] should be used. (see also 6.3.1 c).				
(b) nucleophilic addition reactions of carbonyl compounds with: <ul style="list-style-type: none"> (i) NaBH_4 to form alcohols (ii) HCN [i.e. $\text{NaCN}(\text{aq})/\text{H}^+(\text{aq})$], to form hydroxynitriles (see also 6.2.4 b). 				

6.1. 2 Carbonyl compounds				
Learning outcomes	R	A	G	Comments
<p>You will be required to show and apply knowledge and understanding of:</p> <p>(c) the mechanism for nucleophilic addition reactions of aldehydes and ketones with NaBH₄ and HCN</p> <p style="padding-left: 40px;">For NaBH₄, the nucleophile can be considered as being the hydride ion, H⁻, with subsequent protonation of the organic intermediate from H₂O.</p> <p style="padding-left: 40px;">For HCN, initial nucleophilic attack is from CN⁻ ions; subsequent protonation stage can be shown using H₂O or H⁺.</p> <p style="padding-left: 40px;">Use of reaction mechanisms to explain organic reactions.</p>				
<p>Characteristic tests for carbonyl compounds</p> <p>(d) use of 2,4-dinitrophenylhydrazine to:</p> <p>(i) detect the presence of a carbonyl group in an organic compound</p> <p>(ii) identify a carbonyl compound from the melting point of the derivative.</p> <p style="padding-left: 40px;">The equation for this reaction is not required. Structure of derivative not required.</p> <p style="padding-left: 40px;">(see also 6.3.1 c). Qualitative analysis.</p>				

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6.1.2 Carbonyl compounds				
Learning outcomes	R	A	G	Comments
<p>You will be required to show and apply knowledge and understanding of:</p> <p>(e) use of Tollens' reagent (ammoniacal silver nitrate) to:</p> <p>(i) detect the presence of an aldehyde group</p> <p>(ii) distinguish between aldehydes and ketones, explained in terms of the oxidation of aldehydes to carboxylic acids with reduction of silver ions to silver.</p> <p>In equations involving Tollens' reagent, [O] is acceptable. (see also 6.3.1 c). Qualitative analysis.</p>				
6.1.3 Carboxylic acids and esters				
<p>Properties of carboxylic acids</p> <p>(a) explanation of the water solubility of carboxylic acids in terms of hydrogen bonding</p>				

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6.1.3 Carboxylic acids and esters				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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).				
Esters (c) esterification of: (i) carboxylic acids with alcohols in the presence of an acid catalyst (e.g. concentrated H ₂ SO 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				

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6.1.3 Carboxylic acids and esters				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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.				
6.2.1 Amines				
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. $\text{HCl}(\text{aq})$, to form salts Comparison of basicity of different amines not required. Restricted to inorganic acids.				

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6.2.1 Amines				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(b) the preparation of: <ul style="list-style-type: none"> (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).				
6.2.2 Amino acids, amides and chirality				
Reactions of amino acids <ul style="list-style-type: none"> (a) the general formula for an α-amino acid as $\text{RCH}(\text{NH}_2)\text{COOH}$ and the following reactions of amino acids: <ul style="list-style-type: none"> (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 <ul style="list-style-type: none"> (b) structures of primary and secondary amides (see also 6.1.3 f, 6.2.3 a–b) 				

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6.2.2 Amino acids, amides and chirality				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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) Learners should be able to draw 3-D diagrams to illustrate stereoisomerism.				
(d) identification of chiral centres in a molecule of any organic compound Learners should be able to draw 3-D diagrams to illustrate stereoisomerism.				

6.2.3 Polyesters and polyamides				
Learning outcomes	R	A	G	Comments
<p>You will be required to show and apply knowledge and understanding of:</p> <p>Condensation polymers</p> <p>(a) condensation polymerisation to form:</p> <ul style="list-style-type: none"> (i) polyesters (ii) polyamides. <p>Formation from carboxylic acids/dicarboxylic acids (or respective acyl chlorides) and from alcohols/diols or amines/diamines.</p> <p>Learners will not be expected to recall the structures of synthetic polyesters and polyamides or their monomers.</p>				
<p>(b) the acid and base hydrolysis of:</p> <ul style="list-style-type: none"> (i) the ester groups in polyesters (ii) the amide groups in polyamides. 				
<p>(c) prediction from addition and condensation polymerisation of:</p> <ul style="list-style-type: none"> (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. <p>See also 4.1.3 j.</p>				

6.2.4 Carbon-carbon bond formation				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
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.				
(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)				

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6.2.5 Organic synthesis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Practical skills</p> <p>(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:</p> <p>(i) organic preparation</p> <ul style="list-style-type: none"> • use of Quickfit apparatus • distillation and heating under reflux <p>(ii) purification of an organic solid</p> <ul style="list-style-type: none"> • filtration under reduced pressure • recrystallisation • measurement of melting points. <p>Opportunities to carry out experimental and investigative work.</p>				
<p>Synthetic routes</p> <p>(b) for an organic molecule containing several functional groups:</p> <p>(i) identification of individual functional groups</p> <p>(ii) prediction of properties and reactions.</p> <p>Learners will be expected to identify functional groups encountered in Module 6 (see also 4.2.3 b).</p> <p>Development of synthetic routes.</p>				

6.2.5 Organic synthesis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(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. Development of synthetic routes.				
6.3.1 Chromatography and qualitative analysis				
Types of chromatography (a) interpretation of one-way TLC chromatograms in terms of R_f values Interpretation of TLC to analyse organic compounds.				

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6.3.1 Chromatography and qualitative analysis				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(b) interpretation of gas chromatograms in terms of: <ul style="list-style-type: none"> (i) retention times (ii) the amounts and proportions of the components in a mixture. <p>To include creation and use of external calibration curves to confirm concentrations of components. Peak integration values will be supplied.</p> <p>Interpretation of GC to analyse organic compounds.</p>				

6.3.1 Chromatography and qualitative analysis				
Learning outcomes	R	A	G	Comments
You will be required to show and apply knowledge and understanding of:				
<p>Types of chromatography</p> <p>(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:</p> <ul style="list-style-type: none"> (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) (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) <p>Qualitative analysis.</p>				

6.3.2 Spectroscopy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>NMR Spectroscopy</p> <p>(a) analysis of a carbon-13 NMR spectrum of an organic molecule to make predictions about:</p> <ul style="list-style-type: none"> (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. <p>All carbon-13 NMR spectra that are assessed will be proton decoupled. In examinations, NMR chemical shift values will be provided on the <i>Data Sheet</i>.</p> <p>Restricted to functional groups studied in the A level specification.</p> <p>Interpretation of spectra to analyse organic compounds.</p>				

6.3.2 Spectroscopy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>(b) analysis of a high resolution proton NMR spectrum of an organic molecule to make predictions about:</p> <p>(i) the number of proton environments in the molecule</p> <p>(ii) the different types of proton environment present, from chemical shift values</p> <p>(iii) the relative numbers of each type of proton present from relative peak areas, using integration traces or ratio numbers, when required</p> <p>(iv) the number of non-equivalent protons adjacent to a given proton from the spin-spin splitting pattern, using the $n + 1$ rule</p> <p>(v) possible structures for the molecule.</p> <p>In examinations, NMR chemical shift values will be provided on the <i>Data Sheet</i>.</p> <p>Restricted to functional groups studied in the A level specification.</p> <p>Learners will be expected to identify aromatic protons from chemical shift values but will not be expected to analyse their splitting patterns.</p> <p>Interpretation of spectra to analyse organic compounds.</p>				

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6.3.2 Spectroscopy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
(c) prediction of a carbon-13 or proton NMR spectrum for a given molecule				
(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 .				

6.3.2 Spectroscopy				
Learning outcomes You will be required to show and apply knowledge and understanding of:	R	A	G	Comments
<p>Combined techniques</p> <p>(e) deduction of the structures of organic compounds from different analytical data including:</p> <ul style="list-style-type: none"> (i) elemental analysis (see also 2.1.3 c) (ii) mass spectra (see also 4.2.4 f–g) (iii) IR spectra (see also 4.2.4 d–e) (iv) NMR spectra. <p>Spectral reference data will be provided on the <i>Data Sheet</i>.</p> <p>Restricted to functional groups studied in the A level specification.</p> <p>Learners will not be expected to interpret mass spectra of organic halogen compounds.</p> <p>Interpretation of a variety of different evidence to analyse organic compounds.</p>				



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