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AS AND A LEVEL

Delivery Guide

CHEMISTRY A

H032, H432

For first teaching in 2015

Theme: Organic Chemistry





Version 2

AS AND A LEVEL CHEMISTRY A

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- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
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4.1.1 Basic concepts of organic chemistry

- (a) application of IUPAC rules of nomenclature for systematically naming organic compounds
- (b) interpretation and use of the terms:
- general formula (the simplest algebraic formula of a member of a homologous series) e.g. for an alkane: C_nH_{2n+2}
 - structural formula (the minimal detail that shows the arrangement of atoms in a molecule) e.g. for butane: $CH_3CH_2CH_2CH_3$ or $CH_3(CH_2)_2CH_3$
 - displayed formula (the relative positioning of atoms and the bonds between them)
 - skeletal formula (the simplified organic formula, shown by removing hydrogen atoms from alkyl chains, leaving just a carbon skeleton and associated functional groups)
- (c) interpretation and use of the terms:
- homologous series (a series of organic compounds having the same functional group but with each successive member differing by CH_2)
 - functional group (a group of atoms responsible for the characteristic reactions of a compound)
 - alkyl group (of formula C_nH_{2n+1})
 - aliphatic (a compound containing carbon and hydrogen joined together in straight chains, branched chains or non-aromatic rings)
 - alicyclic (an aliphatic compound arranged in non-aromatic rings with or without side chains)
 - aromatic (a compound containing a benzene ring)
 - saturated (single carbon-carbon bonds only) and unsaturated (the presence of multiple carbon-carbon bonds, including $C=C$, $C\equiv C$ and aromatic rings)
- (d) use of the general formula of a homologous series to predict the formula of any member of the series
- (e) explanation of the term structural isomers (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula

- (f) the different types of covalent bond fission:
- homolytic fission (in terms of each bonding atom receiving one electron from the bonded pair, forming two radicals)
 - heterolytic fission (in terms of one bonding atom receiving both electrons from the bonded pair)
- (g) the term radical (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms
- (h) a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond
- (i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles.

4.1.2 Alkanes

- 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
- 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)
- 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)
- 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)
- 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
- 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)
- the limitations of radical substitution in synthesis by the formation of a mixture of organic products, in terms of further substitution and reactions at different positions in a carbon chain.

4.1.3 Alkenes

- 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
- 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)
- explanation of the terms:
 - stereoisomers (compounds with the same structural formula but with a different arrangement in space)
 - E/Z isomerism (an example of stereoisomerism, in terms of restricted rotation about a double bond and the requirement for two different groups to be attached to each carbon atom of the C=C group)
 - cis–trans isomerism (a special case of E/Z isomerism in which two of the substituent groups attached to each carbon atom of the C=C group are the same)
 - use of Cahn–Ingold–Prelog (CIP) priority rules to identify the E and Z stereoisomers

- determination of possible E/Z or cis–trans stereoisomers of an organic molecule, given its structural formula
- the reactivity of alkenes in terms of the relatively low bond enthalpy of the π -bond
- addition reactions of alkenes with:
 - hydrogen in the presence of a suitable catalyst, e.g. Ni, to form alkanes
 - 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
 - hydrogen halides to form haloalkanes
 - steam in the presence of an acid catalyst, e.g. H_3PO_4 , to form alcohols
- definition and use of the term electrophile (an electron pair acceptor)
- the mechanism of electrophilic addition in alkenes by heterolytic fission (see also 4.1.1 h–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
- addition polymerisation of alkenes and substituted alkenes, including:
 - the repeat unit of an addition polymer deduced from a given monomer
 - identification of the monomer that would produce a given section of an addition polymer
- the benefits for sustainability of processing waste polymers by:
 - combustion for energy production
 - use as an organic feedstock for the production of plastics and other organic chemicals
 - removal of toxic waste products, e.g. removal of HCl formed during disposal by combustion of halogenated plastics (e.g. PVC)
- the benefits to the environment of development of biodegradable and photodegradable polymers.

4.2.1 Alcohols

- (a) (i) the polarity of alcohols and an explanation, in terms of hydrogen bonding, of the water solubility and the relatively low volatility of alcohols compared with alkanes (see also 2.2.2 l and 4.1.2 c)
- (ii) classification of alcohols into primary, secondary and tertiary alcohols
- (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
- (d) elimination of H_2O from alcohols in the presence of an acid catalyst (e.g. H_3PO_4 or H_2SO_4) and heat to form alkenes
- (e) substitution with halide ions in the presence of acid (e.g. $\text{NaBr}/\text{H}_2\text{SO}_4$) to form haloalkanes.

4.2.2 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
- (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)
- (d) explanation of the trend in the rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I)
- (e) production of halogen radicals by the action of ultraviolet (UV) radiation on CFCs in the upper atmosphere and the resulting catalysed breakdown of the Earth's protective ozone layer, including equations to represent:
- (i) the production of halogen radicals
- (ii) the catalysed breakdown of ozone by $\text{Cl}\cdot$ and other radicals e.g. $\cdot\text{NO}$

4.2.3 Organic synthesis

- (a) the techniques and procedures for:
- (ii) use of Quickfit apparatus including for distillation and heating under reflux
- (iii) preparation and purification of an organic liquid including:
- use of a separating funnel to remove an organic layer from an aqueous layer
 - drying with an anhydrous salt (e.g. MgSO_4 , CaCl_2)
 - redistillation
- (b) for an organic molecule containing several functional groups:
- (i) identification of individual functional groups
- (ii) prediction of properties and reactions
- (c) two-stage synthetic routes for preparing organic compounds.

Basic concepts of organic chemistry

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

Common misconceptions of students often link to the sequence of numbering the side chains and functional groups. Generally speaking, students remember the prefixes that number the carbon chain fairly easily. Students often forget to differentiate between molecules such as propan-2-ol and propan-1-ol. Also students often forget to look for the longest carbon chain, instead adding too many side chains (such as naming a chain 1-methylbutane rather than simply naming it pentane).

A step-by-step method should be taken. Students should be given simple chains to begin with, without any side chains. These should be gradually built up in complexity. Students often find it useful to make chains and name them. Molecular modelling kits, or even just modelling clay and toothpicks, could be used to construct example molecules that the students should then name.

Students need to recall the different functional groups listed in this module, namely: alkanes; alkenes; haloalkanes; alcohols; aldehydes; ketones; carboxylic acids and esters. Whilst they do not need to know much else at this stage apart from their existence, when it comes to nomenclature they could be introduced to some of these functional groups.

After the students have mastered the steps needed to name a compound, any functional groups and side chains, you could task students with making a 'mystery' molecule and then asking their partner to name it. Doing this can help both learners. If this is done it is very important to make sure that the questioner can name it themselves, otherwise you will find some students make very complex molecules that they can't name themselves.

(b) interpretation and use of the terms: (i) general formula; (ii) structural formula; (iii) displayed formula; (iv) skeletal formula

Students often get the definitions of these terms mixed up. In particular, students can lose marks when giving a displayed formula for compounds such as alcohols for not showing the bond between the O and the H. This is often drawn as -OH in many textbooks and online, but isn't strictly the displayed formulae.

Due to this, it is best not to draw the shorthand versions at all when delivering this content, as students may get confused. Explain to students the use of the shorthand, as they will see it if they do even casual reading around the course content, but explain to them that the displayed formula has to show every bond.

Students often forget general formula work, even though they may have learnt it in GCSE, so it is important not to assume that students remember it from previous years. Show the students several examples of alkanes and alkenes, getting them to name them to help secure knowledge from section (a). Have students count the number of carbon and hydrogen

atoms in each section, then have them predict the numbers of carbons and hydrogen in very long (40 carbons upwards) chains. This can lead to them using the general formula even if they weren't previously aware of it.

Students may well have never encountered skeletal formulae before, so time should be taken to explain that normally hydrogen atoms are not shown, except where they take part in a reaction or mechanism. This should be emphasised, as some organic mechanisms later on are often shown using skeletal formulae, showing hydrogen atoms where they take part in substitution or elimination reactions.

Again, molecular modelling kits can be used to help learning. Students can be shown (or make) long molecules, and then be asked to draw out the displayed, structural and skeletal formulae of the compounds.

(c) interpretation and use of the terms: (i) homologous series; (ii) functional group; (iii) alkyl group; (iv) aliphatic; (v) alicyclic; (vi) aromatic; (vii) saturated and unsaturated

(d) use of the general formula of a homologous series to predict the formula of any member of the series

These sections should be taught as a part of a sequence with sections (a) and (b); it may be that they can be taught during the same lesson depending on student progress.

When given compounds to name from the previous sections, vocabulary can be introduced where appropriate. For example, students can have explained to them when drawing out simple carbon chains the definition of alkyl groups, and when naming alcohols and other compounds the concept of functional group can be mentioned.

This differs slightly when referring to alicyclic compounds, as when students are naming simple compounds they are unlikely to come into contact with them. Some of the contextual work from section (b) does use these compounds when drawing out skeletal structures. Make sure that the concept and name of alicyclic compounds is mentioned here. Aromatic compounds can be explained here also, although depth is not needed as Aromatic chemistry is not in the AS course.

When learning about the homologous series students must make sure they can recognise different functional groups, and that they can correctly name any compounds that they draw. It is imperative that any misunderstandings about nomenclature are dealt with early on, as when students go on to learning about different organic synthesis reactions they should be concentrating on correctly drawing out mechanisms, not on how to name the products.

(e) explanation of the term structural isomers (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula

A common problem that students find in this area is identifying which isomers are different from each other. Students often forget that bonds can rotate around each other, and as such they often draw out several examples of 'different' isomers which all turn out to be the same molecule.

When drawing out isomers that have the homologous series of C_nH_{2n} , students often fail to see that an isomer of this can be a ringed alkane, as well as an alkene.

To show this, and demonstrate the fact that bonds can rotate (leading to some potentially confusing isomers that are identical), modelling kits, or simpler kit like blu tac and straws, can be used. Students can be asked to give their partner a simple formula for an alkane (not too long, say a 4-5 carbon-chain) and then be challenged to make as many isomers as they can. This can be used in the lesson to quickly spot misconceptions regarding the number of isomers that can exist.

(f) the different types of covalent bond fission

(g) the term radical (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms

(h) a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond

(i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles.

(repeated from previous section, but said again to help with clarity)

Note – due to the concepts in this section being used in multiple areas, heterolytic fission may be best explained when teaching section 4.2.2e. Likewise, the concepts of drawing out reaction mechanisms may be best explained in the sections relating to the different types of mechanisms encountered in AS chemistry, in sections 4.1.3f; 4.2.1c; 4.2.2c, rather than in an independent section per se.

As such, there is a danger of repetition here, but some common misconceptions are worthy of being mentioned. Students often struggle with the accurate placement of curly arrows, especially those who have small handwriting, and as such they can lose marks for a loss in accuracy. Make sure to stress that a curly arrow must originate **either** from the middle of a bond, **or** from the middle of a lone pair **or** from an atom. Sloppy drawing can make it hard to identify that the student fully understands the reaction. More on the accurate drawing of the mechanisms will be covered in the areas below.

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

(b) explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion (see also 2.2.2g–h)

By giving students a very simple brief (each bond has a pair of electrons, and so bonds repel) many students should be able to instinctually work out common bond angles for compounds. Like in previous sections, a hands-on approach to this is recommended. Giving students the ability to make their own molecules out of craft materials will allow them to work out common bond angles given the brief above.

Students need to be confident with drawing out 3D molecules in 2D with 'wedge and dash' notation. After students have predicted common bond angles, the difficulty of drawing out models accurately in two dimensions should be explained. Common alkane models can be given to students (or made by them) and students can sketch out how they think they will appear on mini-whiteboards or rough paper. This can allow the teacher to gauge how much the students understand about this topic. As it is a fundamental skill it is important to ensure students master it early to avoid problems later on.

When students understand the concepts of bond rotation the idea of sigma bonds should be introduced. As (in student terms) a sigma bond is simply the name given to a single covalent bond, this is rarely an area of confusion.

(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 2.2.2k)

Students may need a recap of previous work (from section 2.2.2k) to recall the definition of different intermolecular forces. After a recap, students should be asked to build a couple of common alkanes (such as propane and pentane) and asked to describe them in terms of the difference in intermolecular forces between them.

In doing this students should come to a conclusion on the difference in London forces between them, and so a difference in boiling point between them. A common misconception in this area is that in order to boil an alkane bonds need to be broken. It needs to be stressed to students that covalent bonds do not need to be broken in order to boil an alkane, it is only the (much weaker) intermolecular force that needs to be broken instead.

After this has been explained, ask students to build/draw a couple of branched alkanes

(such as 2-methylpropane and 3-methylpentane). Students should always be encouraged to draw/build molecules without being shown them first as mistakes in nomenclature can be common, and this knowledge should be reinforced throughout the course. These should be compared to the two alkanes previously built, and it should be explained that these have a different (lower) boiling point. Students should be encouraged to think of the difference between the molecules; it should be apparent that the only difference is the side chain and so there is a larger gap between chains, meaning weaker London forces.

(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 2.2.2j)

This area is best reinforced when describing why various reactions happen, such as: addition reaction of alkenes (4.1.2f); electrophilic reactions of alkenes (4.1.2h); and the substitution reactions of alcohols (4.2.1e). In these contexts the lack of bond polarity in alkanes can be compared and explained. If an explanation is needed before introducing these reactions, the lack of reactivity can be explained by the high amount of energy required to break covalent bonds in the hydrocarbon, and the low difference in electronegativity between the carbon and hydrogen atoms. This conceptual idea should have been introduced previously to students when they were learning about intermolecular forces.

(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

Students will have almost certainly already heard about the main gases from complete and incomplete combustion (namely carbon monoxide and carbon dioxide) but it is important that students are aware how the amount of oxygen can change what is produced.

Students need to be familiar with how to balance equations. This is work from GCSE but it may be necessary to go through the topic again, depending on student ability.

(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 4.1.1f–g)

Students typically understand the stages of free radical substitution fairly well when initially taught, but can find their application to an exam-style question difficult. When asked to carry out a sequence of reactions to make a haloalkane, students typically remember initiation but have difficulties with the other two steps.

One approach is to approach the topic backwards. Starting with termination, questions often tell students what they need to make. At the termination step remind students that this happens by two radicals reacting together. By splitting their final product into two radicals, students now know what they need to make in the propagation step.

By looking at their reactants (typically a halide radical from the initiation step, and an alkane that was in the reaction) students can work through several propagation reactions. Their aim should be to make the two radicals that are required for the termination stage.

(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

Modelling kits can be used to explain the problems with substitution reactions in a long carbon chain. Have students show the initiation step of a radical reaction, and then the reaction of the radical with an alkane. Students should realise (or have demonstrated) that the position of the subsequent propagation will affect later reactions, and also that a mixture of different products is possible.

Alkenes

(a) alkenes as unsaturated hydrocarbons containing a C=C bond comprising a π -bond (sideways overlap of adjacent p-orbitals above and below the bonding C atoms) and a σ -bond (overlap of orbitals directly between the bonding atoms) (see also 4.1.2a); restricted rotation of the π -bond

(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 2.2.2g–h, 4.1.2b)

As mentioned in the specification, this section may well be best taught at the same time as 4.2.1b, with students making models of molecules and using electron pair repulsion to explain the bond angles.

One important area to stress is the lack of rotation around the double bond, which may well have not been covered when describing sigma bonding in section 4.2.1b. When showing students the molecular models of alkanes/alkenes (either as a demonstration or as a class activity where they make their own), or when building a model of an alkene, this lack of rotation can be easily demonstrated. Again, a hands-on approach to teaching molecular shapes is recommended. A reminder on how to draw 'wedge and dash' diagrams can be done here also.

(c) (i) explanation of the terms; stereoisomers, E/Z isomerism, cis-trans isomerism (ii) use of Cahn–Ingold–Prelog (CIP) priority rules to identify the E and Z stereoisomers

(d) determination of possible E/Z or cis–trans stereoisomers of an organic molecule, given its structural formula

Students last covered isomerisation in section 4.1.1e when they covered structural

isomerisation, and so they should be familiar with the concept of one molecular formula having different possible shapes. Depending on the gap after the previous section, this may be worth going over again.

By giving students several common alkenes (but-2-ene, pent-2-ene) and asking them to build/draw these out (without first mentioning anything to do with stereoisomerism) you will find that there is some variation in the molecules that students show. The lack of rotation described in 4.1.3a can be mentioned here when comparing the different drawings.

Students often (even after having been shown) get the terms E/Z and cis-trans mixed up, so even if the concepts are easily understood it is still valuable to spend time ensuring students can name molecules using the correct terms. Likewise, these terms should be referred to throughout the course when dealing with alkenes.

In a similar manner, when doing nomenclature from 4.1.1a students should be encouraged to make alkenes and have their partner name them. Ensure the students can name these molecules themselves, or you will find some very large and outlandish molecules get constructed.

(e) the reactivity of alkenes in terms of the relatively low bond enthalpy of the π -bond

(f) addition reactions of alkenes

(g) definition and use of the term electrophile (an electron pair acceptor)

(h) the mechanism of electrophilic addition in alkenes by heterolytic fission (see also 4.1.1h–i)

These sections are often best taught together, as the mechanism for the reaction is largely the same, with the electrophilic addition of a group to the alkene.

Section 4.1.3e should have been covered when teaching about sigma bonds from 4.1.2a. Ensure students understand that the double bond is an electron-rich pi bond, as this information is important for them to access the rest of this section.

Students may find noticing patterns with these reactions difficult at first, so it is important to teach them the key concepts of drawing out curly arrows (repeated here for clarity). Make sure to stress that a curly arrow must originate **either** from the middle of a bond, **or** from the middle of a lone pair **or** from an atom. Sloppy drawing can make it hard to identify that the student fully understands the reaction.

A common misconception is that a curly arrow shows the movement of a molecule, not the movement of a pair of electrons, and as such must originate from certain locations as listed above. Remind students that electrons, being negative, will be attracted to areas of positive charge. Initially give students a simple addition reaction (such as the addition of HBr to

ethene) and have them draw any dipoles on to the molecules. From here students may well be able to predict the direction of the first curly arrow. After the first one is drawn out, explain to students how bonds can break when an atom, due to bonds being formed, has too many valence electrons, and curly arrows can show this as well.

After students have been taught the method of drawing out arrows they should, with practice, be able to work out likely mechanisms without having to memorise every reaction. This memorisation can be problematic, as it can result in students not being able to adapt their mechanism to similar chemical reactions.

Practical work here can be of great use in teaching the tests for alkenes from section (f) (ii). Given the information on how to draw mechanisms above, students may be initially unable to draw a reaction between Br and an alkene as there is no obvious dipole. Knowledge of the electron rich double bond from 4.1.3e should allow students to understand the concept of an induced dipole.

When students are familiar with how to draw electrophilic addition reactions, Markownikoff's rule can be slowly introduced. This can be given to students by allowing them to find it out for themselves. Give students an alkene (such as propene) and ask them to show the reaction (by drawing on the board, or large paper, and then showing the rest of the class) between this alkene and HBr. Some students may have drawn different, but correct, answers (in this case 2-bromopropane and 1-bromopropane). If not, ask students if any different products could be formed. This should lead to a discussion as to how likely each one is to form.

By going back to the intermediate stage, explain what effect nearby alkyl groups have on the stability of the carbocation. From there have students vote on which molecule is more likely to form (in this case 2-bromopropane).

(j) addition polymerisation of alkenes and substituted alkenes

This topic is covered in GCSE, so students should remember the key concepts after being reminded. Ensure it is covered, however, as students can tend to forget work from previous years.

Remind students of the main procedure in addition polymerisation. The double bond of the alkene is broken and this joins to adjacent chains. This is an important concept to remind students of as when they are given more complicated monomers they might find it difficult to predict the chain.

A way to approach this is to have each student (or pair, if equipment is low) make a monomer out of a molecular modelling kit, or craft materials. Have the students then 'polymerise' this by breaking their double bond and adding it to the monomer of a student next to them. By continuing this the class will eventually have built a sizable model of a polymer.

From this, students should realise that the polymer could, in theory, continue indefinitely and so be impractical to draw in a book. Their initial monomer could be drawn as a repeating unit to show the polymer structure.

When drawing repeating units, make sure that students remember to draw the monomer without the double bond, and that the bonds of the monomer extend beyond the brackets.

When this area is understood, students should be able to work backwards to identify monomers from longer polymer chains.

(k) the benefits for sustainability of processing waste polymers

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

Students are most likely familiar with this topic from GCSE. This topic requires mostly recall, so students can be encouraged to deliver presentations on the topic, or sections of it, to the class.

If this is done, students can be briefed to deliver their presentation like a lesson. To ensure the class as a whole gets involved, each group can also design a plenary (such as a quiz) to test how much the class has learnt at the end of their presentation. They can also make a handout which can be given out to the class to act as a revision aid. If this is done, make sure it is proofread (either by peers, or the teacher) to ensure there aren't any errors.

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 2.2.2l and 4.1.2c)

Depending on how long ago hydrogen bonding was taught to students, it may be necessary to go through this work again. Make sure that students are diligent in drawing all the partial charges, as this can allow them to see how alcohols dissolve in water by drawing on hydrogen bonds.

Students should be asked to recall and compare the difference in strength of different intermolecular forces from previous work, and in doing so should realise the difference in reactivity between alkanes and alcohols.

(a)(ii) classification of alcohols into primary, secondary and tertiary alcohols

Ensure students remember the work on nomenclature from 4.1.1c (ii) before the three types of alcohol are explained. As a useful recall tool, students can have several alcohol names

given to them (such as butan-1-ol, butan-2-ol and 2-methyl propan-2-ol) and students should then draw/build them before the difference in primary, secondary and tertiary alcohols is explained. This can also be a useful way of revising isomerisation from 4.1.1e.

(b) combustion of alcohols

Students are probably aware of the products of combustion if they have done any work on combustion/the greenhouse effect from GCSE, so it is useful to ensure that they have this recall.

Time must be taken to ensure that students are able to write out balanced equations showing combustion. If students need time on this, pairs of students can be asked to give an example of an alcohol to their partners to balance. This can then be checked. This can form a useful starter in the lesson to other alcohol reactions from (c).

(c) oxidation of alcohols by an oxidising agent, e.g. $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (i.e. $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$)

A practical-led approach can be very useful here to help students understand the differences in reactivity with primary, secondary and tertiary alcohols. This will help students understand the difference. A common area of misconception here is students who often forget reagents and conditions.

One method that can be done to help consolidate this area is having students make a reference sheet covering the reactions of alcohols, haloalkanes and alkenes. This can be a very useful revision aid (such as the one here: http://1.bp.blogspot.com/_ra2Or-vQRFk/TOcJZlCyl/AAAAAAAAAC4Y/My0am9duF9M/s1600/DSC00999.JPG), which can help students answer synoptic questions which may ask for recall from several different areas. Students can be asked to construct this as they go along throughout the course, or at the end. Students often find linking organic syntheses together challenging and frequent reference to a chart can be helpful.

Be careful when explaining to students the high bond enthalpy in C-C covalent bonds. Ensure students are clear about the difficulties in making tertiary alcohols react. Link this work to previous work on hydrogen bonding/permanent dipoles to explain the difference in the energy required to oxidise primary/secondary alcohols compared to tertiary ones.

(d) elimination of H_2O from alcohols in the presence of an acid catalyst (e.g. H_3PO_4 or H_2SO_4) and heat to form alkenes

The main area of misconception here is students mistakenly thinking that a substitution reaction may take place rather than an elimination reaction. Students often find it hard at first to identify the difference between addition, substitution and elimination reactions. Make sure students know to look for a double bond in the reactants and products of a reaction. If a double bond is only in the products, the reaction is elimination; if only in the reactants, the reaction is addition.

(e) substitution with halide ions in the presence of acid (e.g. NaBr/H₂SO₄) to form haloalkanes

As mentioned above, students can find it hard to identify the difference between an elimination and substitution reaction, and when they occur. As in 4.2.1a (i) and 4.2.1c students should be shown both the substitution and elimination reactions and asked to describe which reaction would require more energy in term of bond enthalpy. This should allow students to identify the differences in conditions required, and when either reaction would occur.

Haloalkanes**(a) hydrolysis of haloalkanes in a substitution reaction****(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 4.1.1h–i)****(d) explanation of the trend in the rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I)**

At this point in the course students should be (hopefully) familiar with drawing out reaction mechanisms, and if given an example haloalkane and a nucleophile should be able to identify a possible reaction. Start with a simple substitution, such as the reaction between 1-chloropropane and NaOH. After explaining that the NaOH dissociates to form OH⁻, like in section 4.2.1a (i) have students draw out the partial charges. Encourage groups of students to predict possible reaction mechanisms (ensuring curly arrows are drawn) before showing the class the correct mechanism.

Ensure students are aware of what classifies as a nucleophile, as initially they might find identification difficult. Some students find breaking the word down helpful (*nucleo* – linked to the nucleus – positive, and *phile* – to like).

(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

This work requires understanding of free radicals previously covered in 4.1.2f, so it is important that students can recall this work. Initially students may not understand the issues with the interaction with CFCs and the ozone layer as the conversion of ozone to oxygen does not seem significant. Ensure students understand that one CFC molecule is able to react with potentially thousands of ozone molecules.

As this part of the course relies on memorisation of reactions, this work can be made more interactive by encouraging groups to make presentations to the class, quizzes and revision handouts for their group.

Organic synthesis**(a) the techniques and procedures for: (i) use of Quickfit apparatus; (ii) preparation and purification of an organic liquid**

These practical techniques are best integrated into organic reactions from 4.2.1, 4.2.2, 4.1.2, 4.1.3. This is also one of the PAG activities so competency in the use of this equipment is required.

Initially students might find the handling of Quickfit equipment difficult, as it is unlikely that they will have covered it in GCSE. For their first foray into using Quickfit apparatus, students should be taken through assembly slowly and in steps.

Common problems in assembly often involve glassware being clamped in incorrect places. Quickfit apparatus can be fragile in places, so make sure students only clamp glassware where it is strongest, such as around the necks of flasks.

Another common problem can be students clamping equipment too high up, and too far from a water source. Make sure the practical is planned out so students are near a tap and sink if they are to carry out any work involving a condenser.

When using a condenser, make sure that the water pressure is not too high, and the water pipes are secured. When carrying out the practical ensure students are aware of where they are heating, as burning rubber pipes with a Bunsen burner is a common mistake.

When first carrying out a practical with a separating funnel, ensure students know the difference between the organic and aqueous layers, and (to ensure they do not mistakenly throw away their product) make sure they (initially) don't throw away either layer.

(b) for an organic molecule containing several functional groups**(c) two-stage synthetic routes for preparing organic compounds**

Throughout the course it can be helpful for students to construct a chart of organic reactions, which can be invaluable for this section. Alternatively students can make one as a revision aid. An example is at the following link:

<https://www.ocr.org.uk/Images/359182-organic-synthesis-reaction-pathways.pdf>

Encouraging students to make a chart containing all the organic mechanisms in the course, along with tests, can allow them to answer difficult synthesis questions that may require

recall from different sections of the course. Students should be encouraged to answer questions in this area 'open book' at first. A common problem students have is linking different mechanisms together to make a synthetic route. To help with this, students should link any chemical synthesis to ones previously covered: reminds them that different alkyl groups will not (necessarily) affect the mechanism. Students should highlight functional groups and concentrate on the reaction around the group. It could help students to use R-groups when teaching mechanisms so patterns can be more easily spotted.

Thinking conceptually – Activities

4.1.1 Basic concepts of organic chemistry

A website that allows students to construct quizzes to identify functional groups in molecules, name molecules, and draw molecules based on names.

<http://www.bbc.co.uk/bitesize/quiz/q53403449>

Another online activity that can be used to test knowledge of organic nomenclature. This can be used to reinforce learning at the end of the section. It also checks on learning about skeletal formulae, which can be used in checking how much the students learn through section 4.1.1b (iv)

<https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/Questions/Nomencl/nomencl.htm>

An extensive worksheet testing student's skills at naming compounds using IUPAC nomenclature. Not all of the compounds will have been covered by this stage, so selection of the questions may be required.

http://vanmaarseveen.weebly.com/uploads/6/2/6/5/6265786/chemistry_worksheet_balancing_equations_and_naming_compounds.doc

(b) interpretation and use of the terms: (i) general formula; (ii) structural formula; (iii) displayed formula; (iv) skeletal formula

An activity that tests the ability of learners to draw out the several different ways of drawing out a compound. This activity only tests knowledge of alkane nomenclature. This can make it accessible as an early activity when learners are not fully confident on how to draw out structures, before going on to more complex nomenclature.

<http://tinyurl.com/q35njxe>

(c) interpretation and use of the terms: (i) homologous series; (ii) functional group; (iii) alkyl group; (iv) aliphatic; (v) alicyclic; (vi) aromatic; (vii) saturated and unsaturated

(d) use of the general formula of a homologous series to predict the formula of any member of the series

An activity that summarises this section and includes work on cyclic compounds, saturation and functional groups.

This can be used as a plenary/end of section test of this work.

http://www.a-levelchemistry.co.uk/uploads/9/0/4/5/90457821/basic_concepts.rtf

(e) explanation of the term structural isomers (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula

This is a useful sheet to summarise structural isomerism which also includes some questions. It can also be useful later on in the organic chemistry topic, with sections on E/Z isomerism and optical isomerism.

<https://chemrevise.files.wordpress.com/2015/09/6-1-5-isomerism.pdf>

(f) the different types of covalent bond fission

(g) the term radical (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms

(h) a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond

(i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles.

As mentioned in other sections above relating to this topic, this work is covered extensively in other sections (namely 4.2.2e; 4.1.3f; 4.2.1c; 4.2.2c and as such it is more appropriate to list activities in those relevant sections.

4.1.2 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

(b) explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion (see also 2.2.2g–h)

<http://www.chemguide.co.uk/atoms/questions/q-shapes1.pdf>

This activity reviews previously-taught concepts of bond angles and common shapes. It is very useful revision for this section. Ensure students can recall common bond shapes, and also explain in terms of repulsion why these shapes occur. Also ensure at the end of this section that they can correctly identify sigma bonding.

(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 2.2.2k)

<http://www.chemguide.co.uk/organicprops/alkanes/background.html>

A website page covering the chemistry of straight-chained and cyclic 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 2.2.2j)

This booklet guides students (with examples and questions) around the concepts of bond enthalpy, and helps students recall previous information about the homologous series.

<http://www.umanitoba.ca/outreach/crystal/resources%20for%20teachers/Saturated%20versus%20Unsaturated%20Hydrocarbons%20C11-5-10.doc>

(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

<https://edu.rsc.org/resources/identifying-the-products-of-combustion/707.article>

This demonstration can be used to model the products made from the incomplete combustion of an alkane (in this case methane). Students can be encouraged afterwards to work out the balanced equation for this combustion for themselves before having it given to them.

<http://www.chemicalformula.org/worksheets/Balancing-combustion-reactions.pdf>

This worksheet gives students a large selection of complete and incomplete combustion equations that they need to balance for themselves. Higher ability students can be encouraged to explain the general pattern for these equations.

(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)

<https://www.stem.org.uk/elibrary/resource/33534>

This classic demonstration shows the rapid (and explosive) nature of a radical chain reaction. Careful attention should be given to the safety of this practical – in particular the need for a fume cupboard when preparing chlorine.

<https://www.youtube.com/watch?v=nz03fpullyo>

This video shows the reaction above, in case further reinforcement of the reaction is needed, or if available facilities do not allow the demonstration to be made.

(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

<http://www.chem.uiuc.edu/weborganic/organictutorials.htm>

This site has a selection of free radical tutorials, and asks students to identify different products made from one free radical substitution.

4.1.3 Alkenes

(a) alkenes as unsaturated hydrocarbons containing a C=C bond comprising a π -bond (sideways overlap of adjacent p-orbitals above and below the bonding C atoms) and a σ -bond (overlap of orbitals directly between the bonding atoms) (see also 4.1.2 a); restricted rotation of the π -bond

(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)

<http://quizlet.com/40319440/organic-chemistry-quiz-3-flash-cards/>

A series of flash cards that can be used to test knowledge of bonding in alkenes. This quiz also relates to topics in sections 4.1.2, 4.1.4 and 4.1.5, and so can be a useful revision activity near the end of the course.

(c) (i) explanation of the terms; stereoisomers, E/Z isomerism, cis-trans isomerism (ii) use of Cahn–Ingold–Prelog (CIP) priority rules to identify the E and Z stereoisomers (d) determination of possible E/Z or cis–trans stereoisomers of an organic molecule, given its structural formula

<http://www.docbrown.info/page06/PRalkenes/alkeneQmc.htm>

This quiz will task students with naming alkenes properly, both in terms of E/Z and cis-trans isomerisation, and also can provide useful revision for naming organic compounds with side chains.

http://ochem.weebly.com/uploads/1/0/5/0/10503018/stereotut_alkene.pdf

This worksheet covers some problems relating to E/Z and cis-trans stereochemistry to ensure students have had some practice in this area.

<http://www.chem.ucalgary.ca/courses/351/WebContent/orgnom/structureToName.html>

This online quiz allows further practice in naming alkenes and also helps students revise skeletal formulae from 4.1.1 (iv).

(e) the reactivity of alkenes in terms of the relatively low bond enthalpy of the π -bond

(f) addition reactions of alkenes

(g) definition and use of the term electrophile (an electron pair acceptor)

(h) the mechanism of electrophilic addition in alkenes by heterolytic fission (see also 4.1.1 h–i)

(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

https://scilearn.sydney.edu.au/fychemistry/tutorial_assignments/chem1002/ws3.pdf

A selection of questions that can be given to students to allow them some much-needed practice in alkene additions. This page also includes a test which can be used (if needed) by the teacher at the end of the section. As these questions challenge students on sections (f)–(h), ensure these areas are fully understood before students are given them.

Some of these questions also cover work from 4.1.3c, which can make them useful revision.

<https://www.youtube.com/watch?v=NjluBvod2eM>

A video showing the bromination of an alkene, if time (or equipment) is insufficient to allow a practical demonstration such as the one listed below.

<https://edu.rsc.org/resources/unsaturation-in-fats-and-oils/394.article>

A simple practical that can be done to show basic halogenation of an alkene, as well as emphasise the tests for unsaturation from section (e) (ii).

(j) addition polymerisation of alkenes and substituted alkenes

<https://edu.rsc.org/resources/addition-polymerisation/479.article>

This practical is very useful to show students how addition reactions can happen. Students should be encouraged to predict the outcome of the polymer given the monomer.

Depending on time and student ability, this may be more suitable as a demonstration which is set up and then explained to students.

<http://www.usetute.com.au/polymers.html>

A useful summary of addition polymerisation. Condensation polymerisation is covered in Module 6.

4.2.1 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 2.2.2l and 4.1.2c)

<https://edu.rsc.org/experiments/the-properties-of-alcohols/463.article>

This practical can be used as an introduction to the properties of alcohols, and forms a useful point of discussion as to the reasons why alcohols are water-soluble.

(a)(ii) classification of alcohols into primary, secondary and tertiary alcohols

http://legacy.chemgym.net/as_a2/topics/naming_and_classifying_alcohols/quiz_2.html

A quick quiz which tests identification of different types of alcohol.

(b) combustion of alcohols

<https://edu.rsc.org/experiments/the-whoosh-bottle-demonstration/708.article>

A fun reaction that demonstrates the combustion of alcohols. The safety instructions must first be read very carefully. The presence of water can be explained by the fact that, once carried out, the plastic bottle cannot be used again due to water vapour condensation inside, which may become visible.

(c) oxidation of alcohols by an oxidising agent, e.g. $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (i.e. $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$)

<https://edu.rsc.org/resources/a-microscale-oxidation-of-alcohols/553.article>

This practical is extremely useful when explaining the differences in reactivity of different alcohols. The practical is micro-scale, which makes it last no longer than 20 minutes, and relatively low risk.

(d) elimination of H_2O from alcohols in the presence of an acid catalyst (e.g. H_3PO_4 or H_2SO_4) and heat to form alkenes

http://www.a-levelchemistry.co.uk/uploads/9/0/4/5/90457821/2.10_hw.doc

A worksheet that contains elimination reactions, and also helps to consolidate work from (d) and (f). Mark scheme is below.

http://www.a-levelchemistry.co.uk/uploads/9/0/4/5/90457821/2.10_hw_ms.doc

(e) substitution with halide ions in the presence of acid (e.g. $\text{NaBr}/\text{H}_2\text{SO}_4$) to form haloalkanes.

<https://edu.rsc.org/resources/the-conversion-of-alcohols-to-halogenoalkanes/558.article>

A substitution reaction that converts ethanol to bromoethane. It requires a fume cupboard, and so may only be appropriate for a demonstration depending on available equipment. Students should, like in all practicals in this section, be encouraged to predict the mechanism and outcome of the reaction.

4.2.2 Haloalkanes

- (a) hydrolysis of haloalkanes in a substitution reaction
- (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)
- (d) explanation of the trend in the rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I)

<http://www.ocr.org.uk/Images/163774-explaining-observations-activity-teacher-instructions.pdf>

A practical activity to investigate the factors affecting the rate of substitution of haloalkanes.

http://www.knockhardy.org.uk/sci_htm_files/mcrx.HTM

A quick online quiz which checks knowledge of bond polarity, identification of nucleophiles and the relative reactions of different halogens from (d).

- (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

<https://www.youtube.com/watch?v=-T0mbgTm1pg>

A useful video outlining the mechanism of ozone destruction by chlorine radicals, as well as some of the background behind ozone depletion.

4.2.3 Organic synthesis

- (a) for an organic molecule containing several functional groups

<http://www.a-levelchemistry.co.uk/unit-6.html>

A series of chemical reactions and organic tests that can be useful for students to carry out to remind them of organic tests. The practicals are multiple-step syntheses which can be used to encourage students to work out the mechanisms at each step using their prior knowledge.

Thinking contextually – Activities

4.1.1 Basic concepts of organic chemistry

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

<https://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/nomen1.htm>

This link lays out the basic rules that need to be followed when naming organic compounds. Students who are new to these rules should ensure that they follow the steps one at a time.

It is advisable that students make their own record of the rules and refer to them at all times.

<https://www.youtube.com/watch?v=BulW2otK854>

This link has a very useful step-by-step tutorial that shows students how to name simple organic molecules.

(b) interpretation and use of the terms: (i) general formula; (ii) structural formula; (iii) displayed formula; (iv) skeletal formula

This link is very comprehensive in explaining the different types of formulae listed above. It explains the differences between the terms, and gives useful examples.

<http://www.docbrown.info/page06/FunctionalGroups.htm>

(c) interpretation and use of the terms: (i) homologous series; (ii) functional group; (iii) alkyl group; (iv) aliphatic; (v) alicyclic; (vi) aromatic; (vii) saturated and unsaturated

(d) use of the general formula of a homologous series to predict the formula of any member of the series

This link contains a functional group chart which could be used as a summary sheet for students. It also includes naming summaries for the different functional groups. Note that it does contain some functional groups which are not covered at A Level.

<https://www.compoundchem.com/2020/02/21/functional-groups/>

This link shows students common functional groups, and contains several mini-tests that they can use to test identification of groups in complex organic molecules.

http://chemed.chem.purdue.edu/genchem/topicreview/bp/2organic/2org_frame.html

This link is a very useful resource for reference. In particular, it differentiates between aliphatic and aromatic compounds. Care must be taken to ensure that learners do not get these terms mixed up.

<http://www.chemguide.co.uk/orgproprsmenu.html>

This link shows the existence of different types of alicyclic compounds. Many of these will be new to students as, before this, they often only see the existence of six carbon rings.

<http://www.citycollegiate.com/organic3.htm>

This link details the differences between saturated and unsaturated hydrocarbons, as well as the chemical tests that can be used to test for the presence of unsaturation in a compound.

<http://www.ivy-rose.co.uk/Chemistry/Organic/Hydrocarbons.php>

<https://www.youtube.com/watch?v=b7NFSSHDmro>

This link can be used as an instructional tool for students to read up on the use of the homologous series to predict formulae. It also provides some revision for the naming of organic compounds, which is crucial for students to know when answering questions on organic synthesis later in the course.

(e) explanation of the term structural isomers (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula

<http://www.s-cool.co.uk/a-level/chemistry/general-principles/revise-it/isomerism>

Here is a straightforward diagram that shows the relationship between different types of structural isomerism. This can be used as a starter to introduce the different terms, or as quick revision when revisiting this topic.

http://chemwiki.ucdavis.edu/Organic_Chemistry/Fundamentals/Isomerism_in_Organic_Compounds/Structural_Isomerism_in_Organic_Molecules

This is a more in-depth explanation of the difference between the different types of isomerism. This link is particularly useful for showing examples where a molecular formula given in a question can lead to a number of different organic molecules.

(f) the different types of covalent bond fission: (i) homolytic fission; (ii) heterolytic fission

(g) the term radical (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms

(h) a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond

(i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles

Note – due to the concepts in this section being used in multiple areas, heterolytic fission may be best explained when teaching section 4.2.2e. Likewise, the concepts of drawing out reaction mechanisms may be best explained in the sections relating to the different types of mechanisms encountered in AS chemistry, in sections 4.1.3f; 4.2.1c; 4.2.2c, rather than as an independent section per se.

However, there are some links that can help introduce these concepts.

<http://www.chemguide.co.uk/mechanisms/frmenu.html>

This link shows the difference between homolytic and heterolytic fission, and it has a small animation that can demonstrate the different products made due to differences in how the bond breaks.

This link also introduces the concept of curly arrows, and the difference between single and double arrows.

<http://padakshp.org/otp/subjects/chemistry/organic-chemistry/bond-fission/>

This link can be used to help students explain or revise the concepts of homolytic/heterolytic fission and free radicals. This can be used as a handy revision tool in section 4.2.2e, as mentioned above.

<https://www.youtube.com/watch?v=OeJ8eECBURg>

This video can be used to introduce the concept of homolytic fission, and as such can also be used as a discussion tool to explain the difference between this and heterolytic fission.

4.1.2 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

(b) explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion (see also 2.2.2g–h)

Explained here is the difference between sigma and pi bonding, the difference in shapes of the molecules. Note that this does branch out slightly into molecular orbitals, which isn't mentioned specifically in the specification but can be useful stretch and challenge work for the more able students.

<http://www.chemguide.co.uk/basicorg/bonding/methane.html>

This link can be used to help students to draw common organic molecules if they are in need of a reference on how to do so.

<http://www.ivy-rose.co.uk/Chemistry/Organic/How-to-draw-organic-molecules-in-3D.php>

(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 2.2.2k)

<https://www.youtube.com/watch?v=kYWIYNBA7Ow>

This link can be used to quickly explain the pattern of boiling points with different alkanes. Note that this video uses the term van der Waals forces, not London forces.

(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 2.2.2j)

<https://www.youtube.com/watch?v=60fYgvUaWrA>

This video explains the relatively low reactivity of alkanes in terms of their bond enthalpies and polarities.

(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

This short video shows the difference between complete and incomplete combustion for an alkane. It is a very useful starter to this section.

<https://www.youtube.com/watch?v=4Ekf71bApl4>

<https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/>

(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 4.1.1f–g)

<https://www.youtube.com/watch?v=7k9UwilnhGw>

This video tutorial explains the process of free radical substitution from start to finish.

(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

<http://www.slideshare.net/RandomLea/basic-concepts-and-alkanes>

This (extensive) slideshow explains the limitation of synthesis on slides 126–127, and also provides a large amount of content relating to the whole of section 4.1.2.

4.1.3 Alkenes

(a) alkenes as unsaturated hydrocarbons containing a C=C bond comprising a π -bond (sideways overlap of adjacent p-orbitals above and below the bonding C atoms) and a σ -bond (overlap of orbitals directly between the bonding atoms) (see also 4.1.2a); restricted rotation of the π -bond

(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 2.2.2g–h, 4.1.2b)

Resource-wise this can be taught alongside section 4.1.2a, as mentioned above. The video below can be used to explain to/refresh students about the nature of sigma/pi bonds, as well as the cause of the trigonal shape of alkenes.

<https://www.youtube.com/watch?v=cPDptc0wUYI>

(c) (i) explanation of the terms; stereoisomers, E/Z isomerism, cis-trans isomerism (ii) use of Cahn–Ingold–Prelog (CIP) priority rules to identify the E and Z stereoisomers (d) determination of possible E/Z or cis–trans stereoisomers of an organic molecule, given its structural formula

<https://www.youtube.com/watch?v=Rara9zhlifE>

This video explains the difference between E/Z and cis-trans, as well as how to determine priority using CIP rules. The video (while relatively long at 10 minutes) explains the topic well.

<https://www.youtube.com/watch?v=CEH3O6l1pbw&list=PL8dPuuaLjXtPHzzYuWy6fYeX9mQQ8oGr&index=41>

This video is in less detail than the one above, and so is of more use as a starter or a quick reminder of previous work. The naming rules start at 1:39.

<http://www.chemguide.co.uk/basicorg/isomerism/ez.html>

This link can be given to students who want further reading or research material. It is also a very useful tool for revision.

(e) the reactivity of alkenes in terms of the relatively low bond enthalpy of the π -bond

(f) addition reactions of alkenes with: (i) hydrogen; (ii) halogens; (iii) hydrogen halides; (iv) steam

(g) definition and use of the term electrophile (an electron pair acceptor)

(h) the mechanism of electrophilic addition in alkenes by heterolytic fission (see also 4.1.1h–i)

(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

<http://www.usetute.com.au/hydraten.html>

This site includes information on the reactions of alkenes in the presence of steam to form alcohols (section (f), (iv)). Like the site above, it also uses vocabulary from section (g).

<https://www.youtube.com/watch?v=FOms5HfJuPw>

This shows the addition reactions of alkenes (section (h)), in particular from 2:50. This is a helpful video as it also talks about these reactions in more general terms as well as using specific examples. This can help students realise that this reaction is applicable to a wider variety of molecules than in the specific examples displayed.

(j) addition polymerisation of alkenes and substituted alkenes

<https://www.youtube.com/watch?v=rHxxLYzJ8Sw>

This video shows the addition reactions of alkenes in an easy-to-deliver style; however it does (briefly) mention condensation polymerisation which is not mentioned in this specification.

<https://www.youtube.com/watch?v=Nhtr7LISwvk>

This video is a re-cap of addition polymerisation from OCR gateway C1, but can be a handy introduction back into this topic.

<http://www.chemguide.co.uk/organicprops/alkenes/polymerisation.html>

This link can be a useful source of information for students who want to research into (or read up before the lesson) alkenes and how they are polymerised.

(k) the benefits for sustainability of processing waste polymers
(l) the benefits to the environment of development of biodegradable and photodegradable polymers

<https://www.youtube.com/watch?v=DOvEqd39498>

This video is a recap of work from OCR Gateway C1 regarding biodegradable plastics, but it can be a useful source of revision.

<https://www.youtube.com/watch?v=OvV3GcBWYN4>

A video regarding a project in China which uses incineration to provide energy and thus limit landfill use.

4.2.1 Alcohols

(a)(i) the polarity of alcohols and an explanation, in terms of hydrogen bonding, of the water solubility and the relatively low volatility of alcohols compared with alkanes (see also 2.2.2 l and 4.1.2 c)

https://www.youtube.com/watch?v=_T9iZWWhZTY8

This clip is an excellent introduction to bond polarities and so can be a useful reminder/teaching aid at the beginning of the section.

<https://sites.google.com/site/chemistryolp/properties-of-alcohols>

This link contains content covering bond polarities and alcohol boiling points. This can be a useful content aid for students to use for revision/advance reading of the section.

(a) (ii) classification of alcohols into primary, secondary and tertiary alcohols

https://www.youtube.com/watch?v=_mdoeSMiPxU

This covers all the required content regarding the identification of primary, secondary and tertiary alcohols.

(b) combustion of alcohols

<http://www.usetute.com.au/combusta.html>

A tutorial on the combustion of alcohols, which also includes a video explaining the reactions that occur.

(c) oxidation of alcohols by an oxidising agent, e.g. $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (i.e. $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$)

https://www.youtube.com/watch?v=j-rBgs_p-bg

A tutorial video showing the oxidation of alcohols, and the difference in the products made.

(d) elimination of H_2O from alcohols in the presence of an acid catalyst (e.g. H_3PO_4 or H_2SO_4) and heat to form alkenes

<https://www.youtube.com/watch?v=U9dGHwsewNk>

A video tutorial that shows the elimination reaction in depth, and also helps revise work on nomenclature.

(e) substitution with halide ions in the presence of acid (e.g. NaBr/H₂SO₄) to form haloalkanes

<https://www.khanacademy.org/science/organic-chemistry/substitution-elimination-reactions>

A source of tutorials covering substitution reactions, as well as reactions covered in (e).

4.2.2 Haloalkanes

(a) hydrolysis of haloalkanes in a substitution reaction

(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 4.1.1h-i)

(d) explanation of the trend in the rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon-halogen bonds (C-F, C-Cl, C-Br and C-I)

<https://www.youtube.com/watch?v=ujJutNEs2Ww>

A video explanation covering the substitution reactions of haloalkanes.

https://webarchive.nationalarchives.gov.uk/20170712125650/http://sustainability.sellafieldsites.com/resources/labmouse/chemistry_as/1703.php

A comprehensive explanation of the mechanisms of substitution, complete with an exercise to test learning at the end.

<https://www.youtube.com/watch?v=-2lmlFJbmFE>

A video showing the relative speed of substitution with AgNO₃, which can be easier to show than carrying out the demonstration in a laboratory.

(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

https://www.youtube.com/watch?v=sw3U7RE_hnY

A video showing the free radical substitution reaction, which can be useful revision of work previously covered in 4.1.2f.

4.2.3 Organic synthesis

<http://www.theozonehole.com/ozonedestruction.htm>

This contains information and a timeline on how the production of CFCs damages the ozone layer, which can be useful research or revision for students. It also contains an animation of the reaction.

(a) the techniques and procedures for: (i) use of Quickfit apparatus; (ii) preparation and purification of an organic liquid

<https://www.youtube.com/playlist?list=PL07AC74BBD3085056>

A playlist that contains a large selection of video tutorials covering the lab techniques above.

(b) for an organic molecule containing several functional groups

<http://www.docbrown.info/page13/ChemicalTests/ChemicalTestsf.htm>

A list of tests that can be used to help students identify the presence of different functional groups.

<https://www.youtube.com/watch?v=MGNRna3JnCk>

A tutorial that can help students with identification of functional groups.

<http://www.rsc.org/learn-chemistry/resources/synthesis-explorer/>

An interactive explorer that allows students to plot the synthesis of organic compounds.

<http://www.chemhume.co.uk/A2CHEM/Unit%201/6%20Stereoisomers%20synthesis/Ch6Stereoisomersc.htm>

A tutorial explaining how to work through an organic synthesis.

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