BIG IDEA:	**Structure Determines Properties**
Interleaved prior learning:	See details for each lesson
Future Learning:	Beyond GCSE, chemistry students will continue their study of carbon chemistry in the organic chemistry topics. They will be able to apply the learning from this unit to describe the structure and properties of the millions of covalent compounds of the element carbon. Students will apply their learning to naturally occuring petroleum fuels, DNA, and the molecules within living systems. They will also study some of the synthetic materials created by chemists. Students will study structural isomers, developing their understanding of molecular shapes and the different orientations of 3D molecules. Many of the homologous series' and processes introduced in this unit will be revisited and developed further, including alkanes, alkenes, alcohols, combustion and cracking. Students will learn to name these compounds using the International Union of Pure and Applied Chemistry (IUPAC) system. They will learn to represent these compounds in a number of ways, including empirical, molecular, general, structural, diplayed and skeletal formulae. The reactions which create these organic compounds will also be studied, and students will learn about the mechanisms that lead to the formation of many molecules. They will learn to use precise notation (such as curly arrows!) to represent the formation of covalent bonds and free-radical mechanisms.
Key misconceptions	The biggest misconceptions in this unit are often around chemical vs physical processes, where students often assume that fractional distillation is a chemical reaction and cracking is a physical process. Another prevalent misconception is confusing intermolecular forces (that determine a boiling point) versus intramolecular bonding such as covalent bonds. See notes for each lesson for more detailed misconceptions.
Unit Sequencing:	This unit begins with a recap of key learning from C4.1 on covalent bonding and structure. Here, students are reminded both of how carbon-carbon and carbon-hydrogen bonds occur and (importantly) how the bonding and structure of molecules results in different properties. From here, students are introduced to crude oil and hydrocarbons. This lesson forms the basis of the rest of this unit as students will be exploring different types of hydrocarbon compounds, each of which can be traced back to crude oil. In this lesson, students will learn what a hydrocarbon is, and are are introduced to their first homologous series, alkanes, The careful introduction of alkanes and the naming of these, if effective, will set students up to understanding the naming and structure of the other homologous series. As crude oil appears early on, the next lesson delves into the process of fractional distillation, as this is the process that allows us to obtain all the various fractions that are the basis of much of the carbon chemistry that students learn about. Learning about this early in the unit is important, because it is here that students learn about the relationahip between hydrocarbon chain length and boiling point, something which allows students to understand the idea of a good and poor fuel, and all of the properties associated with these. The discussion of good and poor fuels is continued in lesson 4, with a deeper exploration of the combustion of hydrocarbons. From here, students are introduced to alkenes and cracking. This is a natural progression from learning about fractional distillation, as students now know about which fractions are in most demand, and so the process of cracking will make more sense to them. Students here build on their new knowledge of alkanes to understand their next homologous series: alkenes. After this, students are introduced to alcohols, and here they will learn about different ways to produce ethanol. This is followed by carboxylic acids and esters, in this order because each depends on the previous one to understand. Each time, the principals of a homogous series are reiterated, and students are gradually getting to know the patterns and formulae for each one. Finally the unit ends by learning about polymers, polymerisation and natually occuring polymers. This is partly revisiting learning from C4.1 where students were introduced to polymers in the context of covalent bonding, and revisits biology topics where they learn about naturally occuring polymers in more detail. The new learning here in this unit builds on students' learning about hydrocarbons, so that students are using their knowledge of functional groups to describe condensation and addition polymerisation.

Lesson code	Lesson title	What do my students need to <u>know</u> by the end of the lesson?	AQA specificaton references	Lesson Objectives	What do my students need to be able to <u>do</u> by the end of the lesson?	What <u>prior knowledge</u> do I expect my students to have? Where is this likely to have come from?	What could help students understand this content?	What are the core <u>practical, enquiry and maths skills</u> that students will learn and practise? Key: Skills in bold are taught for the first time here	What practical activities are planned? What apparatus and chemicals are required?	What <u>misconceptions</u> may students arrive at the lesson with? What could they leave the lesson thinking if we are not careful? How can I address this directly? NOTE: More misconceptions are discussed in the 'notes' section of the powerpoints	What <u>exit ticket questions</u> will the students be required to answer by the end of the lesson?	What <u>keywords</u> am I introducing in this lesson that students may find difficult?
C5.1.1	**Prior Knowledge Review: Covalent Bonding and Structure**	The covalent bonds in molecules and giant structures can be represented in a number of different forms. A single line on a diagram of a molecule represents a single covalent bond (one pair of shared atoms) Atoms may form multiple covalent bonds A double line on a diagram of a molecule represents a double covalent bond (two pairs of shared electrons) Covalent bonding occurs in most non-metallic elements and in compounds of non-metals. For covalent bonding the particles are atoms which share pairs of electrons. The electrons involved in covalent bonding are in the outer shells of electrons. When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. Covalent bonds are strong because both nuclei are strongly attracted to the shared pair of electrons in the covalent bond		Identify different types of bonding from chemical formulae Describe what happens when a covalent bond is formed Use diagrams to show covalent bonding	Complete the chemical formula using the displayed formula (element symbols with single lines between) Which type of bonding is shown in figure X? (displayed formula with single line between element symbols Complete Figure X to show a dot and cross diagram for a water molecule. Show the outer electrons only. Complete the dot and cross diagram to show the bonding in a chlorine molecule. Complete the dot and cross diagram to show the covalent bonding in a nitrogen molecule, N_2. Figure X shows how atoms are bonded in methane (dot and cross diagram). What is the formula for methane? Figure X showing the dot and cross diagram for SO_2. Choose which is the correct chemical formula for this molecule (SO_2, SO^2, S_2O) Complete the sentence: When a sulfur atom and an oxygen atom bond to produce substance C, electrons are (choose from delocalised, shared, transferred)	(C4.1.6) Properties of covalent substances lesson (C4.1.7) Covalent bonding lesson (C3.2) Formulae show which elements are in compounds and the ratio of each element in the compound. (C3.2) Chemical reactions always involve the formation of one or more new substances. (C3.2) Compounds contain two or more elements chemically combined in fixed proportions and can be represented by formulae using the symbols of the atoms from which they were formed (C3.1) Compounds contain two or more elements chemically combined. (C3.1)The relative electrical charges of the particles in atoms are: protons (positive), electrons (negative), neutrons (neutral) (C3.1)The radius of a nucleus is less than 1/10 000 of the radius of an atom (C3.1) In an atom, the number of electrons is equal to the number of protons in the nucleus. (C3.1) The electrons are arranged at different distances from the nucleus (in different energy levels, or shells) (C3.1) The electrons in an atom occupy the lowest available energy levels first (which are the innermost available shells) (C3.1) Elements in the same group in the periodic table have the same number of electrons in their outer shell (outer electrons) and this gives them similar chemical properties (C3.1) The electronic structure of an atom can be represented by numbers or by a Bohr diagram. For example, the electronic structure of sodium is 2,8,1 or showing two electrons in the lowest energy level, eight in the second energy level and one in the third energy level (C3.1) Electrons will fill the lowest available energy level before moving to a higher energy level (C3.1) A stable arrangement of electrons is one in which the outer shell of electrons is full (C3.1) The elements in Group 1 of the periodic table are known as the alkali metals	Watch this clip of how to drink water in space. Why is the water sticking together in clumps? Because of the intermolecular forces! https://www.youtube.com/watch?v=H_qPWZbxFl8 The big idea that encompases this unit is 'Structure Determines Properties". Throughout this lesson and following lessons, thinking about properties and structure as closely linked will help students to make sense of their observations. All of the properties students will learn about in this lesson will be explained by the structure in the following lesson. Making this link explicit will help them to remember the 'why' and not just try to recall a collection of facts.			Students might mix up the weak intermolecular forces and strong covalent bonds (intramolecular forces). Stress the difference between these and use diagrams to show where they each occur in a simple covalent substance. "When you melt a simple covalent substance, you break the covalent bonds". This is incorrect, because when you melt a simple covalent substance, like water, you are only breaking weak intermolecular forces (forces between the covalent molecules) and you are not breaking the covalent bonds that are holding the molecules themselves together. This can be illustrated by showing students particle diagrams of solid and liquid water, and pointing out that the liquid water is atill made of intact H_2O molecules.	1. Which answer correctly defines covalent bonding? **A. Covalent bonding occurs where two or more non-metal atoms share pairs of electrons in order to achieve a stable electronic configuration** B. Covalent bonding occurs where two or more metal atoms share pairs of electrons in order to achieve a stable electronic configuration C. Covalent bonding occurs where electrons are transferred from one atom to another in order to achieve a stable electronic configuration 2. How many pairs of electrons are shared, and how many covalent bonds are shown in this diagram? A. 4 pairs of electrons are shared, and there are two single covalent bonds B. 2 pairs of electrons are shared, and there are two double covalent bonds **C. 4 pairs of electrons are shared, and there are two double covalent bonds** 3. Why doesn't pure water conduct electricity? A. It isn't a solid B. Pure water does conduct electricity **C. It does not contain any free electrons**	
C5.1.2	**Crude Oil and Hydrocarbons**	Crude oil is a finite resource found in rocks. Crude oil is the remains of an ancient biomass consisting mainly of plankton that was buried in mud. Crude oil is a mixture of a very large number of compounds. Most of the compounds in crude oil are hydrocarbons. Hydrocarbons are molecules made up of hydrogen and carbon atoms only. Most of the hydrocarbons in crude oil are hydrocarbons called alkanes. The general formula for the homologous series of alkanes is C_nH_{2n+2} Many useful materials on which modern life depends are produced by the petrochemical industry, such as solvents, lubricants, polymers, detergents. The vast array of natural and synthetic carbon compounds occur due to the ability of carbon atoms to form families of similar compounds. The first four members of the alkanes are methane, ethane, propane and butane.	4.7.1.1 5.7.1.1	Describe where crude oil is found and how it was formed Identify alkanes from their chemical formulae Use the general formula of alkanes to determine the number of atoms in a molecule	Draw a line from the alkane to the correct formula for that alkane. Identify an alkane from a molecular formula. What type of carbon compound is *alkane name? Use data about the relative masses of different fractions to plot a bar graph. Name the next alkane in a series. Give the formula of the next alkane in a series. Name the homologous series that contains ethane, propane, butane. Define hydrocarbon. Explain why *compound name/formula is a hydrocarbon.	(C3.2) The relative atomic mass of an element can be found as the mass number of an element on the periodic table (C3.2) Relative atomic mass has the symbol Ar (C3.2) The relative formula mass of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula (C3.2) Relative formula mass has the symbol Mr (C3.2) In a balanced chemical equation, the sum of the relative formula masses of the reactants in the quantities shown equals the sum of the relative formula masses of the products in the quantities shown (C4.1) A single line on a diagram of a molecule represents a single covalent bond (one pair of shared atoms) (P3.2) Convection is the thermal transfer when particles in a heated fluid rise. (P3.2) During convection, the heated fluid becomes less dense and rises. The denser cold fluid falls into the warm areas forming a convection current. (P3.2) Liquids and gases expand when they are heated. This is because the particles move faster and they take up more volume. The gaps between particles widen but the particles stay the same size (P3.2) A fluid is a substance with no fixed shape – a liquid or gas. (P3.2) Both conduction and convection require particles. (P3.2) Radiation is the transfer of thermal energy as a wave, by infrared radiation. (P3.2) Radiation does not require particles, so can occur in a vacuum (P3.2) Some surfaces are better than others at absorbing and reflecting radiation (P3.2) Shiny silvered surfaces are good at reflecting radiation. Dull, dark surfaces are poor at reflecting radiation	Larger molecules need more energy to evaporate them (because they're heavier, so longer hydricarbons have bigger melting and boiling points Looking at 3D models of the hydrocarbon compounds encountered in this unit will help students to see them as 'more' than the 2D diagrams they will encounter on lesson slides and worksheets. Hold up a 3D model of an alkane and ask students describe what they see. Make links back to their study of covalent bonding and the various models they evaluated to respresent this. Compare the 3D models to the diagram and moelcular formula of the same molecule. One way to introduce homologous series to students is with a 'spot the connection' activity or to ask them to see a pattern and draw the next one in a sequence.	97. Use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.		Students might think that the prefix 'hydro-' on hydrocarbons means that these molecules contain water. In reality, the prefix hydro- refers to hydrogen. Students often forget the word 'only' when defining hydrocarbons. That is, hydrocarbons are molecules containing hydrogen and carbon atoms <u>only</u>. Students sometimes are not able to access questions about fractional distillation or cracking, for example, as they do not know the meaning of the word 'conditions' when used in the context of reaction conditions. When describing what an alkane is, students often forget to state that these are saturated compounds.	1. Which alkane is this? A. Ethane **B. Propane** C. Butane 2. An alkane has 15 carbons. How many hydrogen atoms would it have? A. 30 **B. 32** C. 34 3. What is crude oil? **A. A finite resource formed from ancient plankton biomass** B. A finite resource formed from rocks C. A finite resource containing compounds of carbon and water	
C5.1.3	**Fractional Distillation**	The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by fractional distillation. The fractions can be processed to produce fuels and feedstock for the petrochemical industry. Many of the fuels on which we depend for our modern lifestyle, such as petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases, are produced from crude oil. During fractional distillation, a fractionating column is used. This column has condensers at varying heights. A fractionating column is hot at the bottom and cooler at the top Substances with high boiling points condense at the bottom and those with low boiling points condense at the top During fractional distillation, crude oil is evaporated. It's vapours condense at different temperatures in the fractionating column. Each fraction produced during fractional distillation has a similar number of carbons (or size of hydrocarbons) The vast array of natural and synthetic carbon compounds occur due to the ability of carbon atoms to form families of similar compounds. Some properties of hydrocarbons depend on the size of their molecules, including boiling point, viscosity and flammability. These properties influence how hydrocarbons are used as fuels. Boiling point, viscosity and flammability change with increasing molecular size.	4.7.1.2 4.7.1.3 5.7.1.2 5.7.1.3	Describe uses of different fractions of crude oil Describe how crude oil is separated by fractional distillation Describe and explain trends in the properties of hydrocarbons	Explain why diesel collects above heavy fuel oil but below kerosene in the fractionating column. Suggest two reasons why bitumen is not used as a fuel. Describe how crude oil is separated into fractions during fractional distillation.	(C1.3) Pure substances melt and boil at specific temperatures (C1.3) Melting points and boiling points can be used to identify pure substances or mixtures (C1.3) Mixtures can be separated by physical processes such as filtration, crystallisation, simple distillation, fractional distillation and chromatography (C1.3) These physical processes do not involve chemical reactions and no new substances are made. (C1.3) Fractional distillation is a method used to separate a liquid mixture. (C1.3) Each part of the mixture to be separated is called a fraction. (C1.3) The different fractions in a mixture can be separated due to their different boiling points. The different fractions in a mixture can be separated due to their different boiling points (P3.4) The main energy resources available for use on Earth include fossil fuels (coal, oil and gas), nuclear fuel, biofuel, wind, hydroelectricity, geothermal, the tides, the Sun and water waves. (P3.4) A renewable energy resource is one that is being (or can be) replenished as it is used. (P3.4) Some renewable resources can be replenished by human actions and some are replenished naturally. (P3.4) A non-renewable energy resource is one that is not being (or can be) replenished as it is used. (P3.4) Fossil fuels are non-renewable energy resources. (P3.4) Examples of fossil fuels are coal, oil and natural gas. (P3.4) Fossil fuels can be burnt to heat water, which produces steam. This steam can turn a turbine which powers a generator (generates electricity). (P3.4) The uses of energy resources include transport, electricity generation and heating. (P3.4) Nuclear fuels release energy through nuclear reactions, which involve the breaking up of atomic nuclei. (P3.4) Examples of nuclear fuels are uranium and plutonium. (P3.4) The energy released through the nuclear reactions is used to heat water, which	Using molymod models of different fractions is useful, because you can ask students to phyically life them up and feel the difference in 'energy' required to do this. This will help students to make a lin between the hydrocarbon chain length and the boiling point of each fraction.	41. Safe use of equipment to separate mixtures using distillation	<u>Fractional Distillation Demo</u> See an example of this activity here: https://edu.rsc.org/experiments/the-fractional-distillation-of-crude-oil/754.article	Students sometimes mix up the relationship between boiling point and hydrocarbon chain length, believing that the better fuels with lower boiling points must have the longer chain. When explaining the process of fractional distillation of crude oils, the idea of the temperature gradient within the fractionating column is often not menioned by students. Students often write wordy, confusing and poorly explained explanations of the vapours condensing at different boiling points, and struggle to explain why/how the fractions collect at different levels in the column. Students should use shorter, well-constructed sentences that include only one key point at a time. The omission of any reference to vapours is common	1. How does fractional distillation separate crude oil into fractions? A. Each fraction has a different viscosity B. Each fraction has a different melting point **C. Each fraction has a different boiling point** 2. Which fraction is used for producing material for roads? A. Liquefied gases B. Petrol **C. Bitumen** 3. Which best explains the pattern in boiling points of the alkanes? A. As the alkanes get longer, boiling points increase because there are more atoms B. As the alkanes get longer, boiling points decrease because they are more likely to be liquid **C. As the alkanes get longer, boiling points increase because the intermolecular forces increase**	
C5.1.4	**Combustion of Hydrocarbons**	The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised. The complete combustion of a hydrocarbon produces carbon dioxide and water. The general word equation that describes the complete combustion of an alkane is: alkane + oxygen -> carbon dioxide + water Complete combustion reactions of alkanes can be represented by balanced symbol equations, for example $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	4.7.1.3 5.7.1.3	State the general equation for the combustion of alkanes Describe the advantages and disadvantages of the combustion of hydrocarbons Explain the difference between complete and incomplete combustion	Suggest two reasons why wood is more sustainable than natural gas as a fuel. Explain the process by which carbon monoxide can be produced when methane is burned. Balance the equation for combustion. Given an equation for the combustion of an alkane, calculate the volume of unreacted oxygen when the volume of CO_2 produced is given and the initial volume fo oxygen is given. Name the source of the oxygen needed to burn fuels. Which two gases are produced when fuels burn in car engines? Select the equation which correctly represents incomplete combustion.	(C2.3) The combustion of fuels is a major source of atmospheric pollutants. (C2.3) Most fuels, including coal, contain carbon and/or hydrogen and may also contain some sulphur. (C2.3) The gases released into the atmosphere when a fuel is burned may include carbon dioxide, water vapour, carbon monoxide, sulphur dioxide and oxides of nitrogen. (C2.3) Solid particles and unburned hydrocarbons may also be released that form particulates in the atmosphere. (C2.3) Sulphur dioxide and oxides of nitrogen cause respiratory problems in humans and cause acid rain. (C2.3) Particulates cause global dimming and health problems for humans. (B3.2) Levels of carbon dioxide and methane in the atmosphere are increasing and contributing to global warming (B3.2) The biological consequences of global warming include loss of habitats, changing breeding patterns and changing migratory patterns which all affect biodiversity			<u>Burning Money Demonstration</u> See example of this demonstration here: https://edu.rsc.org/experiments/burning-money-what-makes-combustion-happen/836.article		1. Which is the correct general equation for the combustion of alkanes? A. Alkane + water → oxygen + carbon dioxide **B. Alkane + oxygen → water + carbon dioxide** C. Alkane + air → water + carbon dioxide 2. Which is an advantage of burning hydrocarbons? **A. It releases lots of energy** B. It releases carbon dioxide C. It releases water 3. When does incomplete combustion take place? **A. If there is not enough oxygen** B. If there is not enough alkane C. If there is not the same amount of alkane and oxygen	
C5.1.5	**Cracking**	Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules. Cracking can be done by various methods including catalytic cracking and steam cracking. The products of cracking include alkanes and another type of hydrocarbon called alkenes. Alkenes are more reactive than alkanes and react with bromine water, which is used as a test for alkenes. If alkenes are present, the bromine water will turn from orange to colourless. Alkenes are used to produce polymers and as starting materials for the production of many other chemicals. There is a high demand for fuels with small molecules and so some of the products of cracking are useful as fuels.	4.7.1.4 5.7.1.4	Determine the formulae of compounds produced from cracking Explain why cracking is useful Explain how bromine water can be used to distinguish between alkanes and alkenes	Which two processes are used to make *alkene from crude oil? What would be observed when bromine water was added to *alkene name or *alkane name? Describe the conditions needed to crack hydrocarbon molecules from the diesel oil fraction. Explain why large hydrocarbon molecules in diesel oil are cracked to produce smaller hydrocarbon molecules. Complete the equation for the cracking of $C_{15}H_{32}$. Describe a test to show that propene is an unsaturated hydrocarbon. Which hydrocarbon can be cracked to produce *alkane name? Given the composition of two samples of crude oil, suggest which one is a better source of hydrocarbons for cracking. Explain how alkenes are produced using fractional distillation followed by cracking.	(C3.2) The percentage mass of an element in a compound can be calculated using the relative atomic mass and the relative formula mass (C3.2) In chemical equations, the three states of matter are shown as state symbols (s), (l) and (g), with (aq) for aqueous solutions. (C4.1) The covalent bonds in molecules and giant structures can be represented in a number of different forms.			<u>Cracking demonstration</u> <u>Testing for Alkenes Demonstration</u> Bromine Water Plastic pipette	A common student misconception is that breaking of covalent bonds occurs during changes of state. Comparing cracking with fractional distillation, and the different conditions needed, allows for this misconception to be addressed directly. When describing the test for unsaturation, students need to be careful to use the word 'colourless' and not 'clear'. Further to this, when describing the observation made during this test, it is a good idea to describe the colour of bromine water at the beginning, and to say the change that occured, not just state the end colour. When describing the conditions needed for cracking to occur, the need for a high temperature is most frequently seen as a correct answer, however, students do need to take care when expressing themselves, They will sometimes male the error of using 'hot' or 'heat' instead of '<u>high temperature</u>'. If a specific temperature is given in an answer, it has to be above the boiling point range of the fraction that students are talking about. Studets often find it difficult to explain why cracking is important, or why long hydrocarbons are cracked to produce smaller molecules. They should be able to explain using ideas about demand for fuels, rather that just listing uses of short hydrocarbon fuels. Students in the past have not been able to access questions about fractional distillation or cracking, for example, as they did not know the meaning of the word 'conditions' when used in the context of reaction conditions.	1. Which explains why cracking is useful? A. It increases demand for shorter hydrocarbon chains **B. It increases supply of shorter hydrocarbon chains** C. It separates crude oil into different useful fractions 2. What is the formula of the other product of this cracking reaction? $C_{10}H_{22} \rightarrow C_8H_{18}$ + ________ **A. C_2H_4** B. C_2H_6 C. $C_{18}H_{40}$ 3. What is the difference between alkanes and alkenes? A. Alkanes have a C=C double bond **B. Alkenes have a C=C double bond** C. Alkenes contain more hydrogen atoms	
C5.1.6	**Taking it Further: Alkenes**	Alkenes are hydrocarbons with a double carbon-carbon bond. The general formula for the homologous series of alkenes is C_nH_{2n} Alkene molecules are unsaturated because they contain two fewer hydrogen atoms than the alkane with the same number of carbon atoms. The first four members of the homologous series of alkenes are ethene, propene, butene and pentene. Alkenes can be represented with a chemical formula or a displayed formula Alkenes react with oxygen in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with smoky flames because of incomplete combustion. Alkenes react with hydrogen, water and the halogens, by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond. Alkenes are hydrocarbons with the functional group C=C.	4.7.1.4 4.7.2.1 4.7.2.2	State the general formula of the alkenes Use chemical formulae to determine numbers of atoms in molecules Describe chemical reactions of the alkenes	Draw the missing bonds in a displayed formula for an alkene. Name the next alkene in a series. Give the formula of the next alkene in a series. Name the homologous series that contains ethene, propene, butene. Recognise the chemical formula of an alkene from a list of chemical formulae.	(C3.2) The percentage mass of an element in a compound can be calculated using the relative atomic mass and the relative formula mass (C4.1) Covalently bonded substances may consist of small molecules, for example those in water, hydrogen gas, carbon dioxide. (C4.1) Substances that consist of small molecules are usually gases or liquids that have relatively low melting points and boiling points. (C4.1) Although the covalent bonds holding molecules together are strong, the intermolecular forces acting between molecules are weak. (C4.1) It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils. (C4.1) The intermolecular forces increase with the size of the molecules, so larger molecules have higher melting and boiling points. (C4.1) These substances do not conduct electricity because the molecules do not have an overall electric charge. (C4.1) Atoms may form multiple covalent bonds (C4.1) For covalent bonding the particles are atoms which share pairs of electrons. (C4.1) Covalent bonding occurs in most non-metallic elements and in compounds of non-metals. (C4.1) A double line on a diagram of a molecule represents a double covalent bond (two pairs of shared electrons)	One way to introduce homologous series to students is with a 'spot the connection' activity or to ask them to see a pattern and draw the next one in a sequence. You could give students cards with various members of homologous series on the cards in the form of a displayed formula. Over time, students can get better at sorting these into homolous series, by a trend such as melting point/boiling point, viscocity, etc.			Students often mix up 'saturated' with 'unsaturated'	1. What is the general formula for the alkenes? **A. C_nH_{2n}** B. C_nH_{2n+2} C. C_nH_n 2. Which explains why alkenes are reactive? A. They are saturated **B. They are unsaturated** C. They are small molecules 3. What product would be formed when propene reacts with hydrogen? A. Butene **B. Propane** C. Hydropropene	
C5.1.7	**Taking it Further: Alcohols**	It is the generality of reactions of functional groups that determine the reactions of organic compounds. Alcohols contain the functional group –OH (a hydroxyl group) Methanol, ethanol, propanol and butanol are the first four members of a homologous series of alcohols. Methanol is used as a chemical feedstock. Ethanol is the alcohol present in alcoholic drinks Ethanol is used as a solvent. Propanol is used as a fuel and a solvent. If a small piece of sodium is dropped into ethanol, bubbles of hydrogen gas are produced and the liquid contains sodium ethoxide The reaction between sodium and ethanol can be represented by the equation sodium + ethanol -> sodium ethoxide + hydrogen gas This reaction can be represented by the balanced symbol equation $2Na + 2C_2H_5OH \rightarrow 2C_2H_5ONa + H_2$ Alcohols with short hydrocarbon chains mix with water easily to form a solution The solubility of alcohols decreases as the size of the hydrocarbon chain increases	4.7.2.3	Draw structural formulae for alcohols Describe uses of alcohols Describe chemical reactions of alcohols	(Given a displayed formula for an alcohol.). Circle the functional group for an alcohol. State the elements, element symbols and number of atoms in an alcohol molecule, given the displayed formula. Recall that alcohol can be used as a solvent. Draw a line from the alcohol to the correct formula for that alcohol. Given a table with the formula, melting point and boiling point of alcohols: which alcohol is a liquid over the greatest temperature range? Draw the missing bonds in a displayed formula for an alcohol. Name the homologous series that contains ethanol, propanol, butanol.	(C1.3) A solution is composed of a solute and a solvent. (C1.3) A solvent is the substance a solute dissolves in (C1.3) A solute is the substance that dissolves in a solvent. (C3.2) Aqueous means dissolved in water (C3.1) In Group 7, the further down the group an element is the higher its relative molecular mass, melting point and boiling point (C3.1) The melting and boiling points of the halogens increase going down the group because the molecules become larger, the forces between the molecules become stronger, and so more energy is needed to overcome these forces. (C3.1) In Group 7, the reactivity of the elements decreases going down the group. This is because the atomic radius increases moving down the group. The further the outer shell is from the nucleus, the harder it will be to attract the electron required for a stable electronic configuration.	One way to introduce homologous series to students is with a 'spot the connection' activity or to ask them to see a pattern and draw the next one in a sequence. You could give students cards with various members of homologous series on the cards in the form of a displayed formula. Over time, students can get better at sorting these into homolous series, by a trend such as melting point/boiling point, viscocity, etc.		<u>Investigating the properties of alcohols</u> See an example of this activity here: https://edu.rsc.org/experiments/the-properties-of-alcohols/463.article	Students might think alcohol is a drink, or that all alcohols can be used in alcoholic drinks. Alcoholic beverages contain ethanol, which is one type of alcohol, specifically consisting of 2 carbon atoms and a hydroxyl group. As an activity, you can have students compare different types of alcohols and identify the common functional group (-OH) present in all. This misconception can also be used as a teachable moment where you can also lead into a discussion on the toxicity of ethanol and how it affects the mind, body and society. Students are often unable to list other uses of alcohols, such as ethanol. They should be able to recall that they are used as fuels and solvents. Students often mix up the uses of alcohols with other compounds they've learned about, and common incorrect answers might include 'disinfectant' or 'cleaning product' (although alcohol is used in hand sanitisers) Students will often draw the displayed formula of an alcohol with a double bond (commonly drawing the carbon - oxygen bond as a double bond)	1. What is the chemical formula of ethanol? A. C_2H_5O **B. C_2H_5OH** C. CH_3OH 2. Which is a use of methanol? A. In alcoholic drinks **B. As a chemical feedstock** C. As a fuel 3. What is the pattern in solubility of the alcohols? A. The longer the chain, the more soluble it is **B. The longer the chain, the less soluble it is** C. The longer the chain, the less reactive it is	

C5.1.8	**Taking It Further: Producing Ethanol by fermentation**	Ethanol is produced by fermentation Ethanol has a concentration by distillation Fermentation is an anaerobic process. The equation for the production of ethanol by fermentation is glucose -> ethanol + carbon dioxide Yeast provides the enzymes that are needed for fermentation The typical conditions required for fermentation are - anaerobic conditions (no oxygen present) - sugar dissolved in water, with yeast mixed in - a warm temperature (25-35 degrees Celsius) Fermentation it a slow reaction which may take days or weeks to finish.		State the equation for the production of ethanol through fermentation Describe the conditions required for fermentation Describe the advantages and disadvantages of producing ethanol by fermentation	State what is added to grapes juice to cause fermentation	(C3.2) In chemical equations, the three states of matter are shown as state symbols (s), (l) and (g), with (aq) for aqueous solutions. (C3.2) Aqueous means dissolved in water (C3.2) Concentration can be defined as the mass of solute per unit volume of solvent. (C3.2) Volume means the amount of space that a substance takes up, and can be measured in cm3, dm3, ml3, l, or ml. (C3.2) 1 dm3 is equal to 1 l, and equal to 1000 cm3 (C3.2) To convert from dm3 to cm3 the number should be multiplied by 1000 (C3.2) To convert from cm3 to dm3 the number should be divided by 1000 (C3.2) The concentration of a solution can be measured in mass per given volume of solution, e.g. grams per dm3 (g/dm3 or g dm-3) (C3.2) The mass in grams of solute in a given volume of solution can be calculated from its concentration in g/dm3				Post examination reports show that few students are often unable to describe how ethanol is produced from a sugar solution by fermentation. When students are asked to explain why fermentation is or is not an environmentally friendly way of producing ethanol, they often provide vague reasons such as 'ecofriendly', 'natural' 'cheap' or 'no pollution'. They should be able to link a statement to a reason that this is good or bad, for example stating the fact that this uses up land is bad because this is land that could be used for food crops.	1. Choose the word equation for fermentation. A. Glucose → lactic acid **B. Glucose → ethanol + carbon dioxide** C. Glucose + ethanol → carbon dioxide 2. Why should fermentation take place at a warm temperature? A. So the reaction does not happen too quickly **B. So the enzymes in yeast are not denatured** C. So the ethanol can be evaporated 3. What is a disadvantage of producing ethanol by fermentation? A. It is a very quick process **B. It can take days or weeks** C. It does not require much energy
C5.1.9	**Taking It Further: Producing Ethanol from Ethene**	Alkenes react with hydrogen, water and the halogens, by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond. ethene + water (steam) → alcohol This is called hydration, and it needs a temperature of approximately 300°C and a catalyst. for example: Butene + water → butanol Ethanol can be manufactured by the hydration of ethene The ethene for this reaction comes from cracking crude oil fractions In this process, ethene is heated with steam in the presence of a catalyst of phosphoric acid The catalyst speeds up the reaction The word equation for this reaction is ethene + steam -> ethanol The chemical equation for this reaction is $C_2H_4 + H_2O \rightarrow C_2H_5OH$ The conditions for this reaction are - a temperature of 300 degrees Celsius - a pressure of 60-70 atmospheres Ethanol is the only product of this reaction This is a continuous reaction, which means that as long as ethene and steam are fed into the reaction, ethanol will be produced continually. This makes it an efficient process. Ethene is made from crude oil which is a non-renewable resource. The reaction of ethene with steam can be reversed, allowing ethanol to be converted back to ethene. A catalyst called aluminium oxide can speed up this reaction The word equation for this reaction is ethanol -> ethene + steam		Describe how ethanol can be made from ethene Describe the conditions required for hydration of ethene Evaluate the advantages and disadvantages of different methods of ethanol production	Alkenes react with water (steam) to make alcohols. Given the ration of the masses of the alcohol to water, calculate the mass of alkene that reacts with a given mass of water. Compare/Evaluate the two methods of producing ethanol.	(C3.2) Compounds can only be separated into elements by chemical reactions (C3.2) In chemical equations, the three states of matter are shown as state symbols (s), (l) and (g), with (aq) for aqueous solutions. (C3.2) Aqueous means dissolved in water (C3.2) The law of conservation of mass states that no atoms are lost or made during a chemical reaction, so the mass of the products equals the mass of the reactants (C3.2) This means that chemical reactions can be represented by symbol equations which are balanced in terms of the numbers of atoms of each element involved on both sides of the equation (C3.2) Mass is always conserved in chemical reactions (C3.2) In a chemical reaction where a gas is produced, it may appear that the mass decreases throughout the reaction. In fact, this decreased mass will be due to the gas dissipating into the atmosphere. If the reaction is carried out in a closed container, this will not occur				1. Choose the term for what happens when ethanol is made from ethene. **A. Hydration** B. Hydrogenation C. Fermentation 2. What is a disadvantage of making ethanol from ethene? A. Ethene is obtained from sugar cane so is renewable **B. Ethene is obtained from crude oil so is non-renewable** C. Ethene is obtained from biofuels so is renewable 3. What is an advantage of producing ethanol from ethene? **A. It produces ethanol much more quickly than fermentation** B. It is an energy intensive process C. It requires high temperatures and a catalyst
C5.1.10	**Taking It Further: Carboxylic Acids**	Carboxylic acids have the functional group -COOH. The functional group -COOH is also called the carboxyl group Carboxylic acids can be represented using a chemical formula or a displayed formula. Carboxylic acids have the same general formula: $C_nH_{2n+1}COOH$, where n is the number of carbon atoms in the molecule minus 1 (or $CnH_{2n}O_2$). Carboxylic acids are weak acids, which have the typical properties of acids. Carboxylic acids dissolve in water to form acidic solutions with pH values of less than 7 Vinegar is a dilute solution of ethanoic acid Carboxylic acids react with carbonates to form a salt, water and carbon dioxide because carboxylic acids are weak acids, their solutions do not contain many hydrogen ions compared to a strong acid at the same concentration The first four members of a homologous series of carboxylic acids are methanoic acid, ethanoic acid, propanoic acid and butanoic acid.	4.7.3.4	Identify the functional group found in carboxylic acids Draw structural formulae of carboxylic acids Write chemical equations for reactions of carboxylic acids	Ethanoic acid reacts with sodium carbonate. What is the name of the liquid produced in this reaction? Vinegar is a dilute solution of ethanoic acid. 400 cm3 of vinegar contains 20 g of ethanoic acid. Calculate the mass of ethanoic acid in 1.0 dm3 of vinegar Draw a line from the carboxylic acid to the correct formula for that carboxylic acid. Match the name of a carboxylic acid to its formula. Ethanoic acid ionises in water. Explain how an equation for this reaction shows that ethanoic acid is a weak acid. (incomplete or partial ionisation) Explain what would happen when a solution of ethanoic acid is added to a metal carbonate in an open flask, to the mass of the flask and its contents. Draw the missing bonds in a displayed formula for a carboxylic acid. Name the homologous series that contains ethanoic acid, propanoic acid, butanoic acid. Select the displayed formula that represents a carboxylic acid. Propanoic acid is formed by the oxidation of which compound? (choose from propane, propene, propanol, polyester)	(C4.2) The reactions of acids with metals are redox reactions (C4.2) The reaction between magnesium and hydrochloric acid can be represented by the word equation magnesium + hydrochloric acid → magnesium chloride + hydrogen (C4.2) The chemical equation for this reaction is $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ (C4.2) The ionic equation for this reaction is $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ (C4.2) The two half equations for this reaction are $Mg \rightarrow Mg^{2+} + 2e^-$ (oxidation), and $2H^+(aq) + 2e^- \rightarrow H_2(g)$ (reduction) (C4.2) The reaction between zinc and hydrochloric acid can be represented by the word equation zinc + hydrochloric acid → zinc chloride + hydrogen (C4.2) The chemical equation for this reaction is $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ (C4.2) The ionic equation for this reaction is $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$ (C4.2) The two half equations for this reaction are $Zn \rightarrow Zn^{2+} + 2e^-$ (oxidation), and $2H^+(aq) + 2e^- \rightarrow H_2(g)$ (reduction)	One way to introduce homologous series to students is with a 'spot the connection' activity or to ask them to see a pattern and draw the next one in a sequence. You could give students cards with various members of homologous series on the cards in the form of a displayed formula. Over time, students can get better at sorting these into homolous series, by a trend such as melting point/boiling point, viscocity, etc.			In exams, students consistently fail to recognise that the production of ethanoic acid from alcohols is an oxidation reaction.	1. Choose the functional group found in carboxylic acids. A. Hydroxyl group **B. Carboxyl group** C. Carboxylate group 2. Which carboxylic acid has the formula CH_3COOH? A. Methanoic acid **B. Ethanoic acid** C. Propanoic acid 3. What are the products of a reaction between a carboxylic acid and a metal carbonate? **A. A salt, water and carbon dioxide** B. A salt, water and hydrogen C. A salt and water
C5.1.11	**Taking It Further: Esters**	Carboxylic acids can react with alcohols to make esters Esters contain the functional group -COO- Esters have fruity smells and can be used as solvents The general equation for the formation of an ester is alcohol + carboxylic acid -> ester + water		Describe how esters are formed State the general equation for the formation of esters Describe uses of esters	Ethanol reacts with ethanoic acid to form an ester. What is the name of the ester produced when ethanol reacts with ethanoic acid? Match the displayed formula of an ester with the name of an ester. Draw the missing bonds in a displayed formula for an ester.	(C4.3) The concentration of a solution can be measured in mol/dm3 (C4.3) The amount in moles of solute or the mass in grams of solute in a given volume of solution can be calculated from its concentration in mol/dm3 (C4.3) The concentration of a solution in mol/dm3 is related to the mass of the solute and the volume of the solution.			Making Ethyl Ethanoate: see an example of how this is run here: https://edu.rsc.org/experiment/making-esters-from-alcohols-and-acids/1743.article	Students should be able to describe compounds that are used in perfumes, such as esters, as 'volatile'. They often confuse this word with viscosity, reactivity or flammability. Examiners reports show that only a minority of students are able to name the ester ethyl ethanoate when given the reactants that make it Students often struggle to recall that an acid catalyst is required in the formation of an ester.	1. What are the reactants needed to make an ester? A. An alcohol and an alkene B. A carboxylic acid and an alkene **C. An alcohol and a carboxylic acid** 2. What is the name of the ester formed from ethanol and ethanoic acid? A. Ethanol ethanoate **B. Ethyl ethanoate** C. Ethyl ethanoic 3. What is a use of esters? A. As a fuel B. In alcoholic drinks **C. In scented products**
C5.1.12	**Prior Knowledge Review: Polymers**	Polymers have very large molecules. The atoms in the polymer molecules are linked to other atoms by strong covalent bonds. Polymers can be represented in the form [image] where n is a large number. The intermolecular forces between polymer molecules are relatively strong and so these substances are solids at room temperature. The properties of polymers depend on what monomers they are made from and the conditions under which they are made. For example, low density (LD) and high density (HD) poly(ethene) are produced from ethene. Thermosoftening polymers melt when they are heated. Most composites are made of two materials, a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement. Thermosetting polymers do not melt when they are heated.		Define a polymer Explain the difference between thermosoftening and thermosetting polymers Explain how the properties of a polymer make it suited to a function	Complete the sentence: Between the polymer chains in a thermosoftening polymer there are no _____. Choose the correct answer to complete the sentence: Heating would cause a thermosoftening polymer to condense/dissolve/melt Explain why thermosetting polymers are better than thermosoftening polymers for saucepan handles. What is the name for very large molecules such as poly(propene)? What type of bond joins the atoms in a molecule of "polymer name"? Use data from a table about effect of heating a polymer to determine the type of polymer (thermosetting or thermosoftening). Why does a thermosoftening polymer behave differently to a thermosetting polymer when heated? Refer to crosslinks in your answer. Draw the bonds to complete the displayed formula of a polymer.	(C4.1) Some covalently bonded substances have very large molecules, such as polymers. (C4.1) Some covalently bonded substances have giant covalent structures, such as diamond and silicon dioxide. (C4.1) Polymers have very large molecules. The atoms in the polymer molecules are linked to other atoms by strong covalent bonds. (C4.1) Polymers can be represented with a displayed formula where n is a large number (C4.1) The intermolecular forces between polymer molecules are relatively strong and so these substances are solids at room temperature.		Making a balloon - The Ivory Rose Demonstration See instructions, Chemical and apparatus list at https://edu.rsc.org/download?loc=12243	When describing how a polymer is made, students often forget to mention that there are TWO monomers.	1. How many carbon atoms will the polymer represented by this diagram have? A. 20 **B. 40** C. 60 2. What is between polymer molecules? A. Covalent bonds **B. Intermolecular forces** C. Electrostatic attraction 3. What is the difference between thermosetting and thermosoftening polymers? **A. Thermosoftening polymers melt when heated** B. Thermosetting polymers melt when heated C. Thermosoftening polymers contain crosslinks
C5.1.13	**Taking It Further: Addition Polymerisation**	Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation. In addition polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers). In addition polymers the repeating unit has the same atoms as the monomer because no other molecule is formed in the reaction.	4.7.3.1	Identify monomers used to make given polymers Describe the process of addition polymerisation	What is the name of the alkene used to make poly(propene)? Use data from a table to suggest two advantages and two disadvantages of addition polymers for a particular use. Given the general formula for a polymer, students can be asked to identify the formula of the monomer used to make the polymer. Which process is used to make poly(styrene) from small molecules?	(C4.1) The properties of polymers depend on what monomers they are made from and the conditions under which they are made. For example, low density (LD) and high density (HD) poly(ethene) are produced from ethene. (C2.2) Many chemical reactions take place in solutions (C3.2) The concentration of a solution tells you how much solute is dissolved in a given volume of solvent. (C3.2) Concentration can be defined as the mass of solute per unit volume of solvent. (C3.2) Volume means the amount of space that a substance takes up, and can be measured in cm3, dm3, ml3, l, or ml. (C3.2) 1 dm3 is equal to 1 l, and equal to 1000 cm3 (C3.2) To convert from dm3 to cm3 the number should be multiplied by 1000 (C3.2) To convert from cm3 to dm3 the number should be divided by 1000 (C3.2) The concentration of a solution can be measured in mass per given volume of solution, e.g. grams per dm3 (g/dm3 or g dm-3) (C3.2) The mass in grams of solute in a given volume of solution can be calculated from its concentration in g/dm3				1. What is the name of the polymer formed through the addition polymerisation of propene? A. Poly(ethene) **B. Poly(propene)** C. Poly(propane) 2. What happens to the atoms of monomers in addition polymerisation? A. Some atoms are lost B. Extra atoms are produced **C. Atoms are not lost or produced** 3. What is made during an addition polymerisation reaction? A. A polymer and another product B. A polymer and different monomers **C. A polymer only**
C5.1.14	**(HT) Taking It Further: Condensation Polymerisation**	Condensation polymerisation involves monomers with two functional groups. When these types of monomers react they join together, usually losing small molecules such as water, and so the reactions are called condensation reactions. The simplest polymers are produced from two different monomers with two of the same functional groups on each monomer.	4.7.3.2	Identify the by-products of condensation polymerisation reactions Compare the processes of addition polymerisation and condensation polymerisation	Name the small molecule produced when ethanediol reacts with butanedioic acid (images of displayed formulae provided with a box around the condensed molecule). Compare the polymerisation reaction used to produce poly(ethene) with the polymerisation reaction used to produce a polyester.	(C4.1) Thermosoftening polymers melt when they are heated. (C4.1) Most composites are made of two materials, a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement. (C4.1) Thermosetting polymers do not melt when they are heated.				Students often think that to 'condense' means to get smaller. Condensation reactions are where two compounds are combined and water is released.	1. What is required for monomers to react in condensation polymerisation? A. The monomers must contain a C=C double bond B. The monomers must contain water **C. The monomers must contain two functional groups** 2. What small molecule is usually produced through condensation polymerisation? A. A polymer **B. Water** C. Carbon dioxide 3. Which of these is made through condensation polymerisation? **A. Polyester** B. Poly(ethene) C. Amino acids
C5.1.15	**Taking It Further: Naturally Occurring Polymers**	Amino acids have two different functional groups in a molecule. Amino acids react by condensation polymerisation to produce polypeptides. DNA (deoxyribonucleic acid) is a large molecule essential for life. DNA encodes genetic instructions for the development and functioning of living organisms and viruses. Most DNA molecules are two polymer chains, made from four different monomers called nucleotides, in the form of a double helix. Other naturally occurring polymers important for life include proteins, starch and cellulose. Different amino acids can be combined in the same chain to produce proteins.	4.7.3.3 4.7.3.4	Identify different naturally occurring polymers and their monomers Describe the structure of DNA (HT) Describe how polypeptides are produced from amino acids	Name two naturally occuring polymers produced from glucose. How many functional groups are there in an amino acid? (example displayed formulae provided) Glycine reacts by condensation polymerisation to produce a polypeptide and one other substance. Name the other substance produced. Describe the shape and structure of the polymer DNA. Describe the structure of DNA.					Students might think 'that all polymers are synthetic (made by humans). All of the important biological macromolecules in living organisms are polymers: this includes proteins, DNA, RNA, and carbohydrates. Wool, hair, and fingernails are made mostly of polymers too. The polymers starch and cellulose are often not well known according to examiners reports. Many students incorrectly state that water, oxygen and carbon dioxide are polymers. When describing the structure of DNA, most students identify a double helix, however fewer remember to mention four monomers, nucleotides or bases and very few refer to two polymer chains.	1. What are the monomers that make up DNA? **A. Nucleotides** B. Amino acids C. Base pairs 2. Which of these is a naturally occurring polymer? A. Poly(ethene) **B. Cellulose** C. Glucose 3. How can polypeptides be produced from amino acids? **A. Amino acids contain two different functional groups so can undergo condensation polymerisation** B. Amino acids contain two different functional groups so can undergo addition polymerisation C. Amino acids contain two of the same functional group so can undergo condensation polymerisation
C5.1.16	**Feedback Lesson**												