OXFORD INTERNATIONAL AQA EXAMINATIONS

INTERNATIONAL GCSE CHEMISTRY

(9202)

Outline Schemes of Work

For teaching from September 2016 onward
For International GCSE exams in June 2018 onwards

This scheme of work suggests possible teaching and learning activities for each section of the specification. There are far more activities suggested than it would be possible to teach. It is intended that teachers should select activities appropriate to their students and the curriculum time available. The first two columns summarise the specification references, whilst the Learning Outcomes indicate what most students should be able to achieve after the work is completed. The Resources column indicates resources commonly available to schools, and other references that may be helpful. The timings are only suggested, as are the Possible Teaching and Learning activities, which include references to experimental work. Resources are only given in brief and risk assessments should be carried out.

Many centres will have access to a Virtual Learning Environment (VLE), and Key Stage 4 related science materials. In the resources, reference is made to VLE and interactive software. Most VLE software providers have similar presentations on the topics. Before using any presentation, teachers are reminded that they should decide in advance which slides are most suitable to achieve the learning objectives and edit the presentation accordingly before the lesson.

Throughout this specification students will be expected to write word equations and write and balance symbol equations for reactions specified.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.1 Atomic structure and the Periodic Table						
3.1.1 Solids, liquids and gases						
3.1.1a	Matter can be classified in terms of the three states of matter.	Students should be familiar with the states of matter and be able to name each inter-conversion process. They should be able to describe and explain their inter-conversion in terms of how the particles are arranged and their movement. They should understand the energy changes that accompany changes of state.	1	**Discuss**: Revise states of matter. **Activity**: Students make chart to show differences in properties and structure of solids, liquids and gases **Activity**: Melt ice to water, or cool molten stearic acid back to a solid. Plot a graph of temperature against time. **Discuss**: The plateau of the graph in terms of energy being absorbed and used to break bonds, or energy being given out by bonds forming.	Ice, beakers, thermometers, stop watches, stearic acid in boiling tube, heating equipment, graph paper.	
3.1.1b	Evidence for the existence of particles can be obtained from simple experiments.	Students should be familiar with simple diffusion experiments such as Br_2/air, NH_3/HCl, $KMnO_4$/water.	1	**Demo**; Show suitable examples of diffusion experiments or other experiments to show that matter is made from particles.		
3.1.2 A simple model of the atom						
3.1.2a	All substances are made of atoms. A	Know that substances are made of atoms. State that	2	**Activity:** Use the Periodic Table to elicit answers about:	Periodic Table for chemistry.	

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	substance that is made of only one sort of atom is called an element. There are about 100 different elements. Elements are shown in the Periodic Table.	substances made of only one sort of atom are called elements. Know that elements are found in the Periodic Table. State where metals and non-metals appear in the Periodic Table.		▪ list of known elements (about 100) ▪ location of non-metals and metals ▪ groups and periods ▪ idea of atoms. ▪ use of symbols and rules for their use ▪ proton number, mass number. **Task:** Students make notes on their Periodic Table, and in books.	Information about the Periodic Table can be found on the BBC website at http://www.bbc.co.uk/education by searching for 'Periodic Table'. VLE/Interactive software, eg Periodic Table slides.	
3.1.2b	Atoms of each element are represented by a chemical symbol, eg O represents an atom of oxygen.	Know that symbols represent atoms of different elements. Knowledge of the chemical symbols for elements other than those named in the specification is **not** required.				Be able to use symbols confidently.
3.1.2c	Atoms have a small central nucleus, which is made up of protons and neutrons, and around which there are electrons.	Know the structure of an atom.		**Task:** Students view/draw diagrams of basic atomic structure naming sub-atomic particles.	VLE/Interactive software, eg The Atom.	

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3.1.2d	The relative electrical charges are as shown: Proton – charge of +1 Neutron – no charge Electron – charge of -1	Know the charges on sub-atomic particles.		**Discuss:** charges on sub-atomic particles, and produce chart in books.	View the Atomic structure PowerPoint presentation at www.iteachbio.com/Chemistry/Chemistry/Atomic%20Structure.ppt	.
3.1.2e	In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.			**Task:** Work out number of electrons, protons and neutrons in first ten elements of Periodic Table. Results as diagrams or chart in books.		
3.1.2j	The relative masses of protons, neutrons and electrons are: **Name of particle Mass** Proton 1 Neutron 1 Electron Very small			**Discuss**: Give the students the mass numbers for elements numbers 1-10. Ask them to find the pattern between the mass numbers and sub-atomic particles.		Know the difference between atomic number and mass number.
3.1.2f	The number of protons in an atom of an element is its atomic number. The sum of the protons and neutrons in an atom is its mass number.	Students will be expected to calculate the numbers of each sub-atomic particle in an atom from its atomic number and mass number.				Be able to calculate numbers of protons, neutrons, and electrons in an atom, using the Periodic Table.

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3.1.2g	Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element.			**Task:** Students to complete a chart showing atoms of same element having different numbers of neutrons, to develop idea of isotopes.		
3.1.2k	Isotopes are atoms of the same element which have the same proton number but a different mass number. Radioactive isotopes can have industrial and medical uses.	Students should be able to state one industrial and one medical use of radioactive isotopes.				
3.1.2h	Atoms can be represented as shown in this example: (Mass number) 23 **Na** (Atomic number) 11			Introduce representation of different atoms as: 40 **K** 19 **Homework:** Students draw structures of several named atoms using the Periodic Table.		
3.1.2l	The relative atomic mass of an element (A_r) compares the mass of atoms of the element with the $_{12}$C	Students will not be expected to calculate relative atomic masses from isotopic abundances.		**Discuss**: Why does chlorine have an A_r of 35.5? Introduce idea of average value for mass number, and relate to ^{12}C isotope.		

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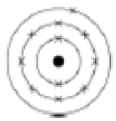
	isotope. It is an average value for the isotopes of the element.					
3.1.2i	Electrons occupy particular energy levels. Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available energy levels (innermost available shells).	Students may answer questions in terms of either energy levels or shells. Students should be able to represent the electronic structure of the first 20 elements of the Periodic Table in the following forms:  *sodium 2,8,1*	1	Review atomic structure, nucleus and electron cloud. **Explain:** Introduce idea of shells within the cloud, and filling numbers and order. Use electron shell sheet to complete them. Teacher completes elements 1,2,3,7 and 11, students complete others.	Electron shell diagram sheet with elements placed in same position as Periodic Table, elements 1–20. VLE/Interactive software, eg Periodic Table slides. View the electron shell PowerPoint presentation at http://education.jlab.org/jsat/powerpoint/chembond.ppt	**Note**: They do not have full outer shells, except for He and Ne. From Ne onwards they have eight electrons in their outer shell.
3.1.3 The Periodic Table						
3.1.3a	The Periodic Table is arranged in order of atomic (proton) number and so that elements with similar properties are in	Students should know that the current Periodic Table is based on the work of Mendeleev.	1	**Discuss:** What is the Periodic Table? or the five 'Ws' (Why, What, Where, When and Who). Limit answers to just a list of elements in a funny shape. **Activity:** Periodic Table card game.	Periodic Table cards. These should be of elements 1–53, excluding the noble gases and 32. Group 1 cards should be one colour, Group 2 a	

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	columns, known as groups. The table is called a Periodic Table because similar properties occur at regular intervals.			The object of the game is to see the problems and solutions found by both Newlands and Mendeleev using only the information they had in 1860s. Each group has 47 cards of elements known by Newlands and Mendeleev, and each card has information on it that they knew. **Round 1**: Working in pairs and not using the Periodic Table sort the cards into a logical order, eg alphabetically or numerically. Place on table. Is it a sensible order, does it tell you anything about the elements and their properties? **Round 2** (Newlands): Draw attention to the cards that are coloured. Remind them about Groups, refer back to Group 1 reactions. Sort according to mass, then place in rows of 8. Note that at first, you get a regular pattern After element with mass 40, the pattern breaks down. This is where Newlands failed to gain recognition. **Round 3** (Mendeleev): Take Newlands' order and adjust it. Show that if H is kept separate, and the third row is elongated, that the pattern re-establishes itself, up to Ga. Show	second colour, Group 5 a third colour, Group 6 a fourth colour and Group 7 a fifth colour. Each card should only have atomic mass, symbol and name. VLE / Interactive software, the Periodic Table.	

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				pattern re-establishes under P. Mendeleev decided that 'he didn't know everything' and so he left a gap for an undiscovered element. Complete final row, and show that on Mendeleev's method, I comes before Te. **Task:** Students make notes on Newland's method, and why it didn't gain acceptance. Mendeleev's method, including the key ideas of leaving gaps for undiscovered elements and also small adjustments to fit known properties of the elements.		
3.1.3b	Elements in the same group in the Periodic Table have the same number of electrons in their highest energy level (outer electrons) and this gives them similar chemical properties.					

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3.2 Structure, bonding and the properties of matter						
3.2.1 Chemical bonds: ionic, covalent and metallic and 3.2.2 How bonding and structure are related to the properties of substances						
3.2.1a	Compounds are substances in which atoms of two or more elements are chemically combined.		1	Discuss the differences between sodium (a highly reactive metal) and chlorine (a toxic gas), and the compound they form, sodium chloride (a white, crystalline food flavouring and preservative).		
3.2.1b	Chemical bonding involves either transferring or sharing electrons in the highest occupied energy levels (outer shells) of atoms in order to achieve the electronic arrangement of a noble gas.					
3.2.1c	When atoms form chemical bonds by transferring electrons, they form ions. Atoms that lose electrons become positively charged ions. Atoms that gain electrons become negatively charged ions. Ions	Students should know that metals form positive ions, whereas non-metals form negative ions. Students should be able to represent the electron arrangement of ions in the following form:		Ionic bonding **Activity:** Draw out ideas of electron shells, and noble gas configuration as being unreactive. **Task:** Students draw diagrams to explain how Na donates/transfers electron to Cl, so both achieve noble gas electronic structure. Students attempt another single	Periodic Table. View the bonding PowerPoint presentation at http://education.jlab.org/jsat/powerpoint/chembond.ppt VLE/Interactive software, eg bonding part 1.	Know that the charge on an ion is related to its group in the Periodic Table. Use their Periodic Table list to check the charge on each ion.

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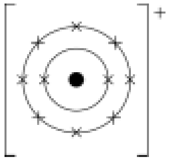
	have the electronic structure of a noble gas (Group 0). Compounds formed from metals and non-metals consist of ions.	for sodium ion (Na+)  Students should be able to relate the charge on simple ions to the group number of the element in the Periodic Table. Know that noble gas structure is unreactive.		electron transfer compound, such as potassium fluoride, before trying magnesium oxide, and calcium chloride. **Homework:** Students could try to explain in terms of electron transfer other simple related ionic compounds.		
3.2.1d	The elements in Group 1 of the Periodic Table, the alkali metals, all react with non-metal elements to form ionic compounds in which the metal ion has a single positive charge.	Knowledge of the chemical properties of alkali metals is limited to their reactions with non-metal elements and water.				
3.2.1e	The elements in Group 7 of the Periodic Table, the halogens, all react with metals to form ionic compounds in	Knowledge of the chemical properties of the halogens is limited to reactions with metals and displacement of				

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	which the halide ions have a single negative charge.	less reactive halogens.				
		Use Periodic Table to write correct formula for ionic compounds.	1	**Explain:** Teacher to explain method for writing formulae. **Task:** Students work out formulae for named compounds using Periodic Table for charges. At first concentrate on simple compounds with only two elements in them. Move on to more complex ones (acid radicals/molecular ions etc) requiring the use of brackets when students are confident about simple balancing of charges. **Homework:** More examples of formulae.	Periodic Table. VLE/Interactive software eg bonding part 1.	Remember the formula multiplies everything inside the brackets by the number outside, when dealing with molecular ions. Be careful to use only subscript numbers to avoid confusion with the charge. Never change the subscript number, instead they should bracket the polyatomic ion and put a fresh subscript outside the bracket.
3.2.1f	An ionic compound is a giant structure of ions. Ionic compounds are held together by strong electrostatic	Students should be familiar with the structure of sodium chloride but do not need to know the structures of other	1			

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	forces of attraction between oppositely charged ions. These forces act in all directions in the lattice and this is called ionic bonding.	ionic compounds. Students given appropriate information, should be able to draw or complete diagrams to show how elements form ions and ionic compounds.				
3.2.2a	Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces of attraction in all directions between oppositely charged ions. These compounds have high melting points and high boiling points because of the large amounts of energy needed to break the many strong bonds.	Describe the NaCl crystal lattice and why it doesn't conduct electricity and is hard to melt. Knowledge of the structures of specific ionic compounds other than sodium chloride is not required.		**Discuss:** Why are ionic compounds hard to melt? Relate this to regular structure of sodium chloride crystal structure, leading to idea of crystal formation from solution in regular way. **Task:** Students could make their own model from marshmallows and spaghetti (or similar). Students draw diagrams to explain properties of sodium chloride. **Explain**: consequences of how these lattices result in high melting and boiling points, and inability to conduct electricity. Students make notes.	NaCl lattice model. View the bonding PowerPoint presentation at http://education.jlab.org/jsat/powerpoint/chembond.ppt VLE/Interactive software, eg bonding part 1. Marshmallows (breakfast size) and spaghetti.	
3.2.2b	When melted or dissolved in water, ionic compounds conduct electricity	Explain the electrical conductivity of ionic substances.		Explain: how ionic substances, when dissolved in water, can conduct electricity (and why as solids they cannot). Students make notes.		

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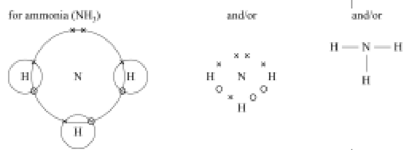
	because the ions are free to move and carry the current.					
3.2.1b	Chemical bonding involves either transferring or sharing electrons in the highest occupied energy levels (shells) of atoms in order to achieve the electronic structure of a noble gas.		1	Recap.		
3.2.1g	When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. Some covalently bonded substances, such as H_2, Cl_2, O_2, HCl, H_2O, NH_3 and CH_4, consist of simple molecules. Others, such as diamond and silicon dioxide, have giant covalent structures (macromolecules).	Students should be able to represent the covalent bonds in molecules such as water, ammonia, hydrogen, hydrogen chloride, methane and oxygen in the following forms:  Students, given appropriate information, should be able to draw or complete diagrams to show how elements form covalent		**Discuss:** Bonding in non-metal compounds. Teacher led discussion into properties of non-metal compounds, relating to the electronic arrangements of non-metals and that electron shells are nearly full. **Task:** Students to show/draw structures of, H_2, Cl_2, O_2, HCl, H_2O, NH_3 and CH_4. Students draw diagrams to explain covalent bonding. Students should do some of these themselves as they demonstrate understanding.	View the bonding PowerPoint presentation at http://education.jlab.org/jsat/powerpoint/chembond.ppt VLE/Interactive software, eg Bonding part 2. Molymods.	

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		compounds by sharing electrons. Students should be able to recognise other simple molecules and giant structures from diagrams that show their bonding.				
3.2.1h	Compounds formed from non-metals consist of molecules. In molecules, the atoms are held together by covalent bonds.					Remember CH_4 is made up of two elements and is not just a single element.
3.2.2c	Substances that consist of simple molecules are gases, liquids or solids that have relatively low melting points and boiling points.		1	**Explain:** Teacher-led explanation that shared pairs of electrons are covalent bonds; why covalent compounds are poor conductors of electricity; why covalent compounds have low melting and boiling points, and that there are very weak forces between molecules, not strong bonds as in ionic compounds.		Be able to explain that intermolecular forces are weak in comparison with covalent bonds.
3.2.2d	Substances that consist of simple molecules have only weak forces between the molecules	Students need to understand that intermolecular forces are weak compared with covalent bonds.		**Task:** Students make notes, or answer questions from DART worksheet, including questions about unknown substances and their structures. **Homework:** Past paper question on		

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	(intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils.	Suggest the type of structure of a substance given its properties.		compound properties and structures.		
3.2.2e	Substances that consist of simple molecules do not conduct electricity because the molecules do not have an overall electric charge.					
3.2.2f	Atoms that share electrons can also form giant structures or macromolecules. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures (lattices) of atoms. All the atoms in these structures are linked to other atoms by strong	Recognise diamond and graphite from their structures. Students should be able to recognise other giant structures or molecules from diagrams showing their bonding.	1	**Task:** Use a DART worksheet with some teacher input and access to models of diamond, graphite and silicon dioxide to allow students to explore and understand how the structure of each substance relates to its properties. Students annotate diagrams and make notes to explain structures and properties. Provide students with diagrams for labelling, particularly of fullerenes.	DART worksheet, and models and diagrams of diamond, graphite and fullerenes. VLE/Interactive software, eg bonding.	Know that graphite is similar to metals in that it has delocalised electrons. Be able to recognise other giant structures or macromolecules from diagrams showing their bonding. Concentrate on

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	covalent bonds and so they have very high melting points.					the use of unknown substances and relate it to the property using knowledge of similar structures and their properties.
3.2.1i 3.2.1j	Metals consist of giant structures of atoms arranged in a regular pattern. The electrons in the highest occupied energy levels (outer shell) of metal atoms are delocalised and so free to move through the whole structure. This corresponds to a structure of positive ions with electrons between the ions holding them together		1	**Demo:** Show metal lattice structure, demonstrate how atoms can slide over each other and relate to properties.	View the bonding PowerPoint presentation at http://education.jlab.org/jsat/powerpoint/chembond.ppt Models of metallic structure such as layers of closely packed similar-sized spheres fixed together or bubble rafts. Model of metal structure with balls to show effect of introducing different atom size to structure. VLE/Interactive software, eg bonding.	

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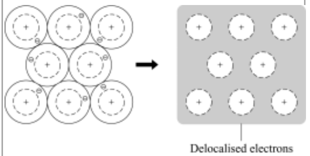
	by strong electrostatic attractions. The bonding in metals is represented in the following form: 				View the bonding PowerPoint presentation at http://education.jlab.org/jsat/powerpoint/chembond.ppt	
3.2.2g	Metals conduct heat and electricity because of the delocalised electrons in their structures.	Explain the flow of an electric current in terms of delocalised electrons. Students should know that conduction depends on the ability of electrons to move throughout the metal.		**Discuss** how atoms in a metal are really ions in a sea of electrons and this allows electrons to flow (electrical conductivity). Students make notes.		
3.2.2h	The layers of atoms in metals are able to slide over each other and so metals can be bent and shaped.	Use the structure of metals to explain their ability to bend and be shaped.				

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3.2.3 Structure and bonding of carbon						
3.2.3a	The element carbon can form four covalent bonds.		1			
3.2.3b	In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure, so diamond is very hard.					
3.2.3c	In graphite, each carbon atom bonds to three others, forming layers. The layers are free to slide over each other because there are no covalent bonds between the layers and so graphite is soft and slippery.	Students should be able to explain the properties of graphite in terms of weak forces between the layers.		**Activity:** Investigate the properties of graphite, including leaving marks on paper, conduction of electricity, high melting point.	Graphite, apparatus to investigate electrical conductivity, test tubes and Bunsen burner.	
3.2.3d	In graphite, one electron from each carbon atom is delocalised. These delocalised electrons allow graphite to	Students should realise that graphite is similar to metals in that it has delocalised electrons. Explain the differences in				

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	conduct heat and electricity.	the properties of diamond and graphite. Know they are examples of the same element carbon. Relate the properties of substances to their uses.				
3.2.3e	Carbon can also form fullerenes with different numbers of carbon atoms. Fullerenes can be used for drug delivery into the body, in lubricants, as catalysts, and in nanotubes for reinforcing materials, eg in tennis rackets.	Students are only required to know that the structure of fullerenes is based on hexagonal rings of carbon atoms.		Research fullerenes, models of fullerenes and their uses.		
3.2.4 Nanoparticles						
3.2.4a	Nanoscience refers to structures that are 1–100 nm in size, of the order of a few hundred atoms. Nanoparticles show different properties from those for the same materials	Students should know what is meant by nanoscience and nanoparticles and should consider some of the applications of these materials, but do **not** need to know specific examples or properties.	1	**Task:** Students use internet and other resources to find out about nanoscience, and nanoparticles, and their current applications. **Task:** In groups produce mini project/ poster. Alternatively groups give class presentation on one use of	View the 'nanoscience uses' PowerPoint presentation at http://nanosense.sri.com/activities/sizematters/applications/SM_AppSlides.ppt	Be able to describe why a named and explained nanoparticle would be useful in a particular application.

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	in bulk and have a high surface area to volume ratio, which may lead to the development of new computers, new catalysts, new coatings, highly selective sensors, stronger and lighter construction materials, and new cosmetics such as suntan creams and deodorants.	Questions may be set on information that is provided about these materials and relating their use to their structure.		nanoparticles they have researched. **Homework:** Student to answer question on development and application of new materials.		**Note:** Students do **not** need to know any specific examples.
3.3 Chemical changes						
3.3.1 Metals						
3.3.1a	Metals are useful materials as they are good conductors of heat and electricity. They can also be bent or hammered into shape because the layers of atoms in metals are able to slide over each other.		1	**Demo:** Show metal lattice structure, demonstrate how atoms can slide over each other and relate to properties, using e.g. polystyrene balls.		

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3.3.1b	An alloy is a mixture of at least two elements, at least one of which is a metal. Alloys often have properties that are different from the metals they contain. This makes them more useful than the pure metals alone. Steels are a mixture of iron with carbon and sometimes other metals.	Students may be given information on the composition of specific alloys so that they can evaluate their uses.		**Demo:** Insert a different-sized ball to show alloy effects make sliding harder to achieve. **Task:** Students draw diagrams to explain metal and alloy structure and properties. **Demo:** Compare samples of pure metals with alloys, eg copper and brass, iron and steel.		
3.3.1c	Copper is useful for electrical wiring and plumbing because it has the following properties: • it is a good conductor of heat and electricity • it can be bent but is hard enough to be used to make pipes or tanks • it does not react with water.					

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3.3.1.1 The reactivity series						
3.3.1.1a	Metals can be arranged in an order of their reactivity from their reactions with water and dilute acids.	Students should be able to recall and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with water or dilute acids, where appropriate, to place them in order of reactivity.	1	**Demo/Starter 1**: Heat some Mg ribbon and then some Cu foil. Ask 'Why does one burn with a bright white light, and the other simply go black?' Draw out ideas of reactivity of metals. **Activity**: Students place small pieces of calcium, magnesium, zinc, iron and copper in different test tubes one-third full of water. Observe result. Any element that is not reacting vigorously (this should be all of them except calcium) after three minutes should have an equal volume of dilute hydrochloric acid added. **Activity**: Students should now be able to make a rudimentary reactivity series, to which they can add further metals. **Demo 2**: Show them the reactions of potassium, sodium, lithium and calcium with water. Ask them to add these metals to their reactivity series.	**For Demo 1:** Mg ribbon, copper foil, calcium lumps (buy new), iron nails, zinc foil or granules, test tubes, dilute hydrochloric acid. **For Demo 2:** Piece of lithium size of a rice grain, trough.	
3.3.1.1b	Displacement reactions involving metals and their compounds in	Students should be able to describe displacement reactions in terms of oxidation and reduction,	1	**Discussion:** What use is the reactivity series? **Activity:** Students carry out a series of reactions between sulfate solutions of	0.2 mol per dm^{-3} solutions of magnesium sulphate, copper sulphate, iron(II) sulfate (freshly made),	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	aqueous solution establish positions within the reactivity series.	and to write the ionic equations. Students should be aware that copper can be obtained from solutions of copper salts by displacement using scrap iron.		metals and the metals. Students should report their findings and: • describe the pattern using the reactivity series from last lesson • write ionic equations for the reactions **Demo:** If time (and nerves) permit, demonstrate a thermite reaction eg iron oxide with aluminium using a magnesium ribbon fuse.	zinc sulfate, test tubes or dropping tiles, foils of Cu, Zn, and Mg, iron filings. **For the demo.** This is a dangerous demo, which you should carry out only if you are confident and competent to do so. Dry iron(III) oxide, aluminium powder. magnesium ribbon, crucible, bucket of sand.	
3.3.1.2 Metal carbonates						
3.3.1. 2a	The carbonates of magnesium, copper, zinc, calcium and lithium decompose on heating (thermal decomposition) in a similar way.	Students should be aware that not all carbonates of metals in Group 1 of the Periodic Table decompose at the temperatures reached by a Bunsen burner.	1	**Activity:** Test each carbonate with acid to see that it evolves carbon dioxide gas, and then dry carbonates are heated to decompose. Use only Mg, Cu, Zn, Ca, and Na carbonates. **Homework:** Tell students they have five samples of rock ores each containing different amounts of copper carbonate. They use today's practical to help them plan an investigation to determine which ore is most likely to contain the most copper carbonate.	Mg, Cu, Zn, Ca, Na, carbonates, dilute hydrochloric acid, test tubes, boiling tubes with delivery tubes, clamps and stands, matches and spills and limewater.	

Spec Reference	**Summary of the Specification Content**	**Learning Outcomes** *What most students should be able to do*	**Suggested timing (lessons)**	**Possible teaching and Learning Activities** *Homework*	**Resource**	**Examination 'hints and tips'** *Students should:*
3.3.1. 2b	Metal carbonates react with acids to produce carbon dioxide, a salt and water.					
3.3.2 Electrolysis						
3.3.2b	Passing an electric current through ionic substances that are molten, eg lead bromide, or in solution breaks them down into elements. This process is called electrolysis and the substance broken down is called the electrolyte.	Know that compounds can be broken down into their elements by using electricity. Know that this process is called electrolysis.	2	**Discuss:** what happens when we pass an electric current through a solution of a salt? **Activity:** Electrolysis of copper chloride solution, using carbon electrodes to obtain copper on the cathode and chlorine at the anode. Students draw diagrams to explain. **Demo:** Electrolysis of molten lead bromide. Students draw diagrams to explain.	Carbon electrodes, power pack and wires, 1 mol dm^{-3} $CuSO_4$ solution, $100cm^3$ beaker. You can find a variety of resources including video clips on the RSC website at www.rsc.org/education/teachers/resources/alchemy/index.htm VLE/Interactive software, eg useful materials from rocks.	
3.3.2a	When an ionic substance is melted or dissolved in water, the ions are free to move about within the liquid or solution.	Know that in solutions and when molten, ionic compounds have ions that are free to move carrying the electric charge with them.				

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.3.2c	During electrolysis, positively charged ions move to the negative electrode the cathode), and negatively charged ions move to the positive electrode (the anode).	Know positively charged ions move to the negative electrode, and negative ions to the positive electrode. Predict the products of electrolysing solutions of ions.		**Discuss:** Relating to ions, movement and attraction to the positive and negative electrodes. Students draw diagrams to explain. **Demo**: If there is time, demonstrate movement of ions, eg the electrolysis of a crystal of $KMnO_4$ on filter paper dampened with sodium chloride solution.		
			1	**Required practical:** Investigate the products at the anode and cathode in the electrolysis of copper sulfate solution.		
3.3.2e	At the cathode, positively charged ions gain electrons; at the anode, negatively charged ions lose electrons.	Explain in terms of oxidation and reduction the changes to ions when touching the electrodes.	1			
3.3.2f	Reactions at electrodes can be represented by half equations, for example: $2Cl^- \rightarrow Cl_2 + 2e^-$ or $2Cl^- - 2e^- \rightarrow Cl_2$	Students should be able to write half equations for the reactions occurring at the electrodes during electrolysis, and may be required to complete and balance supplied half equations.		Use half equations to show electron transfers.		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.3.2d	Oxidation and reduction can be defined as the loss and gain of electrons respectively.					
3.3.2h	Electrolysis is used to electroplate objects. This may be for reasons such as appearance, durability and prevention of corrosion. It includes copper plating and silver plating.	Know what electroplating is and how it works.	1	**Activity:** electroplating copper foil with nickel (using nickel sulfate solution). Students report their experiment. **Discuss:** Uses of electroplating including silver and copper. Explore what is happening in terms of electrons at both electrodes. Students draw diagrams to explain.	Copper electrode, nickel electrode, power pack and wires, 1 mol dm^{-3} $NiSO_4$ solution and 100 cm^3 beaker.	
3.3.2i	Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite. Aluminium forms at the negative electrode and oxygen at the positive electrode. The positive electrode is made of carbon, which reacts with the oxygen to produce carbon dioxide.	Students should understand why cryolite is used in this process. Students should be aware that large amounts of energy are needed in the extraction process.	1	**Task:** Explore the extraction of aluminium, as either video or worksheet, or use RSC Alchemy, or mini-project. Do students know that in the 1850s aluminium was the most expensive metal in the world (it was extracted from its ore by a thermite reaction using sodium metal)? Now, with electrolysis, it is cheap enough to make cans from.	VLE/Interactive software, eg Useful materials from metal ores. Visit the RSC Alchemy for more information on Aluminium at www.rsc.org/Education/Teachers/Resources/Alchemy/index.htm	Remember that the only reason that cryolite is needed for the process is to reduce the melting point of aluminium oxide to less than 1000°C and save money/reduce energy costs.

Spec Reference	**Summary of the Specification Content**	**Learning Outcomes** *What most students should be able to do*	**Suggested timing (lessons)**	**Possible teaching and Learning Activities** *Homework*	**Resource**	**Examination 'hints and tips'** *Students should:*
3.3.2g	If there is a mixture of ions: ▪ at the cathode, the products formed depend on the reactivity of the elements involved ▪ at the anode, the products formed also depend on the relative concentrations of the ions present.	Know that in a mixture of ions, the lowest member of the reactivity series is the element formed at the negative electrode.				
3.3.2j	The electrolysis of sodium chloride solution produces hydrogen and chlorine. Sodium hydroxide solution is also produced. These are important reagents for the chemical industry, eg sodium hydroxide for the production of soap and chlorine for the production of bleach and plastics.	Students should be able to explain, using ideas relating to reactivity, why each of these products is produced.	2	**Activity:** Electrolysis of NaCl solution in Petri dish with universal indicator. To establish split into chlorine (bleaches indicator), an alkali (turns indicator blue/purple) and an unknown gas. Students draw diagrams to show the experiment and the results. **Demo:** Of Hoffman voltameter to show products clearly and also to enable hydrogen gas to be collected and tested (use acidified NaCl and litmus solution to make demo spectacular and easier to understand the electrode processes). **Task:** Students draw diagrams to show the experiment and the results.	Petri dish, carbon electrodes, power pack and wires and 1 mol dm^{-3} NaCl solution. Hoffman voltameter, test tubes, 1 mol dm^{-3} NaCl solution, litmus solution, test tubes, litmus paper and power pack and wires. VLE/Interactive software, eg useful materials from rocks. RSC Alchemy video on Chemicals from Salt can be found at	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				Discuss: Why hydrogen is formed. Relate to reactivity series position of sodium, and industrial uses of sodium chloride. Students make notes.	www.rsc.org/Education/Teachers/Resources/Alchemy/index.htm	
3.4 Chemical Analysis						
3.4.1 Purity, chromatography						
3.4.1a	A pure element or compound contains only one substance, with no other substances mixed in.	Students should be able to identify substances and assess their purity from melting point and boiling point information.	1	**Activity:** Measure the melting and boiling point of water and of salt solution.	Boiling tubes, distilled water, sodium chloride, thermometers, ice, Bunsen burners.	
3.4.1b	Measures of purity are important in everyday substances such as foodstuffs and drugs.					
3.4.1c	A mixture consists of two or more elements or compounds not chemically combined together. The chemical properties of each substance in the mixture are unchanged. It is possible to separate		2	**Discussion:** Reminder about mixtures, elements and compounds. Students write definitions out.		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	the substances in a mixture by physical methods, including distillation, filtration and crystallisation.					
3.4.1d	Paper chromatography can be used to analyse substances present in a solution, eg food colourings and inks/dyes.	Students should be able to describe how to carry out paper chromatography separations and how the components of a mixture can be identified using R_f values. They have to be aware that solvents other than water can be used.		**Activity:** Using paper chromatography. The R_f value for each of the dyes used should be calculated.	Food dyes or inks, filter paper/chromatography paper, pipettes and 250 cm^3 beaker.	
3.4.1e	Chromatography involves a stationary and a mobile phase and separation depends on the distribution between the phase and on the relative solubility of the components.	Students should be able to suggest chromatographic methods for distinguishing pure from impure substances.				

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.4.2 Identification of common gases						
3.4.2a	A pop is heard when a lighted splint is placed near hydrogen gas.	Describe the test for each gas.	1	**Activity:** circus of experiments, testing for one gas at each station (chlorine should be produced and tested only in a fume cupboard).	Zinc, dilute hydrochloric acid, hydrogen peroxide, manganese (IV) oxide, marble chips, ammonium chloride, sodium hydroxide solution, potassium manganate (VII), conc. hydrochloric acid, lime water, red and blue litmus paper, wooden splints.	
3.4.2b	A glowing wooden splint relights in a test tube of oxygen gas.	Recognise each gas from its test result.				
3.4.2c	Carbon dioxide turns limewater (calcium hydroxide solution) cloudy white.					
3.4.2d	Ammonia has a characteristic sharp, choking smell. It also makes damp red litmus paper turn blue. Ammonia forms a white smoke of ammonium chloride when hydrogen chloride gas, from concentrated hydrochloric acid, is held near it.					

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.4.2e	Chlorine has a characteristic sharp, choking smell. It also makes damp blue litmus paper turn red, and then bleaches it white.					
3.4.3 Identification of ions by chemical means						
3.4.3a	Flame tests can be used to identify metal ions. Lithium, sodium, potassium, calcium and barium compounds produce distinctive colours in flame tests: ▪ lithium compounds result in a crimson flame ▪ sodium compounds result in a yellow flame ▪ potassium compounds result in a lilac flame ▪ calcium compounds result in a red flame ▪ barium compounds	Recognise the presence of these ions by this test.	1	**Discuss:** Teacher-led discussion about forensic crime and the need for analytical chemistry to determine what chemicals are present in a variety of situations. **Activity:** Students carry out flame tests on named metal ions to find out the flame colouration. They then use the technique to identify two unknown compounds. **Task:** Prepare results chart and complete it. **Required practical:** Identify the metal ion in an unknown compound using flame testing techniques.	Splints or wires, solid samples of compounds: $LiCl$ $NaCl$ KCl $CaCl_2$ $BaCl_2$ $HCl(aq)$ (to clean wires in) and matches and splints. Unknown compounds labelled X, Y, Z, each to contain one of the metal chlorides in the list.	Flame colours of other metal ions are **not** required knowledge.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	result in a green flame.					
3.4.3b 3.4.3c	Aluminium, calcium and magnesium ions form white precipitates with sodium hydroxide solution but only the aluminium hydroxide precipitate dissolves in excess sodium hydroxide solution. Copper(II), iron(II) and iron(III) ions form coloured precipitates with sodium hydroxide solution. Copper (II) forms a blue precipitate, iron(II) a green precipitate and iron(III) a brown precipitate.	Students should be able to recognise the presence of these ions in water by this test.	1	**Discuss:** Teacher-led discussion about another method of identifying metal ions, this time using sodium hydroxide. **Activity:** Adding sodium hydroxide solution to solutions of metal ions. Students should add small amounts of sodium hydroxide and observe what happens after each addition. Students should be warned that adding more to one solution will produce a further change. **Task:** Students prepare and complete results chart. Remind them that each solid that appears is a precipitate.	Test tubes, NaOH (aq), pipettes, solutions of: $CuSO_4$ $AlCl_3$ $FeSO_4$ $FeCl_3$ $MgCl_2$ $CaCl_2$ NB: $FeSO_4$ must be freshly produced.	
3.4.3d	Carbonates react with dilute acids to form carbon dioxide. Carbon dioxide produces a white precipitate with	Recognise the presence of these ions in water by these tests.	1	**Demo:** Teacher-led demonstration of effect on acid on carbonates, and limewater test as a revision and introduction to testing halide and sulfate ions.	Test tubes and racks, silver nitrate solution, dilute nitric acid, dilute hydrochloric acid, barium chloride, solution, solutions of sodium, sulfate, sodium	

<table>
<tr><th>Spec Reference</th><th>Summary of the Specification Content</th><th>Learning Outcomes
What most students should be able to do</th><th>Suggested timing (lessons)</th><th>Possible teaching and Learning Activities
Homework</th><th>Resource</th><th>Examination ‘hints and tips’
Students should:</th></tr>
<tr><td></td><td>limewater, which turns limewater cloudy white.</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3">Activity: Test halide ions, and then sulfate ions.

Task: Students prepare a results chart and complete it:

<table>
<tr><td rowspan="2">name of compound</td><td colspan="2">effect of adding</td></tr>
<tr><td>silver nitrate and nitric acid.</td><td>barium chloride and hydrochloric acid</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Establish reliable tests for each halide ion and sulfates, using the results of the experiment. Students make notes in their books.

Homework: Write word, then symbol equations for each reaction.</td><td rowspan="3">chloride, sodium bromide and sodium iodide.</td><td rowspan="3"></td></tr>
<tr><td>3.4.3e</td><td>Halide ions in solution produce precipitates with silver nitrate solution in the presence of dilute nitric acid. Silver chloride is white, silver bromide is cream and silver iodide is yellow.</td></tr>
<tr><td>3.4.3f</td><td>Sulfate ions in solution produce a white precipitate with barium chloride solution in the presence of dilute hydrochloric acid.</td></tr>
</table>

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.5 Acids, bases and salts						
3.5.1 The properties of acids and bases						
3.5.1a	Metal oxides and hydroxides are bases. Soluble hydroxides are called alkalis.	Recall the pH scale. Know how alkalis are different from bases.	3	Revise pH scale from KS3. **Discuss:** What makes an acid and an alkali in terms of ions. List and produce formulae for acids and alkalis to get idea that acids have hydrogen (ions), and alkalis have hydroxide (ions). Students make notes.	NaOH 1 mol dm^{-3}, HCl(aq) 1 mol dm^{-3}, 100cm^3 beaker, indicator paper/pH meter, evaporating basin and 25 cm^3 measuring cylinders. VLE/Interactive software, eg chemical reactions.	
3.5.1b	Acids react with bases to form salts. These reactions are called neutralisation reactions.	Know that acid + alkali makes salt + water.		**Activity:** making a salt by neutralisation of an alkali, eg NaCl (pH sensors could be used here instead of indicator paper or solution to be able to crystallise the salt without the need for boiling with carbon).		
3.5.1f	Hydrogen ions, H^+(aq), make solutions acidic, and hydroxide ions, OH^-(aq), make solutions alkaline. The pH scale is a measure of the acidity or alkalinity of a solution.	Students should be familiar with the pH scale from 0 to 14, and know that pH 7 is a neutral solution. Students should be able to describe the use of universal indicator to measure the approximate pH of a solution.		**Homework:** Students draw diagrams to explain the method. Use symbol equation with state symbols to describe reaction (and should use state symbols hereafter when completing symbol equations).		
3.5.1d	Ammonia dissolves in water to produce an			**Activity:** ammonia as an alkaline solution in water and how it can		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	alkaline solution. It is used to produce ammonium salts.			produce salts for fertilisers (and explosives). Students make notes.		
3.5.1e	A solution of calcium hydroxide in water (limewater) reacts with carbon dioxide to produce calcium carbonate.	Students should be familiar with using limewater to test for carbon dioxide gas.				
3.5.1c	The particular salt produced in any reaction between an acid and a base or alkali depends on: • the acid used (hydrochloric acid produces chlorides, nitric acid produces nitrates, sulfuric acid produces sulfates) • the metal in the base or alkali.	Know which acid makes which salt, and which metal makes which salt. Students should be able to suggest methods to make a named soluble salt.	1	Revise all reactions to make salts so far, include writing word and symbol equation (if not already done) for each one, including the state symbols. **Task:** Students to come up with rules for making soluble salts, eg nitric acid makes nitrates etc. Students make notes. **Task**: Making a salt. Students to be given list of salts to make, and they should state the chemicals needed and the method to use to make each salt. A card game could be produced with names of salts, acids, ions, and possible ingredients. Students produce word equation of the reaction needed to make each salt, add the method of production, then attempt to write balanced symbol equation.	VLE/Interactive software, eg chemical reactions.	Be able to state the substances needed to make the salt and name the salt, given the names of the metal and acid used.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				Homework: Making soluble salts. Students complete a worksheet naming the reactants needed to make a named soluble salt, and given the reactants, name the soluble salt produced. They also state the method needed to obtain a solid sample of the salt.		
3.5.2 Preparation of salts						
3.5.2a	Soluble salts can be made from acids by reacting them with: • metals – not all metals are suitable; some are too reactive and others are not reactive enough • insoluble bases – the base is added to the acid until no more will react and the excess solid is filtered off • alkalis – an indicator can be used to show when the acid and alkali have completely	Know how to make a salt from a metal + acid and that this releases hydrogen gas. Write a word equation for the reaction. Students should know that a lighted spill can be used to test for hydrogen. Students should be able to suggest methods to make a named soluble salt. Write symbol equation for the reaction. Interpret a symbol equation containing state symbols. Describe how to make a	4	**Activity:** Making a salt by reacting a metal with hydrochloric acid. Students crystallise the salt and write symbol equation, using state symbols. **Discuss:** Suitability of metals for this reaction, in terms of reactivity series. Students make notes. **Activity:** Making a salt by neutralisation of an insoluble base such as copper oxide to make copper sulfate. Students crystallise the salt, and write symbol equation, using state symbols. **Homework:** Students draw diagrams to explain the method. **Demo:** How much is in the solution? Teacher-led demonstration, followed	Magnesium ribbon, $100cm^3$ beaker, dilute hydrochloric acid, evaporating basin, test tubes, matches and spills and $25cm^3$ measuring cylinders. VLE/Interactive software, eg chemical reactions. CuO, spatula, dilute sulfuric acid, stirring rod, $100cm^3$ beaker, $100cm^3$ conical flask, filter funnel, filter paper, evaporating basin, $25cm^3$ measuring cylinders, matches and spills and heating. Burettes, burette funnels,	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	reacted to produce a salt solution.	soluble salt from an insoluble base.		by class titration practical to establish idea that the volumes of acid and alkali can be measured using a suitable indicator. Whilst universal indicator will work, better to use phenolphthalein as the indicator as it gives a definite end point. **Task:** Students draw equipment and record their results. Calculate the mean for the titration and then compare their results.	measuring cylinder / 25cm^3 pipette, conical flask, white tile clamp and stand solutions of 0.5 mol dm^{-3}, hydrochloric acid, sodium hydroxide, 250cm^3 beakers and phenolphthalein.	**Note:** It should be highlighted that averaging out results can give more reliable results.
3.5.2b	Salt solutions can be crystallised to produce solid salts.					
3.5.2c	Insoluble salts can be made by mixing appropriate solutions of ions so that a precipitate is formed. Precipitation can be used to remove unwanted ions from solutions: for example, in treating water for drinking or in treating effluent.	Explain what precipitation is, and how it can be used to make insoluble salts. Know how making insoluble salts can be useful in the water industry as a cheap and effective way of removing unwanted ions from water. Students should be able to name the substances needed to make a named insoluble salt.	1	**Task:** Students prepare insoluble salt, eg lead iodide and/or barium sulphate. **Discuss:** How precipitation reactions can easily remove unwanted ions from drinking water and effluents. Students make notes. **Homework:** Making insoluble salts. Students complete a worksheet naming the reactants needed to make a named insoluble salt and, given the reactants, name the insoluble salt produced.	1 mol dm^{-3} lead nitrate, 1 mol dm^{-3} potassium iodide or 0.2 mol dm^{-3} barium hydroxide, 0.2 mol dm^{-3} sodium sulphate, 25 cm^3 measuring cylinders, 100 cm^3 beakers, filter paper and filter funnels. VLE/Interactive software, eg chemical reactions.	**Note:** All students need to remember is going to a dance and swapping partners to get the word equations right.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.6 Quantitative chemistry						
3.6.1 Conservation of mass including the quantitative interpretation of chemical equations						
3.6.1a 3.6.1b	Chemical reactions can be represented by word equations or by symbol equations. Information about the states of reactants and products can be included in chemical equations.	Students should be able to write word and balanced symbol equations for reactions in the specification. Students should be able to use the state symbols (g), (l), (s) and (aq) in equations where appropriate.	1	**Task:** Students write one word equation to show general reaction. Introduce symbol equations. **Explain:** Show need for balancing the equation linked to idea of conservation of mass. **Task:** Students balance several equations themselves.	VLE/Interactive software, eg chemical reactions.	
3.6.1c 3.6.1d	No atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants. The masses of reactants and products can be calculated from	Know that all atoms involved in a reaction must be accounted for. Students should be able to calculate the mass of a reactant or product from information about the other masses of the other reactants and products in the reaction and the balanced symbol equation.	1	**Tasks:** Students carry out and report precipitation reaction experiments such as lead nitrate and potassium iodide to observe there is no change in mass on forming products. **Homework:** Students do calculations using mass of reactants and products to find mass formed of one product or mass needed of one reactant. Do calculations on masses of reactants and products from balanced symbol equations. Students make	Balances, boiling tubes, 25cm^3 measuring cylinders, lead nitrate solution 1 mol dm^{-3}, potassium iodide 1 mol dm^{-3}	Be able to calculate the mass of a reactant or product from information about the masses of the other reactants and products in the reaction.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	balanced symbol equations.			notes.		
3.6.1e	Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because: • the reaction may not go to completion because it is reversible • some of the product may be lost when it is separated from the reaction mixture • some of the reactants may react in ways different from the expected reaction.		1	**Discuss:** Class discussion about result of the experiment from last lessons, and why results are not always correct. Include reference to yield, and percentage yield. Students make notes on yield and percentage yield.	Calculation worksheets. VLE/Interactive software, eg quantitative chemistry.	Be able to evaluate and make judgements for the data in the question.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.6.2 Use of amount of substance in relation to masses of pure substances						
3.6.2a	The relative formula mass (M_r) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula.	Students are expected to use relative atomic masses in the calculations specified in the subject content. Students should be able to calculate the relative formula mass (M_r) of a compound from its formula.	1	**Task:** Calculating relative formula mass (M_r). Chemists need to be sure of the amount of a compound present in terms of the number of molecules or atoms. **Explain:** Show how to make the calculation for simple, then more complex formulae. It is a good idea to revise what a formula tells you, especially where brackets are involved. **Task:** Students do examples of calculations with increasing complexity.	Periodic Table and list of formulae. VLE / Interactive software, eg quantitative chemistry.	**Note:** Students can choose to learn the Periodic Table in its entirety; however, the Periodic Table is usually given in the exam.
3.6.2b	The percentage by mass of an element in a compound can be calculated from the relative atomic mass of the element in the formula and the relative formula mass of the compound.	Be able to calculate percentage mass of a named element in a formula.	1	**Explain:** Show how to calculate percentage by mass of one element in the formula. Students provide several examples (they can use the same examples as from the previous lesson).		
3.6.2c	The empirical formula of a compound can be calculated from the	Students should be able to calculate empirical formulae from given	2	**Activity:** Finding the formula of magnesium oxide. Students report their experiment.	Magnesium, crucible and lid, balance, crucible tongs, spills and matches,	Be able to work out the formula of a compound from

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	masses or percentages of the elements in a compound.	information.		**Explain:** Teacher led explanation of how to make the calculation using either the graph method or from mass readings. Students find the formula using chosen method. You could use either a graphical method where each group plots their result on a graph to establish best fit line to get answer from, or calculate mean for the class to process using atomic masses. You could also use both methods to see which gives result closest to the true value. **Homework:** Give a formula calculation from reacting masses for another compound. Make sure students know the method from the experiment.	tripod, gauze, and Bunsen burner. Graph paper. VLE / Interactive software, eg quantitative chemistry.	the reacting masses provided in the question.
3.6.3 The mole concept						
3.6.3a	Relative atomic mass A_r is the average mass of naturally occurring atoms of an element on a scale where ^{12}C has a mass of exactly 12 units.	Students are expected to be able to use balanced equations to calculate masses of reactants or products. Students are expected to calculate empirical	1			

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
		formulae and molecular formulae.				
3.6.3b	Relative molecular mass M_r is the sum of the relative atomic masses in the compound.					
3.6.3c	The relative formula mass of a substance, in grams, is known as one mole of that substance.	Students are expected to use the relative formula mass of a substance to calculate the number of moles in a given mass of that substance and vice versa.		**Explain:** Show how to make the calculation for simple, then more complex formulae. **Task:** Students do examples of calculations with increasing complexity.		
3.6.3d	One mole contains 6.023×10^{23} atoms or molecules. This number is known as Avogadro's constant.					

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.6.4 Molar concentrations						
3.6.4a	The concentration of a solution is related to the mass of the solute (in terms of number of moles) and the volume of the solution. The concentration of a solution is calculated as follows: $\text{concentration}\left(\text{mol/dm}^3\right)=\frac{\text{number of moles}}{\text{volume}\left(\text{in dm}^3\right)}$		1	**Explain:** Show how to do the calculations for simple, then more complex examples. Mass of solute could be introduced, to convert to moles. **Task:** Students do examples of calculations with increasing complexity.		
3.6.4b	The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.	Students should be able to carry out titrations using strong acids and strong alkalis only (sulfuric, hydrochloric and nitric acids only).	2	**Required practical:** Establish the concentration of an unknown strong acid through titration with a strong base.		
3.6.4c	If the concentration of one of the reactants is known, the results of a titration can be used to find the concentration of the other reactant.	Students should know how to carry out a titration and be able to calculate the chemical quantities in titrations involving concentrations (in moles per dm^3) and masses (in		Remind students about relative molecular mass (M_r). Remind them that the M_r in grams if dissolved in water provides a concentration unit that we can use to compare different solutions. **Task:** Students make brief notes on molecules and how dissolving different		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
		grams per dm^3).		proportions of the M_r produces solutions of different concentrations. **Explain:** Using last time's results, show how to work out the concentration of the acid assuming 1 mol dm^{-3} sodium hydroxide was used. Tell students they need the balanced equation to work out reacting amounts and to work out the unknown using the equation: *Conc of acid x volume used* *conc of alkali x volume used* = *no of acid molecules in equation* *no of alkali molecules in equation* Give students other examples to calculate the answers for. One should also involve using grams instead of moles.		
3.6.4d	The molar gas volume at room temperature and pressure is assumed to be 24 dm^3	Students are expected to be able to calculate the amount of gas in a reaction by using molar amounts of gases and their volumes.	1	**Explain:** Show how to do the calculations for simple, then more complex examples. Include mixed calculations involving masses of reactants or products as well as gas volumes.		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				Task: Students do examples of calculations with increasing complexity.		
3.7 Periodicity						
3.7.1 Group properties						
3.7.1a	The elements in Group 1 of the Periodic Table (known as the alkali metals): • are metals with low density (the first three elements in the group are less dense than water) • react with non-metals to form ionic compounds in which the metal ion carries a charge of +1. The compounds are white solids that dissolve in water to form colourless solutions • react with water, releasing hydrogen	Describe the reactions of Group 1 metals with water, air and chlorine. Know that Group 1 metals form 1+ ions. Know that they form hydroxides that dissolve in water to give alkaline solutions.	1	Review metals in the Periodic Table. **Demo:** Place potassium, sodium and lithium in water, to obtain ideas of density in water, release hydrogen and form hydroxides. Burn sodium in chlorine gas, show formation of compound, and charges on both Group 1 metal and also Group 7 non-metal. **Task:** Students draw diagrams of the reaction of Na with Cl. **Homework:** Write word and balanced equations for the reactions.	**Demo:** large glass trough**,** universal indicator**,** small pieces (rice grain) of alkali metals Li, Na, K, forceps, paper towels, scalpel, safety screen, glass tube (8mm wide), splints and matches.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	• form hydroxides that dissolve in water to give alkaline solutions.					
3.7.1b	In Group 1, the further down the group an element is, the more reactive the element.					
3.7.1c	The elements in Group 7 of the Periodic Table (known as the halogens) react with metals to form ionic compounds in which the halide ion carries a charge of –1.		2	Revise Na +Cl_2 reaction to get halogens as elements that form 1- charged ions.		
3.7.1d	In Group 7, the further down the group an element is: • the less reactive the element • the higher its melting point and boiling point.	Know that the further down the group: • the less reactive the element is • the higher its melting point and boiling point.		**Demo:** Students make list of halogens, their colours and their state at room temperature. Remind students of colour of chlorine (seen with NaCl reaction). Show samples of other halogens if possible, if not use halogen waters from the class experiment to show their colour when dissolved in water.	Samples of chlorine, bromine and iodine in sealed containers.	Be able to write and balance symbol equations**.**

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.7.1e	A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.	Know that a more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.		**Activity:** Displacement reactions – Students add chlorine water to each of the three compounds and observe results. Add bromine water to fresh samples of the compounds and observe results. Add iodine solution to fresh samples of the compounds and observe results. **Discuss:** Findings from results chart. Conclude that halogens higher in the Group displace halogens that are lower from their compounds. **Task:** Write symbol equations and balance for one reaction. All reactions standard.	Aqueous solutions of chlorine, and bromine, and iodine solution (iodine in potassium iodide). Pipettes, test tubes, test tube racks, solutions of sodium chloride, sodium iodide, and sodium bromide (alternatively these could be potassium compounds).	
3.7.1f	The trends in reactivity within groups in the Periodic Table can be explained because the higher the energy level of the outer electrons: • the more easily electrons are lost • the less easily electrons are gained.	Students should be able to explain the relative reactivities of the elements in Group 1 and 7.	1	**Discussion** on reactivity in Group 7 and Group 1. This should be in terms of ease of losing/gaining outer electrons. Metals easier to lose from outside as less attracted to nucleus further down the group. Non-metals easier to gain up the group due to stronger attraction from nucleus as fewer electron shells.		Explain the reactivity trends within both Group 1 and Group 7 in terms of the distance of the outer electron from the central, positively charged nucleus, and the attraction of the nucleus to those outer electrons.

<table>
<tr><th>Spec Reference</th><th>Summary of the Specification Content</th><th>Learning Outcomes
What most students should be able to do</th><th>Suggested timing (lessons)</th><th>Possible teaching and Learning Activities
Homework</th><th>Resource</th><th>Examination ‘hints and tips’
Students should:</th></tr>
<tr><td colspan="7">3.7.2 Transition metals</td></tr>
<tr><td>3.7.2a</td><td>Transition metals are those in the centre of the Periodic Table between Groups 2 and 3. Many transition metals have ions with different charges, form coloured compounds and are useful as catalysts.</td><td></td><td rowspan="2">1</td><td rowspan="2">Look at transition metals and their compounds.

Circus of 15 stages with samples of compounds in sealed bottles, and samples of transition metals, with a beaker of water.

Task: Students record each base on a results chart. For compounds they use this chart:
<table>
<tr><td>name of compound</td><td>formula</td><td>description</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>
For metals they use this chart:
<table>
<tr><td>name of metal</td><td>can it be bent?</td><td>can it float on water?</td><td>description</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>
Discuss: elicit ideas of coloured compounds, different properties and use of transition metals as catalysts (they have already met MnO_2 as a catalyst in Unit 2).

Task: Students make notes of outcomes of transition metals in comparison to Group 1.</td><td rowspan="2">Sealed samples of every transition metal compound in the chemical store that is coloured (avoid zinc compounds). Each sample to be labelled and given its formula.

Samples of five transition metals: Zn, Fe, Ni, Cu, Ag.

5 × 250cm^3 beakers of water.

VLE / Interactive software, eg transition metals.</td><td rowspan="2"></td></tr>
<tr><td>3.7.2b</td><td>Compared with the elements in Group 1, transition elements:
• have higher melting points (except for mercury) and higher densities
• are stronger and harder
• are much less reactive and so do not react as vigorously with water or oxygen.</td><td>Know that transition metals typically:
• form coloured compounds
• are used as catalysts
• are harder and denser than Group 1 metals.
• are less reactive with water and oxygen.</td></tr>
</table>

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				Homework: DART sheet on melting points of transition metals and Group 1, to show differences in property and hence uses.		
3.8 The rate and extent of chemical change						
3.8.1 Rate of reaction						
3.8.1a	The rate of a chemical reaction can be found by measuring the amount of a reactant used or the amount of product formed over time:	Students need to be able to interpret graphs showing the amount of product formed (or reactant used up) with time, in terms of the rate of the reaction.	1	**Activity:** React marble chips with dilute hydrochloric acid and measure the volume of carbon dioxide evolved against time taken. Record results in a chart and plot a graph of results of volume of gas produced against time. Analyse the graph to obtain rate of reaction at one time. Explain clearly what the graph shows at each part:	Marble chips, balance, dilute hydrochloric acid, burette/measuring cylinder/gas syringe, conical flask with delivery tube, washing-up bowls/troughs and stopwatches. Graph paper.	Knowledge of specific reactions other than those in the subject content is **not** required, but students will be expected to have studied examples of chemical reactions and processes in developing their

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	rate of reaction = $\frac{\text{amount of product used}}{\text{time}}$ rate of reaction = $\frac{\text{amount of product formed}}{\text{time}}$			▪ Initially rate is fast ▪ Slows down ▪ Reaction is complete. Students make notes on a graph. **Homework:** Students calculate rate of reaction at two more times to show change in rate over the experiment. **Or** Students plan an investigation using the method from lesson into how concentration of the acid would affect the rate of reaction.		skills during their study of this section.
3.8.1c 3.8.1b	Increasing the temperature increases the speed of the reacting particles so that they collide more frequently and more energetically. This increases the rate of reaction. Chemical reactions can only occur when reacting particles collide with each other	Know how temperature affects rate of reaction. Know that for a reaction to happen particles have to collide. Use collision theory to explain the change in rate in terms of particle behaviour.	2	**Activity:** Investigate the effect of temperature on the same reaction as last lesson. Students report their experiment. You can get different groups to do the experiment using different instruments to measure gas volume, eg gas syringe, burette, measuring cylinder etc to develop ideas of precision. Students plot graph of results. Compare results between groups. Class discussion on why increasing temperature might make the reaction faster. Develop hypothesis based on collision theory. Suggest we need to	Marble chips, balance, dilute hydrochloric acid, burette/measuring cylinder/gas syringe, conical flask with delivery tube, washing up bowl / troughs, stopwatches, thermometers and hot water beakers to heat acid in. Graph paper.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	and with sufficient energy. The minimum amount of energy particles must have to react is called the activation energy.	Know that for a reaction to happen particles have to collide with sufficient energy to react, and that this amount of energy is called the activation energy. Know that a hypothesis has to be successfully tested before it becomes accepted scientific knowledge.		test out theory to see if it explains how rates of reaction change. **Homework:** Explain the difference between a guess, hypothesis, and theory.		
3.8.1f	Increasing the surface area of solid reactants increases the frequency of collisions and so increases the rate of reaction.	Know how particle size affects rate of reaction. Use collision theory to explain the change in rate in terms of particle behaviour.	1	**Demo:** Use decreasing mass method to investigate reacting equal masses of large chips and small chips of marble with dilute hydrochloric acid. Students describe the experiment. Students plot graph of results, and use the hypothesis of collision theory to explain the results. **Discuss:** Discussion on why every particle doesn't react at once to get idea of minimum (activation) energy required for a collision to cause a reaction. Students make notes.	Large and small marble chips, balance, dilute hydrochloric acid, 250 cm^3 conical flask, cotton wool, stopwatch. Graph paper. VLE/Interactive software, eg Rates.	**Note:** Allow students to 'do' the experiment themselves. A video camera showing the balance, and stop watch, connected to a projector allows students to take measurements themselves.
3.8.1e	Increasing the concentration of reactants in solutions	Know how concentration affects rate of reaction.	1	**Activity:** Disappearing cross method. **Task:** Students investigate sodium	Sodium thiosulfate solution, hydrochloric acid, conical flasks,	Always remember to mention how the particle speed

Spec Reference	**Summary of the Specification Content**	**Learning Outcomes** *What most students should be able to do*	Suggested timing (lessons)	**Possible teaching and Learning Activities** *Homework*	**Resource**	**Examination 'hints and tips'** *Students should:*
	increases the frequency of collisions and so increases the rate of reaction.	Use collision theory to explain the change in rate in terms of particle behaviour. Know that collision theory has now been successfully tested.		thiosulfate solution and dilute hydrochloric acid. Can be done with datalogging or by eye. Use different methods to obtain results/instrumentation. Students explain the results again in terms of the hypothesis. Teacher-led discussion, should we make this a theory rather than hypothesis? **Homework:** Students plot graph of results and interpret it.	stopwatches, graph paper. Laminated, photocopied crosses on paper are a good idea, to give a standard image for viewing through the flask.	and/or numbers and/or temperature accounts for the observed change, when asked why a rate changes.
3.8.1d	Increasing the pressure of reacting gases increases the frequency of collisions and so increases the rate of reaction.	Use the collision theory to explain how the change in conditions affects the rate of any reaction, in terms of particle behaviour. Know how gas pressure affects rate of reaction.	1	Consolidation lesson on collision theory, rates of reaction and activation energy. **Task:** Students could draw particle diagrams to show how each change in conditions affects the particle mixture in the reaction and how this relates to the theory. **Homework:** Make a prediction on the effect of altering the pressure on a gas reaction. **Required practical:** Investigate factors affecting the rate of a reaction. (Any of the above practicals)	VLE/Interactive software eg rates.	

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3.8.1g 3.8.1h	Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts. Catalysts are important in increasing the rates of chemical reactions used in industrial processes to reduce costs.	Know that catalysts change the rate of a chemical reaction. This is important in industry to reduce costs. Describe the benefit of using a catalyst for a given process to the industry involved.	1	**Discuss:** Why do cars have catalysts in their exhaust system? What do they do? **Activity:** Investigating effect of catalysts. Use one or more of these catalysts on hydrogen peroxide: liver, potato, manganese(IV) oxide. Students report their experiment. **Explain:** Develop idea of catalysts helping the reaction to take place. You may wish to mention how catalysts work, active sites, forming intermediates etc. **Explain:** The value to industry of using catalysts in terms of reducing costs etc. Students make notes. **Homework:** Past paper question on rates.	Manganese (IV) oxide /liver/potato spatula, 20 vol hydrogen peroxide, balance, measuring cylinder and boiling tube. VLE/Interactive software, eg transition metals.	**Note:** In questions involving industry and catalysts, students should be given information that they need to evaluate eg Why is a catalyst used that reduces the reacting temperature? Because reducing the temperature will save energy and make the process cheaper.
3.8.2 Factors affecting equilibrium						
3.8.2a	When a reversible reaction occurs in a closed system, equilibrium is reached when the reactions occur at exactly the same rate in each direction.		1	**Demo:** Show effect of adding acid, then alkali, to bromine water to demonstrate what we mean by an equilibrium. Students to make notes on equilibrium and the use of the symbol to represent reversible reactions. **Discuss:** How equilibrium is only reached when the products are being	VLE / Interactive software, reversible reaction	**Note:** Dynamic equilibrium is just like the latest ride at a theme park. There's always the same number on the ride; it is just that at the

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				made as quickly as the reactants.		end of each trip, the people on board change.
3.8.2b	The relative amounts of all the reacting substances at equilibrium depend on the conditions of the reaction.	Describe and evaluate the effect of changing the conditions of temperature and pressure on a given reaction or process.		**Demo:** Model dynamic equilibrium with two 25 cm^3 measuring cylinders, each with an open ended glass tube but with different diameters. Put 25 cm^3 of water into one cylinder. Transfer water from one cylinder to the other using a finger over the end of each tube in turn (keep the tubes in the same cylinder) until the level in each cylinder does not change any more.		
3.8.2c	If the temperature is lowered, ▪ the yield from the endothermic reaction decreases ▪ the yield from the exothermic reaction increases.					
3.8.2d	In gaseous reactions: ▪ an increase in pressure will favour the reaction that produces the least number of molecules as shown by the symbol equation for that reaction			This is true only under the same conditions of temperature and gas pressure. Use slides from a PowerPoint presentation and/or the RSC Alchemy website to show how changing each condition affects the equilibrium. **Task:** Students make notes on effect of changing temperature for		

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	▪ a decrease in pressure will favour the reaction that produces the greatest number of molecules as shown by the symbol equation for that reaction.			exothermic and endothermic reactions. **Task:** Students make notes on the effect of changing pressure for gas reactions to show how gas production is favoured or inhibited. **Discuss:** How we can make the most ammonia, as cheaply as possible, and as environmentally friendly as possible.		
3.8.2e	These factors, together with reaction rates, are important when determining the optimum conditions in industrial processes, including the Haber process.	Evaluate the conditions used in industrial processes in terms of energy requirements.		**Video**: Show RSC ammonia video again to refresh and revise process. **Homework:** Candidates complete worksheet from RSC Alchemy about impact of conditions on proportions made.	RSC Alchemy worksheet can be found at www.rsc.org/Education/Teachers/Resources/Alchemy/am/question.doc	
3.8.2f	Sulfuric acid is produced industrially using the contact process. It is a three-stage process, which incorporates a reversible process and the use of a catalyst. Stage 1: Sulfur is burned in air to produce sulfur dioxide	Students should be able to describe the stages in the contact process and also to explain why a catalyst, a high temperature and atmospheric pressure result in more yield of sulfur trioxide in Stage 2.	1	**Discuss:** How we can make the most sulfuric acid, as cheaply as possible, and as environmentally friendly as possible. **Explain:** Use resources from Royal Society of Chemistry (RSC) Alchemy to explain and provide activities for students to understand the basics of the Contact process. Watch video clip.	Resources and a video on sulfuric acid can be found on the RSC Alchemy website at www.rsc.org/Education/Teachers/Resources/Alchemy/index.htm	

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	$S (s) + O_2 (g) \rightarrow SO_2 (g)$ Stage 2: Sulfur dioxide reacts with more oxygen to make sulfur trioxide $2SO_2(g) + O_2 (g) \rightleftharpoons 2SO_3 (g)$ This stage is reversible and it requires a catalyst of Vanadium (V) oxide V_2O_5, a temperature of around 450 °C and atmospheric pressure. Stage 3: Sulfur trioxide reacts with water to make sulfuric acid $H_2O(l) + SO_3 (g) \rightarrow H_2SO_4(aq)$					
3.8.3 Production of ammonia						
3.8.3a	The raw materials for the Haber process are nitrogen and hydrogen. Nitrogen is obtained from the air and hydrogen may be	Evaluate the conditions used in industrial processes in terms of energy requirements.	1	**Activity:** Draw chemical bonding of ammonia on the board, write the formula as well. **Discuss:** Ammonia as an important chemical in terms of production of	Further resources and a video on ammonia can be found on the RSC Alchemy website at www.rsc.org/Education/Teachers/Resources/Alchem	**Tip:** As a quick revision draw a flow chart of each starting material, where it comes from and what it

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	obtained from natural gas or other sources.			fertilisers and explosives. How is it made? You could go for a historical perspective as well. Did you know: ▪ the Navy has the legal right to enter your bathroom (to collect nitrates from urine) ▪ explosives and fertilisers were made from bird droppings from the Pacific.	y/index.htm	becomes.
3.8.3b	Ammonia is a raw material in the production of fertilizers.	Students should be able to explain the global need for fertilizers to maximize food yields.		**Explain:** Use resources from Royal Society of Chemistry (RSC) Alchemy to explain and provide activities for students to understand the basics of the Haber process. Watch video clip.		
3.8.3c	The purified gases are passed over a catalyst of iron at a high temperature (about 450°C) and a high pressure (about 200 atmospheres). Some of the hydrogen and nitrogen react to form ammonia. The reaction is reversible so ammonia breaks down again into nitrogen and hydrogen: nitrogen + hydrogen $\rightleftharpoons$ ammonia On cooling, the	Evaluate the conditions necessary in an industrial process to maximise yield and minimise environmental impact.		**Task:** Students complete flow charts from RSC Alchemy ammonia to show process. **Discuss:** Brief discussion on the need to minimise energy requirements and release of pollutants, students to make notes.		Understand why the temperature and pressure used are the best compromise.

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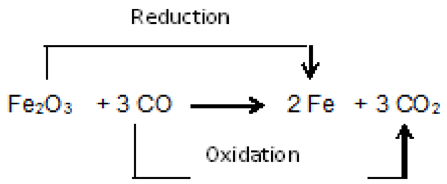
	ammonia liquefies and is removed. The remaining hydrogen and nitrogen are recycled.					
3.8.4 Redox reactions						
3.8.4a	Oxidation can be described as the gain of oxygen by a substance and reduction as the loss of oxygen from a substance.		1	This is a consolidation lesson of ideas encountered previously.		
3.8.4b	Oxidation can also be described as the loss of electrons and reduction as gain of electrons.	Students should be able to describe chemical reaction within this specification in terms of oxidation and reduction using the definitions above.		**Discuss:** why a reaction can be oxidation and reduction under both definitions, by breaking it down into the ions involved. Use Mg + CuO → Cu + MgO as an example.		
3.8.4c	When oxidation and reduction are happening at the same time this is known as a redox reaction, for example:					

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	 					
3.9 Energy changes						
3.9.1 Exothermic and endothermic reactions						
3.9.1a	When chemical reactions occur, energy is transferred to or from the surroundings.	Knowledge of delta H (ΔH) conventions and enthalpy changes, including the use of positive values for endothermic reactions and negative values for exothermic reactions, is required. Describe the differences between exothermic and endothermic reactions.	2	**Activity:** Circus of reactions. Students discover what happens to the temperature in each reaction: ▪ sodium hydroxide solution and hydrochloric acid ▪ mixture of equal masses of sodium hydrogencarbonate, citric acid and ammonium nitrate dissolved in water ▪ zinc in copper sulfate solution. Students keep record of results as equations and changes in temperature.	NaOH 1 mol dm^{-3}, HCl(aq) 1 mol dm^{-3}, 100 cm^3 beaker, thermometers, balance, 25 cm^3measuring cylinders, $NaHCO_3$, citric acid powder. NH_4NO_3, zinc granules, $CuSO_4$ solution (1 mol dm^{-3})	
3.9.1b	An exothermic reaction is one that transfers energy to the surroundings. Examples of	Students should be able to give examples of exothermic reactions including combustion, many oxidation reactions and		**Discuss:** results leading to two types of reaction exothermic and endothermic, and energy transfer ideas. Students make notes.	VLE/Interactive software, eg energy transfer.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.9.1c	exothermic reactions include combustion, many oxidation reactions and neutralisation. An endothermic reaction is one that takes in energy from the surroundings. Some sports injury packs are based upon endothermic reactions.	neutralisation. Everyday uses of exothermic reactions include self-heating cans (eg for coffee) and hand warmers. Know several exothermic and endothermic reaction uses. Explain self-heating cans / hand warmers, and sports injury packs in simple terms. (No need to recall chemicals or equations for processes).		**Demo:** Uses of heat changes in chemical reactions. Exothermic: ▪ burning fuel (Bunsen burner) ▪ concentrated sulfuric acid and sugar ▪ a thermite reaction ▪ hand warmer (if available). Endothermic: ▪ ammonium nitrate and barium hydroxide. Sports injury pack. Students make brief notes on self-heating warmers and injury packs.		
3.9.1d	In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented as follows:	Explain what is meant by a reversible reaction, and its symbol. Name a reversible reaction.	1	**Task:** Students carry out circus of reversible reactions: ▪ copper sulfate hydration/ dehydration ▪ heating ammonium chloride in a test tube ▪ adding alkali and acid alternately to bromine water or to potassium chromate solution	Test tube, copper sulfate, spatulas, stand and clamp, pipette and 100cm^3 beaker. VLE/Interactive software, eg reversible reactions.	

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	$A + B \rightleftharpoons C + D$ For example: $\text{ammonium chloride} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{ammonia + hydrogen chloride}$			▪ 'blue bottle' reaction (RSC Classic Chemistry Experiments no. 83) ▪ oscillating reaction (RSC Classic Chemistry Experiments no.140). Students make notes on reversible reactions and the meaning of the double headed arrow.		
3.9.1e	If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example: $\text{hydrated copper sulfate (blue)} \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}} \text{anhydrous copper sulfate (white) + water}$	Realise that in a reversible reaction the same energy change takes place in either direction.	1	**Activity:** Students should investigate the temperature changes for the reversible reaction: **Homework:** Students report their experiment.	Copper sulfate, spatula, test tubes, pipettes, and 100 cm^3 beaker.	
3.9.2 Calculating and explaining energy change						
3.9.2a	The relative amounts of energy released when substances burn	Students should be able to calculate and compare the amount of energy released	2	Remind students that burning releases energy, how can we calculate the	Alcohol burners, 250 cm^3 beakers, measuring cylinders, thermometers,	If students are required to convert from

Spec Reference	**Summary of the Specification Content**	**Learning Outcomes** *What most students should be able to do*	**Suggested timing (lessons)**	**Possible teaching and Learning Activities** *Homework*	**Resource**	**Examination 'hints and tips'** *Students should:*
3.9.2b	can be measured by simple calorimetry, eg by heating water in a glass or metal container. This method can be used to compare the amount of energy produced by fuels. Energy is normally measured in joules (J). For comparison purposes, energy values could be given in kJ or calories for a given mass or amount of substance, eg calories per gram, kJ per mole or kJ per gram.	by different fuels given the equation: $Q = mc\,\Delta T$		energy released? Students list likely variables that will have impact including: ▪ mass/ volume of water ▪ temperature rise ▪ how much energy it takes to heat the water by 1^0C Discuss how these link into the equation: $Q = mc\,\Delta T$ **Activity:** Find the amount of energy produced by different alcohols when burned. Suggest alcohol is burned for two minutes, as a control. Two practical groups could do each alcohol, so they can compare their results for reliability, and analyse errors. Students describe their method and results. Students should then use their results to do the calculation and then compare their results with the other group using the same alcohol. Students should discuss causes of error in their method, and understand the importance of control variables. They should jointly produce a list saying how they could improve their control of the variables they identify.	balances and samples of alcohols for the burners, eg methanol, propanol, ethanol and butanol.	calories to joules, the conversion factor should be given in questions.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.9.2c	The amount of energy produced by a chemical reaction in solution can be calculated from the measured temperature change of the solution when the reagents are mixed in an insulated container. This method can be used for reactions of solids with water or for neutralisation reactions.		1	**Activity:** Measuring energy changes in other reactions. Students do neutralisation reaction in expanded polystyrene cup. Measure temperature rise and calculate using: $Q = mc\,\Delta T$ Remind students that energy change is measured in joules. **Discuss:** Class discussion on how to represent the result in the class experiment graphically.	Expanded polystyrene cup, glass rod, measuring cylinders, dilute acid and alkali and a thermometer.	
3.9.2d	Simple energy level diagrams can be used to show the relative energies of reactants and products, the activation energy and the overall energy change of a reaction.	Students will be expected to understand simple energy level diagrams showing the relative energies of reactants and products, the activation energy and the overall energy change, with a curved arrow to show the energy as the reaction proceeds. Students should be able to relate these to exothermic and	1	**Task:** Draw energy level diagram for combustion. **Task:** Students draw their own energy level diagram for their neutralisation reaction. **Homework:** Students are given five energy level diagrams, and they calculate from the y-axis the energy change. At least one should be an endothermic reaction.		Be able to calculate the energy change from an energy level diagram. **Tip:** Subtract the value for the reactant line from the value for the product line. If the value is negative, then the reaction is exothermic,

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
		endothermic reactions.				positive and it is endothermic.
3.9.2h	Catalysts provide a different pathway for a chemical reaction that has a lower activation energy.	Students should be able to represent the effect of a catalyst on an energy level diagram.		**Activity:** What happens when we use a catalyst? Using a catalyst, eg MnO_2 with H_2O_2, simply in terms of rate of reaction. You could instead demonstrate adding copper sulfate to already reacting zinc granules and hydrochloric acid to see rate increase. **Discuss:** The idea of activation energy as a hurdle of energy that the reacting particles have to overcome before collisions become reactions (collision theory link here). **Activity:** Represent the reaction as an energy level diagram, showing the uncatalysed reaction with high activation energy (hurdle), and the catalysed reaction having a lower activation energy (hurdle) to pass.	Test tubes, measuring cylinders, MnO_2 powder, spatula and 20 vol H_2O_2 **Or** $CuSO_4$ powder, conical flask, zinc granules and dilute HCl(aq).	Understand that lowering the activation energy reduces costs in industrial processes.
3.9.2e	During a chemical reaction: ▪ energy must be supplied to break bonds ▪ energy is released	Students should be able to calculate the energy transferred in reactions and interpret simple energy level diagrams in terms of bond breaking and bond	1	Why do chemical reactions have energy changes? Use zinc reacting with hydrochloric acid as example. Make molymods to represent the atoms and molecules in the balanced equation (useful to get students to give	Molymods. $CuSO_4$ powder, conical flask, zinc granules and dilute HCl(aq).	Remember to count every bond as the first step in the calculation. Students should also remember

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	when bonds are formed.	formation (including the idea of activation energy and the effect on this of catalysts).		you the equation first). **Discuss:** The need for energy to break the bonds in hydrochloric acid. Draw energy level diagram showing the atoms separated, then ask if energy is needed to break bonds and what is produced when bonds form? Add products to the energy level diagram to show the reaction is exothermic.		the need to multiply bond energies by the number of each type of bond to get the right answer.
3.9.2f	In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds.	Students should be able to calculate the energy transferred in reactions using bond dissociation energies supplied.		**Task:** Students construct molymods to show breaking bonds and re-forming them, then draw energy level diagram. **Task:** Students explain how they think an endothermic reaction happens, and make notes, and draw energy level diagram.		
3.9.2g	In an endothermic reaction, the energy needed to break existing bonds is greater than the energy released from forming new bonds.			**Explain:** That chemists know how much energy is needed to break a bond between two atoms. Represent how to use these to work out the energy transferred in one reaction, eg: $2 H_2 + O_2 \rightarrow 2H_2O$ **Homework:** For four examples or more, students use bond energies to calculate energy transfer, and if a reaction is endothermic or exothermic (give them the balanced equation).		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.9.3 Chemical cells and fuel cells						
3.9.3a	A chemical cell produces a potential difference until the reactants are used up.		1	**Activity:** Investigate the voltage of simple cells involving two metals and a dilute acid. Allow one cell to run down over time and monitor the voltage. The voltage can also be measured when two different metals are stuck into a lemon or other fruit.	Strips of copper, zinc, magnesium ribbon; dilute sulfuric acid, small beakers, voltmeters.	
3.9.3b	Fuel cells produce electricity through the reaction of a fuel with oxygen. Hydrogen-oxygen fuels cells use hydrogen as their fuel, and are useful in cars and spacecraft. Water is the only waste product from a hydrogen-oxygen fuel cell, so they cause less pollution when in use.	Students should be able to compare the advantages and disadvantages of the combustion of hydrogen with the use of hydrogen fuel cells from information that is provided. Students should know and understand the benefits and disadvantages of hydrogen fuel in terms of: ▪ storage and use ▪ products of combustion. Knowledge of the details of the reactions in fuel cells is not required.	1	**Task:** Students research the advantages and disadvantages of fuel cells with other forms of energy. This could be set as a homework.		

<table>
<tr><th>Spec Reference</th><th>Summary of the Specification Content</th><th>Learning Outcomes
What most students should be able to do</th><th>Suggested timing (lessons)</th><th>Possible teaching and Learning Activities
Homework</th><th>Resource</th><th>Examination 'hints and tips'
Students should:</th></tr>
<tr><td colspan="7">3.10 Organic chemistry</td></tr>
<tr><td colspan="7">3.10.1 Carbon compounds as fuels</td></tr>
<tr><td colspan="7">3.10.1.1 Crude oil</td></tr>
<tr><td>3.10.1 .1a

3.10.1 .1b

3.10.1 .1c</td><td>Crude oil is a mixture of a very large number of compounds.

Most of the compounds in crude oil are hydrocarbons, which are molecules made up of hydrogen and carbon atoms only.

The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is called fractional distillation.</td><td>Know what a mixture is in terms of elements and compounds.

Students should know and understand the main processes in continuous fractional distillation in a fractionating column.

Describe fractional distillation as based on each compound having a different boiling point.

Know that each compound vaporises and condenses at different temperatures, and so they are separated.</td><td>1</td><td>Recap what a mixture is, and explain that crude oil is a mixture.

Demo: Experiment of distillation of crude oil (CLEAPSS recipe), followed by analysis and burning of obtained fractions.

Task: Students make diagram of experiment and chart the results from the demonstration:
<table><tr><td>fraction</td><td>colour</td><td>viscosity</td><td>ease of ignition</td><td>amount of smoke</td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table>
Discuss: Discuss how these properties affect how we use hydrocarbons as fuels, diesel in winter, amount of soot etc. Students make notes.

Discuss: Differences between the demo and fractional distillation as continuous process. Use video.</td><td>Fake crude oil (CLEAPSS/Hazcard recipe), boiling tube with side arm, bung for boiling tube with 0 - 360^{O}C thermometer, side arm, four test tubes, 250cm^3 beaker, four watch glasses, heat mat, matches and spills and fume cupboard.

Molymods or similar. Information and videos of fractional distillation can be found on BBC GCSE Bitesize at www.bbc.co.uk/schools/gcsebitesize

RSC Alchemy disc has a section on Oil Refining. This can also be found at www.rsc.org/Education/Teachers/Resources/Alchemy/index2.htm</td><td>Knowledge of the names of specific fractions or fuels is not required.</td></tr>
</table>

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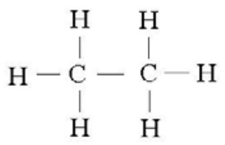
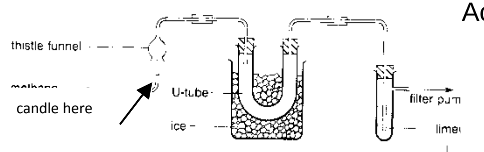
3.10.1.2 Hydrocarbons						
3.10.1 .2c	Some properties of hydrocarbons depend on the size of their molecules. These properties influence how hydrocarbons are used as fuels.	Describe the relationship between molecule size and boiling point, viscosity, ease of ignition, and flammability. Knowledge of trends in properties of hydrocarbons is limited to: ▪ boiling points ▪ viscosity ▪ flammability.	1	Refer back to the table of results from the previous lesson.		
3.10.1 .2a 3.10.1 .2b	Most of the hydrocarbons in crude oil are saturated hydrocarbons called alkanes. The general formula for the homologous series of alkanes is C_nH_{2n+2}. Alkane molecules can be represented in the following forms: C_2H_6 **or**	Students should know that in saturated hydrocarbons all the carbon–carbon bonds are single covalent bonds. Describe what the structural formula shows. Know the general formula for alkanes. Students should know that in displayed structures a —	1	**Demo /Activity:** Name each formula and draw methane, ethane and propane as examples of alkanes in both forms. Show as models. Elicit general formula for alkanes. **Discuss:** the use of a line as representing a single covalent bond. **Task:** Students draw molecular diagrams adding in notes to the diagrams of methane, ethane, and propane as alkanes.	VLE/Interactive software, eg 'organic chemistry' and 'useful organic'. Molymods or similar.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
		represents a covalent bond. Students should be able to recognise alkanes from their formulae in any of the forms, but do **not** need to know the names of specific alkanes other than methane, ethane and propane.				
3.10.1 .2d	Most fuels, including coal, contain carbon and/or hydrogen and may also contain some sulfur. The gases released into the atmosphere when a fuel burns may include carbon dioxide, water (vapour), carbon monoxide, sulfur dioxide and oxides of nitrogen. Solid particles (particulates) may also be released. Solid particles may contain soot (carbon) and unburnt fuels.	Students should be able to relate products of combustion to the elements present in compounds in the fuel and to the extent of combustion (whether complete or incomplete). No details of how the oxides of nitrogen are formed are required, other than the fact that they are formed at high temperatures.	1	**Demo:** Burning a candle, and passing exhaust gases through anhydrous copper sulfate/cooling U tube and cobalt chloride paper, then limewater.  Draw attention to need for control experiment to compare the results. Students label diagram and make results chart. **Note**: Soot formation by incomplete combustion.	Equipment as in diagram. VLE/Interactive software eg, 'useful air' and 'Earth and atmosphere'. Access to internet.	Know that products of combustion depend on the elements present in the fuel (check the formula) and how much oxygen is present. Carbon monoxide is made if there is not enough oxygen present for complete combustion, but really serious shortage of oxygen makes soot (carbon).

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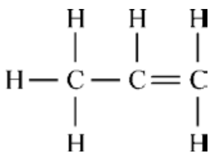
3.10.1 .2e	The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised.					
3.10.1 .2f	Ethanol can be made by reacting ethene with steam. $C_2H_4 + H_2O \rightarrow C_2H_5OH$ Phosphoric acid is used as a catalyst to increase the rate of the reaction. This is efficient because it is a continuous process. However, ethene is a non-renewable resource which may run out one day. Ethanol can also be made by fermenting sugar: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ Enzymes in yeast are natural catalysts for	Students should be able to compare the two ways of making ethanol in terms of type of raw material, type of process, labour, rate of reaction, conditions needed, purity of product and energy requirements. Students should know that ethanol for use as a biofuel is produced from a dilute solution of ethanol obtained by the fermentation of plant materials at a temperature between 20 °C and 35 °C. Detailed knowledge of the methods used to produce other biofuels is not required. Students should know and understand the benefits	2	**Discuss:** Evaluate the advantages and disadvantages of making ethanol from renewable and non-renewable sources. **Homework:** Past paper questions/ worksheet on advantages and disadvantages of making ethanol from renewable and non-renewable sources. **Activity:** Making ethanol with yeast. (You could start the culture and in the second lesson distil the ethanol.) Students make notes on fermentation and distillation.	Sugar, yeast, limewater, 250 cm^3 conical flask and bung with delivery tube. test tube, distillation apparatus VLE/Interactive software, eg organic chemistry.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.10.1 .2g	this reaction, and this is a batch process. Unlike ethene, sugar is a renewable resource. Biofuels, including biodiesel and ethanol, are produced from plant material, and are possible alternatives to hydrocarbon fuels.	and disadvantages of biofuels in terms of: ▪ use of renewable resources ▪ their impacts on land use ▪ their carbon footprint.				
3.10.1.3 Obtaining useful substances from crude oil						
3.10.1 .3a	Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules. This process involves heating the hydrocarbons to vaporise them. The vapours are either passed over a hot catalyst or mixed with steam and heated to a very high temperature so that thermal decomposition reactions then occur.	Recall that heating large alkanes with a catalyst or steam and hot temperature decomposes to make the hydrocarbon smaller molecules. Know that some of these smaller molecules are called alkenes.	1	**Task:** List five products from crude oil, and ask how we get enough of each of them. It is interesting to tell students that 100 years ago petrol was a waste product, but now we can't get enough of it! **Demo:** Demonstrate cracking or use video to show process of cracking. Students make notes. **Explain:** That cracking makes larger molecules into smaller, more useful ones, including a group of compounds called alkenes. **Task:** Students draw diagrams to explain cracking.	VLE/Interactive software, eg organic chemistry. You can find a variety of resources including video clips on the RSC website at www.rsc.org/Education/Teachers/Resources/Alchemy/index.htm VLE/Interactive software, eg organic chemistry.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.10.1 .3b	The products of cracking include alkanes and unsaturated hydrocarbons called alkenes. The general formula for the homologous series of alkenes is C_nH_{2n}.	Students should know that in unsaturated hydrocarbons some of the carbon–carbon bonds are double covalent bonds.				Be able to recognise 'n' alkene by the double bond in its structure, or that the name ends in –'ene'.
3.10.1 .3c 3.10.1 .3d	Unsaturated hydrocarbon molecules can be represented in the following forms: C_3H_6 or  Alkenes react with bromine water, turning it from orange to colourless.	Students should know that '=' represents a double bond in the structure. Students should be able to recognise alkenes from their names or formulae, but do not need to know the names of individual alkenes other than ethene and propene. Know that the presence of double bonds in a molecule can be tested for by the decolourisation of bromine water.	2	**Discuss:** Introduce idea of double bond using structural formula of ethene and propene. **Required practical:** Test for the presence of a double bond in an unknown hydrocarbon. **Activity:** Class practical testing for double bonds using bromine water. Students should test a range of named alkenes and alkanes. Students make notes. **Homework:** Students predict reactions of a variety of molecules displaying single and double bonds with bromine water.	Molymods. Bromine water, test tubes, test tube racks, liquid alkanes, eg pentane, hexane, liquid alkenes, eg hexene, cyclohexene.	Remember that '=' means a double covalent bond, and that '–' means a single covalent bond. A double bond means that the compound is unsaturated. A single bond means that the compound is saturated.

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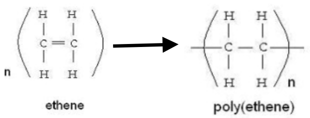
3.10.1 .3e 3.10.1 .3f	Some of the products of cracking are useful as fuels. Ethanol can be produced by reacting ethene with steam in the presence of a catalyst.	Know that cracking produces more useful molecules including alkenes and fuels.		**Explain:** Show with models how breaking large molecules produces not only alkenes, but also more fuels like petrol (octane) and diesel (dodecanes). **Task:** Students draw diagrams to explain the above.		
3.10.2 Synthetic and naturally occurring polymers						
3.10.2 a	Alkenes can be used to make polymers such as poly(ethene) and poly(propene). In polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers). For example: 	Students should be able to recognise the molecules involved in these reactions in the forms shown in the subject content. They should be able to represent the formation of a polymer from a given alkene monomer. Further details of polymerisation are **not** required.	1	**Demo:** Making Perspex. Use molecular models to demonstrate how polymers form. Class make own polymer chain by: ▪ each student making a monomer either with model or drawn onto front of paper chain piece. ▪ two students joining their monomer together and drawing on back structure at the joining. ▪ groups joining together to make long chain with monomer structure on front of each piece of paper and polymer structure on rear of chain. Students draw diagrams to explain ethene polymerisation.	Molymods. Paper chain pieces (use waste paper) and marker pens. VLE/Interactive software, eg organic chemistry. RSC Alchemy disc has section on poly(ethene). Further information can be found at www.rsc.org/Education/Teachers/Resources/Alchemy/index2.htm	**Note**: Although students will probably know the names of some common polymers, these are **not** required knowledge, unless they are included in the subject content for this section. Students only need to learn the basic polymerisation of

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				Homework: Students to draw diagrams showing propene polymerisation.		ethene, as the propene simply changes one H atom for a CH_3 group.
3.10.2 b	The properties of polymers depend on what 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 using different catalysts and reaction conditions.	Know that: ▪ LD polythene and HD poly(ethene) are made using different catalysts and conditions ▪ the differences in polymers' properties depend on the monomer used and also the conditions under which they are made, as these influence the type of structure produced.	1	Review ideas of polymers. Show examples of polymers or use circus on properties such as transparency, flexibility, stretching etc. Including LD and HD poly(ethene). Ask what causes these differences. **Activity:** Identifying LD and HD poly(ethene) using 50 parts ethanol and 50 parts water mix. **Discuss:** a variety of possible monomers, and refer to the differences as being due to the structure achieved when the different monomers polymerise. Students make notes.	Selection of polymers with different properties including LD and HD poly(ethene).	Be able to explain why the structure gives the property or vice versa.
3.10.2 c	Thermosoftening polymers consist of individual, tangled polymer chains. Thermosetting polymers consist of polymer chains with cross-links between	Students should be able to explain thermosoftening polymers in terms of intermolecular forces.	1	**Demo:** Show that there are two types of polymers, thermosetting and thermosoftening polymers, by heating in a fume cupboard. Students can see which of a number of common polymers belong to each group. **Task:** Students report their experiment. Students suggest possible	A video on the properties of plastics can be found on the BBC website at www.bbc.co.uk/learningzone/clips by searching for clip '903'. More information on poly(ethene) can be found	

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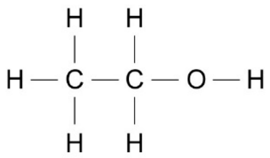
	them so that they do not melt when they are heated.			uses for polymers based on their properties. **Explain:** Develop explanation of the difference in the polymers' behaviour in terms of structure. Students make notes.	on the RSC Alchemy website www.rsc.org/Education/Teachers/Resources/Alchemy/index2.htm	
3.10.2 d	Polymers have many useful applications and new uses are being developed. Example include: new packaging materials, waterproof coatings for fabrics, dental polymers, wound dressings, hydrogels and smart materials (including shape memory polymers)	Students should consider the ways in which new materials are being developed and used, but will not need to recall the names of specific examples. Know that we use a wide range of polymers developed for specific purposes. Identify from properties relevant uses for a polymer.	2	**Activity:** Choose from ▪ making a polymer from cornstarch ▪ testing a polymer's strength, eg plastic carrier bag testing strength to breaking point (not a Hooke's Law investigation) ▪ testing waterproofing of different polymer fabrics ▪ investigating the amount of water absorbed by hydrogels. Students plan and report their investigation.		
3.10.2 e	Many polymers are not biodegradable, ie they are not broken down by microbes. This can lead to problems with waste disposal.	Realise that polymers are often hard to dispose of, and that biodegradable ones offer some solutions to these problems.		**Discuss** polymer developments, and waste disposal issues. **Activity**: Make notes on need for disposal of plastics via recycling and biodegradability rather than landfill. Advantages and disadvantages of each disposal method.		
3.10.2 f	Plastic bags are being made from polymers	Knowledge of specific named examples is **not**				

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	and cornstarch so that they break down more easily. Biodegradable plastics made from cornstarch have been developed.	required, but students should be aware of the problems that are caused in landfill sites and in litter.		**Homework:** Recycling plastics – give two advantages and two disadvantages of recycling plastics.		
3.10.3 Organic compounds – their structure and reactions						
3.10.3.1 Alcohols						
3.10.3 .1a	Alcohols contain the functional group –OH. Methanol, ethanol and propanol are the first three members of a homologous series of alcohols. Alcohols can be represented in the following forms: CH_3CH_2OH or	Students should be able to recognise alcohols from their names or formulae, but do **not** need to know the names of individual alcohols other than methanol, ethanol and propanol.	1	**Activity:** Name these compounds: Diagrams of CH_4, C_2H_6, C_3H_8. Produce a blank chart (like the one below) only showing the headings for each column (shown in bold). Complete the first three columns with students. Leave the 'alcohol name' column until the task listed below. **number of carbon atoms in molecule** / **start to name** / **alkane name** / **alcohol name** 1 / meth / methane / methanol 2 / eth / ethane / ethanol 3 / prop / propane / propanol Use molymods to make structures of each alkane.	Molymods.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				**Task:** Students to draw structural formulae of methane, ethane and propane in the left hand side of their books. Students name the alcohols and complete the rest of the chart. **Explain:** Show students molymods of both methane and methanol. Students should spot the differences and then draw methanol structure alongside methane, and write formula. **Task:** Students should draw what they think ethanol and propanol will look like, and write their formulae, again alongside the alkane. Review using Molymods to check answers. **Task:** Draw out idea of homologous series, by using models of all three alcohols to show that the formulae only changes by the addition of CH_2 to each successive molecule. **Homework:** Predict formulae and draw structures for alcohols with 5, 6, 7 and 8 carbon atoms (only show straight chain molecules).		

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3.10.3 .1b	Methanol, ethanol and propanol: ▪ dissolve in water to form a neutral solution ▪ react with sodium to produce hydrogen ▪ burn in air ▪ are used as fuels and solvents, and ethanol is the main alcohol in alcoholic drinks.	Describe key reactions of alcohols, and why alcohols are useful.	2	**Discuss:** Why are alcohols useful to us? **Demo:** To show: ▪ alcohols dissolve in water to give a neutral solution ▪ reactions of alcohols with sodium or magnesium produce hydrogen gas ▪ that they burn in air ▪ solvent effect, eg on grass stains. Add acidified potassium dichromate solution to some dilute ethanol solution until next lesson. **Demo:** Of 50:50 ethanol/water mixtures burning without damaging paper. Soak old book/notepad in 50:50 ethanol water, place in enamel tray, and set it alight. Let it burn for two minutes so the flames can be seen, then put heat proof mat over the top to extinguish fire. Retrieve book/notepad and show it is damp, but undamaged. Students report the experiment and write symbol equation for combustion of ethanol with air. Mention use of ethanol as a drink. Mention it is mildly poisonous and this is why it is intoxicating, whilst others are highly poisonous.	Methanol, ethanol, propanol, sodium, distilled water, universal indicator, grass stained fabric, crucibles.	**Note:** Students do **not** need to write balanced chemical equations for the reactions of alcohols other than combustion reactions.

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
				Homework: Write and balance equations for the burning of methanol and propanol in air.		
3.10.3 .1c	Ethanol can be oxidised to ethanoic acid, either by chemical oxidising agents or by microbial action. Ethanoic acid is the main acid in vinegar.	Students should be aware that vinegar is an aqueous solution that contains ethanoic acid.		**Activity:** Ask students to safely smell some ethanol, and then the flask with ethanoic acid in from last lesson. Ask students what has happened, and to tell you what has been made. **Discuss:** The oxidation of ethanol to ethanoic acid, and use molymods to show what has happened to the molecule of ethanol as it has been oxidised. Students should explain why brewing wine and beer need to ferment without oxygen present.		**Note:** Students do **not** need to write balanced chemical equations for the reactions of carboxylic acids.
3.10.3.2 Carboxylic acids						
3.10.3 .2a	Ethanoic acid is a member of the homologous series of carboxylic acids, which have the functional group –COOH The structures of carboxylic acids can be represented in the following forms:	Students should be able to recognise carboxylic acids from their names or formulae, but do **not** need to know the names of individual carboxylic acids other than methanoic acid, ethanoic acid and propanoic acid.	1	**Task:** Students can now draw the structure and formula of ethanoic acid. Students name carbon-based compounds, and then draw or make methanoic acid and propanoic acid.		

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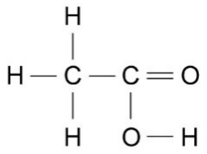
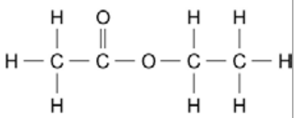
	CH_3COOH or 					
3.10.3 .2b	Carboxylic acids: ▪ dissolve in water to produce acidic solutions ▪ react with carbonates to produce carbon dioxide ▪ react with alcohols in the presence of an acid catalyst to produce esters ▪ do not ionise completely when dissolved in water and so are weak acids ▪ aqueous solutions	Students are expected to write balanced chemical equations for the reactions of carboxylic acids.	2	**Demo:** To show: ▪ carboxylic acids dissolve in water to form acidic solutions ▪ sodium carbonate produces CO_2 gas. **Discuss**: Carboxylic acids react like acids, but have a higher pH, and so are weaker acids. This is why it is safe to use vinegar in cooking but not hydrochloric acid. **Activity:** Test dilute ethanoic acid with indicator paper, sodium hydrogencarbonate (and test the gas produced) and magnesium ribbon (and test the gas produced). Students make notes on these reactions, and use equations.	Test tubes, ethanoic acid, pipettes, sodium hydrogencarbonate, spatula, indicator paper, wooden splints and limewater. Test tubes, ethanoic acid, ethanol, concentrated H_2SO_4, pipettes, sodium hydrogencarbonate, spatula and indicator paper.	

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
	of weak acids have a higher pH value than aqueous solutions of strong acids with the same concentration.			Explain properties of carboxylic acids: ▪ They are not fully ionised so only make weak acids in water. You may want to show them how the molecule dissociates here to produce H+ ions. ▪ Their pH is higher (less acidic) than other acids students may be familiar with. **Demo:** Mix equal quantities of ethanol and ethanoic acid in test tubes. Add three drops of concentrated H_2SO_4(aq). Leave to stand for 10 minutes, add spatula of sodium hydrogencarbonate to neutralise the acid, then ask students to safely smell it. Pour mixture into a beaker of water and ask students to smell it again, to show water helps carry the scent. Whilst waiting, produce molymods of ethanoic acid and ethanol. Tell students that the two react together to make one molecule of a compound we call an ester, and a molecule of water.		

Spec Reference	Summary of the Specification Content	Learning Outcomes *What most students should be able to do*	Suggested timing (lessons)	Possible teaching and Learning Activities *Homework*	Resource	Examination 'hints and tips' *Students should:*
3.10.3.3 Esters						
3.10.3.3a	Esters have the functional group –COO– The structures of esters can be represented in the following forms: $CH_3COOCH_2CH_3$ or  Ethyl ethanoate is the ester produced from ethanol and ethanoic acid. $C_2H_5OH + C_2H_5COOH \rightarrow C_2H_5COOC_2H_5 + H_2O$ Ethanol Ethanoic acid Ethyl ethanoate water	Students will **not** be expected to give the names of esters other than ethyl ethanoate, but should be able to recognise a compound as an ester from its name or its structural formula.	1	Students make notes on uses of esters for perfumes and flavourings. Explain to students that milk goes slightly 'fruity' before it goes off because esters are produced in the milk by bacteria.		
3.10.3.3b	Esters are volatile compounds with distinctive smells and are used as flavourings and perfumes.					