National Unit specification: general information

Unit title: Organic Chemistry (SCQF level 7)

Unit code: H1FR 13

Course: Chemistry (Advanced Higher)

Superclass: RD

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Version: 01

Summary

This Unit develops a knowledge and understanding of Organic Chemistry within the contexts of molecular orbitals, molecular structure and stereochemistry, synthesis, molecules and colour, experimental determination of structure and drug interactions.

The Unit develops the candidate's knowledge and understanding of molecular orbitals, hybridisation of atomic orbitals, geometric and optical isomerism, a variety of different reactions in organic chemistry including reaction mechanisms for some and curly arrow notation used to represent electron shifts during a reaction. The Unit also introduces aromatic hydrocarbons and their more common chemical reactions as well as the concept of chromophores leading to coloured organic compounds. Methods used to determine the structure of organic compounds including elemental microanalysis and various spectrophotometric methods are covered in some detail as well as the development of the understanding of how drugs can be classified and how they work within the body. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

Outcomes

1 Demonstrate and apply knowledge and understanding related to *Organic Chemistry*.
2 Demonstrate skills of scientific experimentation and investigation within the context of *Organic Chemistry*.

General information (cont)

Unit title: Organic Chemistry (SCQF level 7)

Recommended entry

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by the following or equivalent:

- Higher Chemistry (Revised)
- Higher Chemistry

Credit points and level

1 National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Unit gives automatic certification of the following:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Graphical Information at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

National Unit specification: statement of standards

Unit title: Organic Chemistry (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate and apply knowledge and understanding related to *Organic Chemistry*.

Performance Criteria

(a) Make accurate statements about facts, concepts and relationships relating to *Organic Chemistry*.
(b) Use knowledge of *Organic Chemistry* to solve problems.
(c) Use knowledge of *Organic Chemistry* to explain observations and phenomena.

Outcome 2

Demonstrate skills of scientific experimentation and investigation in the context of *Organic Chemistry*.

Performance Criteria

(a) Use a range of data-handling skills in a scientific context.
(b) Use a range of skills related to the evaluation of scientific evidence.

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

For each of the Unit Outcomes, written and/or recorded oral evidence of the appropriate level of achievement is required. This evidence must be produced under closed-book, supervised conditions within a time limit of 45 minutes.

The Instrument of Assessment must sample the content in each of the following areas:

- Molecular orbitals
- Molecular structure and stereochemistry
- Synthesis
- Molecules and colour
- Experimental determination of structure
- Drug interactions

An appropriate Instrument of Assessment would be a closed-book, supervised test with a time limit of 45 minutes. Items in the test should cover all the Performance Criteria associated with both Outcomes 1 and 2, and could be set in familiar or unfamiliar contexts.

National Unit specification: statement of standards (cont)

Unit title: Organic Chemistry (SCQF level 7)

Further detail on the breadth and depth of content is provided within the appendix to the specification.

For Outcome 2, PC (a) candidates are required to demonstrate that they can use a range of data-handling skills. These skills include selecting, processing and presenting information. Information can be presented in a number of formats including: chemical formulae, structural formulae including skeletal representations, balanced chemical equations, reaction mechanisms showing curly arrow notation, diagrams depicting laboratory apparatus, tables, diagrams and text.

For Outcome 2, PC (b), candidates are required to demonstrate that they can use a range of skills associated with the evaluation of scientific evidence. These skills include drawing valid conclusions and making predictions.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

National Unit specification: support notes

Unit title: Organic Chemistry (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

The recommended content together with suggestions for possible contexts and activities to support and enrich learning and teaching are detailed in the Course specification.

This Unit allows candidates to develop knowledge and understanding of Organic Chemistry within the contexts of molecular orbitals, hybridisation of atomic orbitals, geometric and optical isomerism, various reactions in organic chemistry including the reaction mechanisms for some and curly arrow notation used to represent electron shifts during a reaction. The Unit also introduces aromatic hydrocarbons and their more common chemical reactions as well as the concept of chromophores leading to coloured organic compounds. Methods used to determine the structure of organic compounds including elemental microanalysis and various spectrophotometric methods are covered in some detail as well as the development of the understanding of how drugs can be classified and how they work within the body. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

This Unit offers a diverse and rich vein of contexts and opportunities for practical work as highlighted in the 'Possible contexts and activities' column of the content tables. Opportunities exist for candidates to learn as part of a group through practical work undertaken in partnership or in teams.

By developing a greater understanding of the different types of bonds in organic compounds candidates are better able to understand more about shapes of organic molecules, stereoisomerism, reactions and reaction mechanisms in organic chemistry, different methods of elucidating structures of organic compounds and how drugs work within our bodies.

Guidance on learning and teaching approaches for this Unit

General advice on approaches to learning and teaching is contained in the Course specification.

National Unit specification: support notes (cont)

Unit title: Organic Chemistry (SCQF level 7)

Guidance on approaches to assessment for this Unit

Outcomes 1 and 2

It is recommended that a holistic approach is taken for assessment of these Outcomes. Outcomes 1 and 2 can be assessed by an integrated end of Unit test with questions covering all the Performance Criteria. Within one question, assessment of knowledge and understanding and skills of experimentation and investigation can occur. Each question can address a number of assessment standards from either Outcome 1 or 2.

Appropriate assessment items are available from the National Assessment Bank.

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003), SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

This Unit provides opportunities to develop *Communication, Numeracy, Information and Communication Technology (ICT)* and *Problem Solving* skills in addition to providing contexts and activities within which the skills associated with *Working with Others* can be developed.

Outcome 1, PC (b) and (c) develop a candidate's ability to communicate effectively key concepts and to explain clearly chemical phenomena in written media.

Within this Unit candidates will need to extract and process information presented in both tabular and graphical formats developing the Core Skill of *Numeracy*. Candidates will gain experience in a range of calculations building competence in number.

The appendix to this Unit specification contains an extensive list of 'Possible Contexts and Activities' which include a large number of web based activities, computer simulations and modelling opportunities which all serve to develop higher levels of competence in the key *ICT* skills including; accessing information and providing/creating information.

The Unit appendix contains an extensive range of practical laboratory exercises which provide candidates with the opportunity to Work Co-operatively with Others.

Problem Solving skills are central to the sciences and are assessed through Outcome 1, PCs (b) and (c) and also through Outcome 2, PCs (a) and (b).

National Unit specification: support notes (cont)

Unit title: Organic Chemistry (SCQF level 7)

This Unit has the Using Graphical Information component of Numeracy, and the Critical Thinking component of Problem Solving, embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show that they have achieved Using Graphical Information and Planning and Organising at SCQF level 6.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes to Unit

Version	Description of change	Date

The left hand column below details the content in which candidates should develop knowledge and understanding. The middle column contains notes, which give further details of the breadth and depth of content expected. The right-hand column gives possible contexts and activities which could be used to develop knowledge, understanding and skills. Further details on many of the activities mentioned in the final column can be obtained from **National Qualifications Online**, part of the Learning and Teaching Scotland online service. Where such online support exists the 💻 symbol appears in the text.

Organic Chemistry 40 hour Unit		
Content	**Notes**	**Possible contexts and activities**
1 Molecular orbitals		
1(a) Molecular orbitals	When atoms approach each other, their separate sets of atomic orbitals merge to form a single set of molecular orbitals. Some of the molecular orbitals, known as 'bonding molecular orbitals', occupy the region between two nuclei. The attraction of positive nuclei to negative electrons occupying bonding molecular orbitals is the basis of bonding between atoms. Each molecular orbital can accommodate a maximum of two electrons.	Chem.purdue.edu has information about atomic orbitals becoming molecular orbitals 💻
1(b) The bonding continuum	In a non-polar covalent bond, the bonding molecular orbital is symmetrical about the midpoint between two atoms. Polar covalent bonds result from bonding molecular orbitals which are asymmetric about the midpoint between two atoms. Ionic compounds represent an extreme case of asymmetry with the bonding molecular orbitals being almost entirely located around just one atom.	Markrosengarten.com has a fun song and video covering covalent, polar covalent and ionic bonding. Useful as revision of Higher bonding. 💻
1(c) Hybridisation	Hybridisation is the process of mixing atomic orbitals within an atom to generate a set of new atomic orbitals called hybrid orbitals. Bonding in alkanes can be described in terms of sp^3 hybridisation and sigma bonds. Bonding in alkenes can be described in terms of sp^2 hybridisation and both sigma and pi bonds. A sigma bond is a covalent bond formed by end-on overlap of two atomic orbitals lying along the axis of the plane. A pi bond is a covalent bond formed by the sideways overlap of two parallel atomic orbitals lying perpendicular to the axis of the bond.	mhhe.com has pages which cover hybridisation including an animation💻 Consider effect that the different types of bonds have on the shapes of molecules, eg shape of CH_4 v C_2H_4 v C_2H_2. As an extension, bonding in alkynes can be described in terms of sp hybridisation with both sigma and pi bonds. ibchem.com has information on sigma bonds, pi bonds and hybridisation 💻 There are also other videos on the internet covering hybridisation.

Content	Notes	Possible contexts and activities
2 Molecular Structure and Stereochemistry		
2(a) Structural formulae	Candidates should be able to draw structural formulae and skeletal formulae and to interconvert between molecular, structural and skeletal formulae for organic molecules with no more than 10 carbon atoms in their longest chain. In a skeletal formula neither the carbon atoms, nor any hydrogens attached to the carbon atoms, are shown. The presence of a carbon atom is implied by a 'kink' in the carbon backbone, and at the end of a line.	Molecular drawing packages such as ChemSketch can be set to display structures in skeletal representation if required. 3D representations of relatively small molecules (less than 10 carbon atoms) containing common functional groups can be created and manipulated by candidates using molymods or similar. Wireframe, stick, ball and stick and space-filling representations should all be familiar. Candidates can rotate molecules around the x, y and z axes to align any chosen bond horizontally or vertically, to align any three atoms in a given plane, to zoom in and out and to switch on and off atom labels. Molecules sketched in 2D mode can be converted into 3D representations in Chemsketch. CHIME (a free plugin for web browsers) can also display a huge range of molecules in 3D. Extensive free libraries of 3D molecules are available to be downloaded from the internet. The structures of aliphatic compounds can be drawn on a Chemsketch type system. The functional groups -OH, -COOH, -C=O, $-NH_2$, -CONH-, -COO- can also be drawn and added to these compound using a Chemsketch type system. A free alternative to Chemdraw is Chemsketch, which is available from ACD labs or ISIS Draw. The structural formulae of aliphatic compounds can be represented in skeletal form using a Chemdraw type system. Molecular drawing packages such as ChemSketch can be set to display structures in skeletal representation if required. Candidates may learn how to interconvert between full and shortened structural formulae and skeletal formulae using the Chemsketch type system.

Content	Notes	Possible contexts and activities
2(a) Structural formulae (cont)		Tutorials on using Chemsketch and drawing skeletal formulae are available on the internet. 💻 Alternatives to Chemsketch include Chemdraw and ISIS Draw.
2(b) Stereoisomerism	Stereoisomers are molecules with the same molecular formula and in which the atoms are bonded together in the same order. However, they are non-superimposable due to a different 3D arrangement of their atoms.	Videos on different forms of isomerism by Dr. Chris Arthur and 'Brightstorm' are available on the internet. 💻
2(c) Geometric isomerism	Geometric isomerism is one type of stereoisomerism. It arises due to the lack of free rotation around a bond, frequently a carbon–carbon double bond, but not always. Geometric isomers are labelled *cis* and *trans* according to whether the substituent groups are on the same side or on different sides of the carbon-carbon double bond. Geometric isomers display differences in some physical properties. Geometric isomerism can also influence chemical properties.	Make molecular models of *cis* and *trans* isomers. The influence of geometric isomerism on chemical properties can be illustrated by the fact that *cis*-butenedioic acid is more readily dehydrated than *trans*-butenedioic acid. Melting points and densities of *cis*-butenedioic and *trans*-butenedioic acid can also be compared. Health issues associated with *trans* fatty acids Also the *cis* geometry of combretastatin is crucial to anticancer activity. Alkenes often used to rigidify structures into active conformations.
2(d) Optical isomerism	Optical isomers are non-superimposable mirror images of asymmetric molecules and such molecules can be described as chiral molecules or enantiomers. Optical isomerism occurs in substances in which four different substituent groups are arranged around a central 'chiral' carbon atom. Optical isomers, in general, have identical physical and chemical properties, except when they are in a chiral environment. However they have an opposite and equal effect on the direction of rotation of plane-polarised light, and are therefore said to be optically active. Racemic mixtures contain equal amounts of both optical isomers, and are optically inactive. In biological systems only one optical isomer of each asymmetric organic compound is usually present.	Thalidomide story could be discussed here. 💻 Limonene exists in two isomeric forms. One has the scent of oranges, and the other of pine. A microscale investigation of the isomers of limonene is available from the RSC. 💻 Chm.bris.ac.uk has more information about limonene. 💻 Ibuprofen is normally sold as a mixture of two optical isomers, one of which is an effective pain-killing drug and the other of which is inactive. This gives a low atom economy for the desired product. Recent research has produced a more efficient synthetic route to produce only the desired isomer. More information from the RSC. 💻 Chiral drugs are often sold as racemates despite the fact that activity is due mainly to one of the enantiomers.

Content	Notes	Possible contexts and activities
2(d) Optical isomerism (cont)		However, there are cases where the pure enantiomer is sold if there is a clear clinical advantage (for example if the other enantiomer has toxic side effects). An example is esomeprazole which is the active enantiomer of omeprazole — an antiulcer agent. R- and S- enantiomers can be discussed but will not be assessed. Can discuss chirality in drugs such as ibuprofen. S-Naproxen is a pain reliever and its enantiomer R-Naproxen is a liver toxin. 💻 Use a polarimeter, if one is available, to demonstrate the rotation of plane polarised light by optical isomers. Many links show the number of synthetic steps involved in making an asymmetric compound. Enzymes are now being used to produce asymmetric compounds in fewer synthetic steps. A simple polarimeter can be made from polaroid sun glasses using the instructions from the RSC Classic Chemistry Demonstrations No.13, page 26 and is also available on the internet. 💻 Colby.edu has a video which covers chirality, stereoisomerism and optical activity. Also covers R- and S-enantiomers 💻
3 Synthesis	*An understanding of organic reaction types and mechanisms is key to understanding the types of reactions used in the synthesis of organic chemicals. By the end of this section, candidates should be able to look at a molecular structure and deduce the reactions it should undergo. Candidates should also be able to work out reaction sequences for the synthesis of given molecules.*	

Content	Notes	Possible contexts and activities
3(a) Bond fission	When an organic reaction takes place, bonds are broken and formed. If, when the bond between atoms breaks, each atom retains one electron from the former covalent bond, then two free radicals are formed. This is known as homolytic fission. Reactions involving free radicals tend to result in formation of very complex mixtures of products, thus making them unsuitable for synthesis. If, when the bond between atoms breaks, one atom retains both of the electrons from the former covalent bond, then an ion pair is formed. This is known as heterolytic fission. Reactions proceeding via heterolytic fission tend to produce far fewer products and are therefore better suited for synthesis. Heterolytic fission will be favoured when the bond between the atoms is polar.	Free radical chain reaction mechanism covered in Higher. Chemguide.co.uk has information which covers free radical substitution reaction mechanism in more detail than in Higher. 💻 Tutorvista provides more information on homolytic and heterolytic fission. 💻 Pi bonds are easier to break than sigma due to weaker overlap of orbitals. This can be used to explain why carbonyls are important in synthesis (pi bond and polarity).
3(b) Electrophiles and nucleophiles	In reactions involving heterolytic bond fission, attacking groups are classified as 'nucleophiles' or 'electrophiles'. Nucleophiles are atoms or groups of atoms which are attracted towards atoms bearing a (partial) positive charge. Nucleophiles are capable of donating and sharing an electron pair to form a new bond. Electrophiles are atoms or groups of atoms which are attracted towards atoms bearing a (partial) negative charge. Electrophiles are capable of accepting an electron pair.	Avogadro.co.uk provides definitions and examples of nucleophiles and electrophiles. 💻

Content	Notes	Possible contexts and activities
3(c) Curly arrow notation	Curly arrows are used to show the movement of electron pairs during a reaction. The base of the arrow shows the original location of the pair of electrons. The head of the arrow indicates the destination of the pair of electrons. An arrow starting at the middle of a covalent bond indicates that heterolytic bond fission is occurring. When an arrow is drawn with the head pointing to the space between two atoms, this indicates that a covalent bond will be formed between the two atoms. A double-headed arrow indicates the movement of an electron pair and a single-headed arrow indicates the movement of a single electron.	Chemguide.co.uk has information on use of curly arrows. 💻 abdn.ac.uk also has a brief introduction to using curly arrows with some animations and examples of specific mechanisms. 💻
3(d) Haloalkanes	Haloalkanes (alkyl halides) are named according to IUPAC rules. Monohaloalkanes can be classified as primary, secondary or tertiary. Monohaloalkanes undergo nucleophilic substitution reactions. They react with: 1 alkalis to form alcohols, 2 alcoholic alkoxides to form ethers, 3 ethanolic cyanide to form nitriles which can be hydrolysed to carboxylic acids (chain length increased by one carbon atom). Monohaloalkanes can also undergo elimination reactions to form alkenes.	Alkaline hydrolysis of a bromoalkane. Experiment on nucleophilic substitution reactions of haloalkanes — See 'Chemistry in Context Laboratory Manual, fifth edition' by Graham Hill and John Holman, published by Nelson Thornes. React monohaloalkanes with aqueous alkali and test for halide ion using silver nitrate solution React monohaloalkanes with ethanolic potassium hydroxide and test for alkene produced Some haloalkanes are used as anticancer agents and are called alkylating agents. Associated with toxic side effects.

Content	Notes	Possible contexts and activities
3(e) The reaction mechanism for S_N1 and S_N2 reactions	The reaction mechanisms for S_N1 and S_N2 reactions can be represented using curly arrows. The dominance of an S_N1 or S_N2 mechanism for a particular haloalkane can be explained in terms of steric hindrance and the inductive stabilisation of an intermediate carbocation. An S_N2 reaction proceeds via a single five-centred transition state, whereas an S_N1 reaction occurs in two steps via a carbocation.	Not necessary to go into inductive stabilisation in great detail. Mechanisms and animations for S_N1 and S_N2 are available on the internet. 💻 Chemguide.co.uk gives information on nucleophilic substitution reactions. 💻 Abdn.ac.uk covers a variety of reaction mechanisms including nucleophilic substitution reactions. 💻
3(f) The properties, preparation and reactions of alcohols	Alcohols exhibit hydrogen bonding and as a result have anomalously high boiling points compared to many other organic compounds of comparable relative formula mass and shape. The shorter chain alcohols are miscible with water, but their solubility in water decreases as chain length increases. Alcohols can be prepared from: 1 alkenes by acid-catalysed hydration; 2 haloalkanes by substitution. Alcohols react with some reactive metals to form alkoxides. Alcohols can be dehydrated to alkenes. Alcohols undergo condensation reactions with carboxylic acids and react more vigorously with acid chlorides to form esters. Primary alcohols undergo mild oxidation reactions to form aldehydes. Secondary alcohols undergo mild oxidation reactions to form ketones.	Preparation of esters, ethanol reacting with Na to form sodium ethoxide, oxidation of ethanol, ethanal and propan-2-ol by acidified dichromate, etc. Dehydration of ethanol to ethene using aluminium oxide. Alcohol groups present in a lot of drugs since they are involved in hydrogen bonding with protein binding sites (for example β-blockers and anti-asthmatics).

Content	Notes	Possible contexts and activities
3(g) Ethers	Ethers have the general formula R'-O-R'' where R' and R'' are alkyl groups. Ethers are named according to IUPAC rules. Due to the lack of hydrogen bonding between ether molecules, they have lower boiling points than the corresponding isomeric alcohols. Ethers can be prepared by the reaction of haloalkanes with alkoxides. Ethers are commonly used as solvents since they are relatively inert chemically and will dissolve many organic compounds. The solubility of ethers in water decreases as the molecular size increases.	Ethers were the first anaesthetics. Williamson ether synthesis, eg synthesis of 1-ethoxy butane from 1-bromo butane and ethanol — can also be done as a kinetic experiment. Ethoxyethane is not fully miscible in water, having the same solubility as n-butanol. Methoxymethane and methoxyethane are more soluble in water than ethoxyethane, but they are not fully miscible. This is due to the formation of hydrogen bonds between the ether molecules and water molecules. Ethers, of low relative molecular mass are highly flammable and on exposure to air may form explosive peroxides. Ether runway experiment can be demonstrated.
3(h) Preparation of alkenes	Alkenes can be prepared in the laboratory by: 1 dehydration of alcohols using aluminium oxide, concentrated sulfuric acid or orthophosphoric acid; 2 base-induced elimination of hydrogen halides from monohaloalkanes.	Preparation of cyclohexene from cyclohexanol.
3(i) Electrophilic addition to alkenes	Alkenes can undergo the following electrophilic addition reactions: 1 catalytic addition of hydrogen to form alkanes; 2 addition of halogens to form dihaloalkanes; 3 addition of hydrogen halides according to Markovnikov's rule, to form monohaloalkanes; 4 acid-catalysed addition of water according to Markovnikov's rule, to form alcohols. The mechanism for both the addition of hydrogen halides and the acid-catalysed addition of water involves a carbocation intermediate. The mechanism for addition of a halogen involves a cyclic ion intermediate. Both mechanisms can be written using curly arrows.	abdn.ac.uk covers a variety of reaction mechanisms including reactions of alkenes such as addition of H-X to an alkene and also Markovnikov's rule (with a different spelling). 💻

Content	Notes	Possible contexts and activities
3(j) Oxidation and reduction of carbonyl compounds	Both aldehydes and ketones contain the carbonyl C=O functional group. It is possible to further oxidise aldehydes to form carboxylic acids. Aldehydes reduce the complexed silver(I) ion to silver to produce a silver mirror with Tollens' reagent. Aldehydes also reduce the complexed copper(II) ion in Fehling's solution to copper(I) oxide. Aldehydes and ketones can be reduced to primary and secondary alcohols respectively, by reaction with lithium aluminium hydride in ethoxyethane.	Previous Higher PPA using Tollens' reagent. Lots of information about the silver mirror test can be found by carrying out an internet search. 💻 Chemguide.co.uk has pages on oxidation of aldehydes and ketones. 💻 Faraday Lecture on making double glazing by oxidation of glucose using Tollens' Reagent. Manufacture of silver mirrors. Aldehydes are fairly rare in the natural world due to air oxidation to carboxylic acids. Many drugs contain ketones (eg methadone), but none contain aldehydes.
3(k) Preparation and reactions of carboxylic acids	Carboxylic acids can be prepared by: 1 oxidising primary alcohols and aldehydes; 2 hydrolysing nitriles, esters or amides. Reactions of carboxylic acids include: 1 formation of salts by reactions with metals or bases; 2 condensation reactions with alcohols to form esters in the presence of an acid catalyst; 3 reaction with amino groups to form amide links; 4 reduction with lithium aluminium hydride to form primary alcohols.	Preparation of benzoic acid from ethyl benzoate (previously a PPA). Carboxylic acids are weak acids, neutralisation with alkalis to form salts, reaction with Mg — covered in Physical Chemistry Unit. Carboxylic acids are often ionised in drugs and form ionic interactions with binding sites. Penicillins contain a carboxylate ion that plays a crucial binding role. Consider role of carboxyl functional group in polymerisation the formation of polyesters, polyamides and proteins.
3(l) Amine classification and reactions	Amines are organic derivatives of ammonia and can be classified as primary, secondary or tertiary. Primary and secondary amines, but not tertiary amines, associate by hydrogen bonding. As a result, primary and secondary amines have higher boiling points than isomeric tertiary amines. Amine molecules can hydrogen-bond with water molecules thus explaining the appreciable solubility of the shorter chain length amines in water. The nitrogen atom in amines has a lone pair of electrons which can accept a proton from water, producing hydroxide ions.	Solubility of lower amines in water, test pH of solutions formed. Compare pH of ethylamine solution with pH of ammonia. Neutralise solutions of amines with mineral acids. chem.purdue.edu provides some information about amines in drugs 💻 Indiana.edu also provides information about amines and their salts in medicines. 💻 Elmhurst.edu has some homework ideas on amines but need to be selective. 💻

Content	Notes	Possible contexts and activities
3(l) Amine classification and reactions (cont)	Amines are weak bases which react with aqueous mineral or carboxylic acids to form salts.	
3(m) Aromatic hydrocarbons and reactions of benzene	Benzene C_6H_6 is the simplest member of the class of aromatic hydrocarbons. The benzene ring has a distinctive structural formula. The stability of the benzene ring is due to the delocalisation of electrons. A benzene ring in which one hydrogen atom has been substituted by another group is known as the phenyl group. The phenyl group has the formula $-C_6H_5$. The benzene ring resists addition reactions. One or more hydrogen atoms of a benzene molecule can be substituted to form a range of consumer products. Bonding in benzene can be described in terms of sp^2 hybridisation, sigma and pi bonds and electron delocalisation. Consider only alkylation, nitration, sulfonation and halogenation as examples of electrophilic substitution in benzene and other aromatic compounds.	Many everyday consumer products have very distinctive smells as a result of the presence of key aromatic compounds. A brief interest raising activity can be a display of household products containing these products. Examples would include well known antiseptics and disinfectants containing tricholorophenol or 4-chloro-3,5-dimethylphenol, permanent markers containing xylene or toluene etc. An internet search using these compounds as key words will return the names of several well known products. Benzene and its related compounds are important as feedstocks in the dyes and pigments industry, the pharmaceuticals industry and the detergents industry. Many drugs contain aromatic rings. They play a crucial role in binding as a result of their planar shape and hydrophobic character Mechanism not necessary but should be able to work out the product formed from benzene and the electrophile/reaction mixture. Information about mechanisms is available on the internet. 💻
3(n) Recognising and using types of reaction in organic synthesis	Given equations, the following reaction types can be identified: substitution, addition, elimination, condensation, hydrolysis, oxidation, reduction. Candidates should be able to devise synthetic routes, with no more than three steps, from a given reactant to a final product.	It is important that many, varied, real-life contexts for these reactions are provided. Similarities/parallels between the different reaction types should be constantly reinforced and opportunities to make connections frequently provided.

Content	Notes	Possible contexts and activities
4 Molecules and Colour		
4(a) Absorption of visible light by organic molecules	Most organic molecules appear colourless because the energy difference between the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) is relatively large resulting in the absorption of light in the ultraviolet region of the spectrum. Coloured organic compounds contain delocalised electrons within molecular orbitals which extend across several atoms. This is known as a conjugated system. The more atoms the delocalised molecular orbital spans, the smaller the energy gap between the delocalised orbital and the next unoccupied orbital and hence the lower the frequency of light (or longer the wavelength or lower the energy of radiation) absorbed by the compound. When the wavelength of the light absorbed is in the visible region, the organic substance will appear coloured. Molecules in which the structural formula contains alternate double bonds will exhibit molecular orbitals containing delocalised electrons which will extend the conjugated section of the molecule.	Candidates can examine information on a number of molecules comparing the absorptions of conjugated and non-conjugated dienes. Vitamin A very clearly exhibits a conjugated structure (retinol). They can also look at the structure of natural compounds such as beta-carotene. When ninhydrin reacts with amino acids a highly conjugated product is formed which absorbs light in the visible region and an intense purple colour (λ_{max} 750 nm) is observed. This is used in the detection of α-amino acids. Candidates can prepare a variety of dyes themselves and examine the structures to locate the chromophore. Examples would include the preparation of azo dye from aminobenzene (aniline), sodium nitrite and 2-naphthol at low temperatures. The azo dye can be used to dye a piece of cotton. 💻 Synthetic Indigo can also be prepared using a microscale method. 💻
4(b) Chromophores	The chromophore is the group of atoms within a molecule which is responsible for the absorption of light in the visible region of the spectrum. Light can be absorbed when electrons in a chromophore are promoted from one molecular orbital to another. If the chromophore absorbs light of one colour, the compound will exhibit the complementary colour.	For example, a compound in which the chromophore absorbs blue light will appear yellow. Complementary colours can be demonstrated very effectively using online resources which will allow colour mixing to be demonstrated on a computer screen or interactive whiteboard. An internet search using 'RGB colour mixing' will produce suitable simulations and animations. 💻 Simple spectroscopes made from DVDs can be used to view light transmitted or reflected by coloured compounds.

Content	Notes	Possible contexts and activities
5 Experimental Determination of Structure	*In organic chemistry, a number of experimental techniques are carried out to verify that the correct chemical structure has been synthesised.*	The RSC has produced 'Spectroscopy in a suitcase' which is an outreach activity giving school students the chance to learn about spectroscopy through hands-on experience. As well as covering the principles of spectroscopic techniques, the activities use real-life contexts to demonstrate the applications of the techniques. This can be used to teach mass spectrometry, infra-red spectroscopy and proton nmr spectroscopy. 💻 The RSC 'spectraschool' is also very useful and as well as providing useful background information, it also gives candidates the opportunity to print their own spectra for a range of compounds. 💻
5(a) Elemental microanalysis	Elemental microanalysis can be used to determine the masses of C, H, O, S and N in a sample of an organic compound in order to determine its empirical formula.	SnI_4 or CuO empirical formula experiment can be done again here but probably not necessary Opportunity to practise empirical formula calculations from results of elemental microanalysis experiments. Other elements in organic compounds can also be determined by elemental microanalysis.
5(b) Mass spectrometry	Mass spectrometry can be used to determine the accurate molecular mass and structural features of an organic compound. Fragmentation takes place producing parent ion and ion fragments. A mass spectrum is obtained showing a plot of the relative abundance of the ions detected against the mass-to-charge ratio. The molecular formula can be confirmed from a high accuracy determination of the mass of the parent ion. The fragmentation pattern can also be interpreted to gain structural information.	In mass spectrometry, the sample is first vaporised and ionised, and fragmentation occurs when excessive energy is used to ionise the molecules. The ion fragments are separated according to their mass-to-charge ratio using an electric or magnetic field. Many types of mass spectrometer will automatically compare the mass spectrum of the sample against a large database of known organic compounds to look for an exact match and to allow identification. The mass spectrum is like a fingerprint for a particular compound.

Content	Notes	Possible contexts and activities
5(c) Infra-red spectroscopy	Infra-red spectroscopy can be used to identify certain functional groups in an organic compound. Infra-red radiation causes parts of a molecule to vibrate. The wavelengths which are absorbed to cause the vibrations will depend on the type of chemical bond and the groups or atoms at the ends of these bonds. In infra-red spectroscopy, infra-red radiation is passed through a sample of the organic compound and then into a detector which measures the intensity of the transmitted radiation at different wavelengths. Infra-red absorbances are measured in wavenumbers, the reciprocal of wavelength, in units of cm^{-1}.	IR is still widely used as it is cheaper than NMR and can be used to follow reaction progress (ie carbonyl group present or absent). It also has many specialist applications in forensics, polymer chemistry and quality control. Chemguide.co.uk provides much background information on infra-red spectroscopy. 💻
5(d) Interpretation of ^{1}H NMR spectra	Proton nuclear magnetic resonance spectroscopy (proton NMR) can give information about the different environments of hydrogen atoms in an organic molecule, and about how many hydrogen atoms there are in each of these environments. In the proton NMR spectrum the peak position (chemical shift) is related to the environment of the H atom. The area under the peak is related to the number of H atoms in that environment. An interaction with H-atoms on a neighbouring carbon atoms can result in the splitting of NMR peaks into 'multiplets'. The number of H-atoms on the neighbouring carbon will determine the number of lines within a multiplet. Candidates would be expected to be able to draw and analyse low resolution proton NMR spectra and to analyse high resolution proton NMR spectra.	Hydrogen nuclei behave like tiny magnets and in a strong magnetic field some are aligned with the field (lower energy) whilst the rest are aligned against it (higher energy). Absorption of radiation in the radio-frequency region of the electromagnetic spectrum will cause the hydrogen nuclei to 'flip' from the lower to the higher energy alignment. As they fall back from the higher to the lower level, the emitted radiation is detected. The standard reference substance used in NMR spectroscopy is tetramethylsilane (TMS) which is assigned a chemical shift value equal to zero. The RSC website provides online NMR spectroscopy resources with video, tutorials and spectra databases. 💻 There is also a large RSC resource providing background theory for nmr and simple correlation information. 💻 Chemguide.co.uk provides background information on NMR spectroscopy as well as information on interpreting both low resolution and high resolution nmr spectra. 💻

Content	Notes	Possible contexts and activities
5(d) Interpretation of ^{1}H NMR spectra (cont)		Application of NMR in medical body scanners can be discussed here.
6 Drug Interactions		
6(a) Medicines	Drugs are substances which alter the biochemical processes in the body. Drugs which have beneficial effects are used in medicines. A medicine usually contains the drug plus other ingredients.	Discuss paracetamol which taken according to the correct dosage is beneficial but is very dangerous when taken in larger quantities and may lead to liver failure and death. Most drugs bind to a protein target by intermolecular binding forces and do not undergo any reaction. An induced fit normally leads to the effects observed. 'The Design Studio' is a useful, interactive RSC resource to introduce the topic of drugs and medicines. The resource gives candidates the opportunity to learn about the causes and effects of diseases such as cancer, HIV and asthma using their knowledge of chemistry. It then challenges the candidate to design an 'optimal' drug to treat one of the diseases using their knowledge of organic chemistry. 💻 Another interactive resource from the RSC is the 'Masterminding Molecules' package. This resource combines learning with game-play and involves cracking a code to reveal hidden chemical concepts involved in design of drugs and medicines. Clinical trials allow safety and efficacy data to be collected for new drugs or devices. Depending on the nature of the study, healthy volunteers or patients may be used in a small pilot study. If the safety and efficacy data is satisfactory, the scale of the study will be increased. In randomised drug trials a group of patients are divided with some being given the drug. 💻

Content	Notes	Possible contexts and activities
6(b) How drugs work	Most drugs work by binding to receptors. Receptors are usually protein molecules on the surface of cells where they interact with small biologically active molecules, or are enzymes that catalyse chemical reactions (catalytic receptors). The structural fragment of a drug molecule which confers pharmacological activity upon it normally consists of different functional groups correctly orientated with respect to each other. The overall shape and size of the drug has to be such that it fits a binding site. The functional groups on both the drugs and the receptor are positioned such that the drugs can interact with and bind to the receptor. Candidates should be able to identify the types of interaction between drugs and binding sites. By comparing the structures of drugs that have similar effects on the body, the structural fragment that is involved in the drug action can be identified.	Emphasise importance of shape. Binding of the active molecule to the binding site initiates a series of chemical events which results in a change in the cell chemistry. This can lead to an observable effect such as a muscle cell contracting, Protein databanks offer a huge number of PDB files containing examples of proteins with various drug molecules bound to a receptor site. Candidates can use CHIME, PYMOL or Chem3D to explore the interactions between the functional group and the receptor site. Some computer packages allow H-bonding interactions to be displayed- or electrostatic potential surfaces to be examined. Design Studio and Masterminding Molecules (RSC) can be used to illustrate these concepts. Excellent opportunity to investigate structural fragments common to different medicines using websites given above.
6(c) Classification of drugs	Many drugs can be classified as agonists or as antagonists at receptors, according to whether they enhance or block the body's natural responses. An agonist will produce a response similar to the body's natural active compound. An antagonist produces no response but prevents the action of the body's natural active compound. Many drugs act as enzyme inhibitors by binding to the enzyme's active site and blocking the reaction normally catalysed there.	Andanamide (also known as the bliss molecule) is a recently discovered messenger molecule that plays a role in pain, depression, appetite, memory, and fertility. Frostburg.edu provides more information about andanamide. 💻 The resource also describes the way in which nerve cells communicate, through molecular keys and receptors. There are other drug targets apart from receptors and enzymes, such as DNA and RNA.