OXFORD
INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL AS LEVEL CHEMISTRY

(9620)

OUTLINE SCHEME OF WORK

For teaching from September 2016 onwards
For AS exams in June 2017 onwards

CONTENTS

INTRODUCTION

This scheme of work has been prepared by teachers for teachers. We hope you will find it a useful starting point for producing your own schemes.

The scheme of work is designed to be a flexible medium term plan for the teaching of content and development of the skills that will be assessed. It covers the needs of the specification for the International AS units of Chemistry 9620.

The teaching of investigative and practical skills is embedded within the specification. We are producing a practical handbook that provides further guidance on this. There are also opportunities in this scheme of work, such as the inclusion of rich questions.

We have provided links to some resources. These are illustrative and in no way an exhaustive list. We would encourage teachers to make use of any existing resources, as well as resources provided by Oxford AQA Examinations (OxfordAQA) and new textbooks written to support the specification. Please note there maybe access restrictions to certain websites from certain countries.

Within the Scheme of work we have identified the prior knowledge a student would find beneficial to have covered. This knowledge could be gained from following the new International GCSEs or if the student had previously followed Core and Additional Science courses. In some instances knowledge from more than one separate science is needed.

We know that teaching times vary from school to school. In this scheme of work we have made the assumption that it will be taught over about 30 weeks with 4½ to 5 hours of contact time per week. Teachers will need to fine tune the timings to suite their own students and the time available. It could also be taught by one teacher or by more than one teacher with topics being taught concurrently.

The **assessment opportunities** column details AQA past paper questions that have been mapped to this new OxfordAQA qualification and are available through the International Exampro from early 2016. Of course there are also Sample Assessment Materials for download at oxfordaqaexams.org.uk/9620

SCHEME OF WORK

3.1 Physical Chemistry

This could be taught alongside topics from Organic and/or Inorganic Chemistry. Prior knowledge required from other topics on the specification will be highlighted at the start of each section of the Scheme of work. Many centres that use two teachers teach topics 3.1.1 Atomic Structure and 3.1.3 Bonding alongside 3.1.2 Amount of Substance at the start of the course.

3.1.1 Atomic structure

The chemical properties of elements depend on their atomic structure and in particular on the arrangement of electrons around the nucleus. The arrangement of electrons in orbitals is linked to the way in which elements are organised in the Periodic Table. Chemists can measure the mass of atoms and molecules to a high degree of accuracy in a mass spectrometer. The principles of operation of a modern mass spectrometer are studied.

Prior knowledge:

International GCSE Chemistry
- The structure of atoms (although this is revisited here).

International GCSE Physics
- The structure of atoms (although this is revisited here).
- The effect of a force on moving objects.
- The effect of a magnetic field on a moving, electrically charged particle (Separate Science)

3.1.1.1 Fundamental particles

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The structure of atoms.	0.2 week	**Students should be able to:** • appreciate that knowledge and understanding of atomic structure has evolved over time • describe the structure of atoms in terms of protons, neutrons and electrons • recall the relative mass and relative charge of protons, neutrons and electrons.	• Students could research how the model of the atom changed over time (examples of key contributions could include the Ancient Greeks, Dalton, Thompson, Rutherford, Bohr, Chadwick). • Rich question – How can we tell what is inside an atom if we can't see it?		RSC: Chemists in a social and historical context: rsc.org/learn-chemistry/resource/res00001332/the-atom-detectives?cmpid=CMP00002843 RI Christmas Lecture – section on atomic structure rsc.org/learn-chemistry/resource/res00001119/ri-christmas-lectures-2012-atomic-structure

3.1.1.2 Mass number and isotopes

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
To define atoms and ions in terms of protons, neutrons and electrons. Explain the existence of isotopes. How a time of flight (TOF) mass spectrometer works and some of its simple uses.	0.4 weeks	**Students should be able to:** • define atoms and ions in terms of numbers of protons, neutrons and electrons, as well as atomic number and mass number (including isotopes) • describe how a time of flight mass spectrometer works • identify elements and calculate relative atomic mass from mass spectroscopy data • find the relative formula mass of compounds from mass spectroscopy data.	• Students identify atoms and ions from numbers of protons, neutrons and electrons, and vice versa. • Students determine the relative atomic mass of elements using isotope abundance data (this could include data for elements found in meteorites to show some difference) quoting answers to a suitable number of significant figures for data provided. • Students look at the mass spectra of compounds to determine the relative formula mass.	• SAMS AS Paper 1 Q2 • June 2013 Unit 1 Question 1abcf (QS13.1.01) • January 2012 Unit 1 Question 7a (QW12.1.07) • June 2010 Unit 1 Question 8ab (QS10.1.8A)	RSC: Build an atom simulation: rsc.org/learn-chemistry/resource/res00001433/build-an-atom-simulation-rsc-funded Isotope data: chem.ualberta.ca/~massspec/atomic_mass_abund.pdf Data on isotopes in meteorites: 'The Elements: Their Origin, Abundance, and Distribution' by P. A. Cox
Extension			Students investigate the use of mass spectroscopy in drug testing athletes.		

3.1.1.3 Electron configuration

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Describe the electron structure of atoms and ions. Define and write equations for ionisation energy. Explain how ionisation energy data provides evidence for electron structure.	0.5 weeks	**Students should be able to:** • give the electron structure of atoms and ions up to Z=36 in terms of s, p and d sub-shells • write equations for first and successive ionisation energies • explain how data from ionisation energies in Period 3 and in Group 2 provides evidence for electron structure.	• Students write the electron structure of atoms and ions with Z=1 to 36 • Students research values of first ionisation energies for elements Z=1 to 36 and plot them on a graph and then explain trends. • Students write explanations for trends in ionisation energies down a Group and across a period. • Students determine which Group an element is in using successive ionisation energy data.	• January 2012 Unit 1 Question 5ab (QW12.01.05) • June 2013 Unit 1 Question 6bcd (QS13.01.06) • January 2010 Unit 1 Question 1 (QW10.01.01) • June 2009 Unit 1 Question 1ab (QS09.01.01) • January 2002 Unit 1 Question 4d (QW02.01.04)	Orbitron (shows shapes of orbitals): winter.group.shef.ac.uk/orbitron/ Ionisation energy data (1st and successive) wikipedia.org/wiki/Molar_ionization_energies_of_the_elements

3.1.2 Amount of substance

When chemists measure out an amount of a substance, they use an amount in moles. The mole is a useful quantity because one mole of a substance always contains the same number of entities of the substance. An amount in moles can be measured out by mass in grams, by volume in dm^3 of a solution of known concentration and by volume in dm^3 of a gas.

Prior knowledge:

International GCSE Chemistry

- Relative atomic mass, relative molecular mass, relative formula mass (although this is revisited here)
- Writing formulae (elements, common compounds and ionic compounds)
- Balancing equations (although this is revisited here)
- Moles (although this is revisited here)
- Calculations involving Masses (although this is revisited here)
- Concentration of solutions (Separate Science - although this is revisited here)
- Empirical and molecular formulae (although this is revisited here)

3.1.2.1 Relative atomic mass and relative molecular mass

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Relative mass of atoms, elements and compounds.	0.1 week	**Students should be able to:** • define relative atomic mass (A_r) • define relative molecular mass (M_r) • determine relative molecular mass (M_r) of a substance using relative atomic mass (A_r) values.	• Calculate the relative mass of different substances from the formula. • The mass of everyday objects could be measured relative to a specific object of known mass. • Determine the relative formula mass (M_r) of substances using relative atomic mass values.	• Students can calculate M_r given the formula of compounds.	Suitable resources can be found at docbrown.info
Extension			• Students could research why ^{12}C was chosen as the standard.		

3.1.2.2 The mole and Avogadro constant

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Calculations using moles for solids and solutions.	1 week	**Students should be able to carry out calculations:** • using the Avogadro constant • using mass of substance, M_r, and amount in moles • using concentration, volume and amount of substance in a solution.	• Students calculate the mass (in g) of atoms/ions using the mass' sub atomic particles, quoting answers to a suitable number of significant figures for data provided • Practical opportunity: Students measure out 1 mole (and other mole quantities) of different substances (eg sucrose, salt, water) • Students practice doing calculations involving Avogadro constant, involving mass, M_r and moles, and involving concentration, volume and amount of substance and quoting the final results to the appropriate number of significant figures for data provided. • Students find the concentration of NaCl in intravenous saline (9g per dm^3), glucose in isotonic sports drinks (17g in $500cm^3$) and other similar calculations for everyday solutions.	• Calculating the mass (in g) of atoms/ions using the mass' sub atomic particles to 5 sf. • Calculations linking mass, M_r and moles. • Calculations linking volume, moles and concentration. • Calculations to determine the mass of a substance needed to produce a set volume of a solution with a pre-determined concentration. • Calculations to determine the concentration of a solution when a set mass is dissolved in a set volume.	Many suitable calculations can be found at docbrown.info

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
				• Calculations using Avogadro's number to determine the number of particles in a solution or given mass.	
Extension			Students research how Avogadro determined the value of his constant.		

3.1.2.3 The ideal gas equation

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Perform calculations using the ideal gas equation.	0.8 week	**Students should be able to carry out calculations:** • using the ideal gas equation.	• Students will need to rearrange the ideal gas equation, work in appropriate units and quote answers to an appropriate number of significant figures. • Practical Opportunity: Students find the M_r of a volatile liquid. • Students find the mass of argon inside a gas cylinder (23 MPa pressure, 146 x 23 cm dimensions).	• June 2006 Unit 1 Question 3 (QS06.1.03) • June 2005 Unit 1 Question 2b (QS05.1.02) • January 2005 Unit 1 Question 2b (QW05.1.02) • January 2004 Unit 1 Question 4a (QW04.1.04)	Finding M_r of butane: nuffieldfoundation.org/practical-chemistry/determining-relative-molecular-mass-butane Data on gas cylinders: boconline.co.uk/en/index.html Many suitable calculations can be found at docbrown.info
Extension			Students investigate the link between the gas laws and the ideal gas equation; (they could also research how the behaviour of real gases deviates from ideal gas behaviour although this is beyond the specification).		

3.1.2.4 Empirical and molecular formula

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Calculate empirical and molecular formulae from data	0.6 week	**Students should be able to:** • explain the difference between empirical and molecular formulae • carry out calculations • find empirical formula from data giving composition by mass or percentage by mass • find molecular formula from the empirical formula and relative molecular mass.	• Practical Opportunity: Students find the empirical formula of a metal oxide (eg magnesium oxide or copper oxide) • Students find empirical formulae (and molecular formulae where relevant) from data.	• June 2010 Unit 1 Question 4a (QS10.1.04) • June 2009 Unit 1 Question 2c (QS09.1.02)	Finding empirical formula of copper oxide nuffieldfoundation.org/practical-chemistry/finding-formula-copper-oxide Many suitable calculations can be found at docbrown.info
Extension			Students look at some further information about elemental microanalysis using the RSC resource (this is beyond the specification but relevant).		RSC resource on elemental microanalysis: nationalstemcentre.org.uk/elibrary/resource/9890/elemental-microanalysis

3.1.2.5 Balanced equations and associated calculations

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources

To write balanced full and ionic equations.
 	
To use equations to calculate masses, percentage yields, percentage atom economies, volumes of gases, concentrations and volumes of solutions.
 	
To understand the importance of processes having a high percentage atom economy for society and industry.
 	
Required practical 1
Make up a volumetric solution and carry out a simple acid–base titration.
	2 weeks	**Students should be able to:**
		• write balanced equations
		• write ionic equations
		• carry out calculations for reactions involving:
		  • masses,
		  • percentage yields,
		  • percentage atom economies,
		  • volumes of gases,
		  • concentrations and volumes of solutions,
		• give economic, ethical and environmental advantages for society and industry of processes with a high atom economy.
			• Students balance equations, including ones where formulae are given and some where they are not.
			• Students write ionic equations from given equations.
			• Students practise calculations to find masses, percentage yields, percentage atom economies, volumes of gases, concentrations and volumes of solutions.
			• Practical Opportunity: the yield for the conversion of magnesium to magnesium oxide.
			• Practical Opportunity: Students find the M_r of a hydrated salt (eg copper sulfate or magnesium sulfate) by heating to constant mass
			• Practical Opportunity: Students find the percentage conversion of a Group 2 carbonate to its oxide by heat.
			
			• **Required practical 1** - Make up a volumetric solution and carry out a simple acid–base titration
				• January 2011 Unit 1 Question 3 (QW11.1.03)
				• June 2010 Unit 1 Question 3 (QS10.1.03)
				• January 2009 Unit 1 Question 5 (QW09.1.05)
				• June 2004 Unit 1 Question 2 (QS04.1.02)
				• January 2004 Unit 1 Question 3 (QW04.1.03)
				• January 2002 Unit 1 Question 7 (QW02.1.07)
				• January 2009 Unit 1 Question 3
					Finding the M_r of a hydrated salt: nuffieldfoundation.org/practical-chemistry/finding-formula-hydrated-copperii-sulfate
					
					Many suitable calculations and practical activities can be found at docbrown.info
					
					Chemistry Review article: Atom Economy (Volume 19, edition 2)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			• Practical Opportunity: Students perform titration to analyse many substances, including many everyday substances : • the concentration of ethanoic acid in vinegar • the mass of calcium carbonate in an indigestion tablet • the Mr of a group 2 hydrogencarbonate • the Mr of succinic acid • Analysis of coffee descaler • the mass of aspirin in an aspirin tablet.		

3.1.3 Bonding

The physical and chemical properties of compounds depend on the ways in which the compounds are held together by chemical bonds and by intermolecular forces. Theories of bonding explain how atoms or ions are held together in these structures. Materials scientists use knowledge of structure and bonding to engineer new materials with desirable properties. These new materials may offer new applications in a range of different modern technologies.

Prior knowledge:

International GCSE Chemistry

- Structure and bonding (re-visited here)

3.1.3.1 Ionic bonding

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand ionic bonding. Write formulas of ionic compounds.	0.2 weeks	**Students should be able to:** • describe the structure of ionic compounds • explain the properties of ionic compounds using an understanding of ionic bonding • predict the formula of simple ions based on the position of the element in the Periodic Table and knowledge of common compound ions, eg sulphate, hydroxide, nitrate, carbonate, ammonium • write the formula of ionic compounds.	• Students explain the properties of ionic compounds. • Students write the formula of ionic compounds, including those with common compound ions. • Rich question: Which of the following ionic compounds have the highest and lowest melting points: sodium chloride, potassium chloride; magnesium chloride – explain your reasoning?	• Write the formula of ionic compounds • January 2012 Unit 1 Question 5 (QW12.1.05)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510

3.1.3.2 Nature of covalent and dative covalent bonds

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand covalent bonding, including co-ordinate bonds. Draw molecules with lines/arrows showing covalent/co-ordinate bonds.	0.4 weeks	**Students should be able to:** • describe the nature of covalent bonds, including co-ordinate and multiple bonds • represent molecules by diagrams where lines represent each covalent bond, with an arrow to represent a co-ordinate bond • describe the structure of molecular substances • explain the properties of molecular substances.	• Students describe differences between ionic and covalent bonding. • Students describe similarities and differences between covalent and co-ordinate bonds. • Students draw diagrams of molecules showing covalent and co-ordinate bonds as lines/arrows respectively ('stick' diagrams). • Students explain the properties of molecular substances. • Rich question: The ammonium ion has three covalent N-H bonds and one co-ordinate N-H bond – how does the strength of the covalent bonds compare to the co-ordinate bond – explain your reasoning?	• Draw 'stick' diagrams of molecules.	

3.1.3.3 Metallic bonding

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand metallic bonding.	0.2 weeks	**Students should be able to:** • describe the nature of metallic bonding • describe the structure of metals • explain the properties of metals.	• Students describe differences between metallic, ionic and covalent bonding. • Students explain the properties of metals. • Rich question: Which metals have the highest and lowest melting points – sodium, potassium, magnesium – explain your reasoning?		Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510

3.1.3.4 Bonding and physical properties

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the structure of ionic, molecular, giant covalent and metallic substances. Describe and sketch details of the structures of diamond, graphite, ice, iodine, magnesium and sodium chloride.	1 week	**Students should be able to:** • describe and explain the properties of ionic, molecular, giant covalent and metallic substances, in terms of melting/boiling points and conductivity • describe in detail and draw the structures of diamond, graphite, ice, iodine, magnesium and sodium chloride.	• Practical opportunity: investigate the melting point, (solubility) and conductivity of substances with different structure types. • Students create a summary table to describe and explain the structure and properties of ionic, molecular, giant covalent and metallic substances. • Students sketch the structures of diamond, graphite, ice, iodine, magnesium and sodium chloride as solids and label the diagrams to explain their melting/boiling points and conductivity. • Students determine which type of structure a substance has from its properties using data and/or experimentally (eg to test *solubility,* conductivity and ease of melting.)	• June 2013 Unit 1 Question 3 (QS13.1.03) • June 2011 Unit 1 Question 4 (QS11.1.04) • June 2010 Unit 1 Question 7 (QS10.1.07) • June 2006 Unit 1 Question 2 (QS06.1.02) • January 2006 Unit 1 Question 6 (QW06.1.06) • January 2005 Unit 1 Question 5A (QW05.1.05A) • January 2003 Unit 1 Question 1e(QW03.1.01)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 *Chemistry Review* article: Graphene (Volume 19, edition 2) *Chemistry Review* article: The disguises of carbon (Volume 18, edition 1)

3.1.3.5 Shapes of simple molecules and ions

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Work out, name and sketch the shape of molecules and ions. Explain why molecules and ions have the shapes that they have.	0.6 week	**Students should be able to:** • work out, name and sketch the shape of molecules and ions with up to six electron pairs surrounding the central atom, including bond angles • explain using VSEPR theory why molecules and ions have the shapes that they do, including the effect on the bond angles of the great repulsion by lone (non-bonding) pairs.	• Make models of molecular shapes. • Use balloons to represent electron pairs to demonstrate shapes. • Deduce, sketch and name the shapes of given molecules and ions, including bond angles with up to 6 electron pairs.	• June 2011 Unit 1 Question 3 (QS11.1.03) • January 2010 Unit 1 Question 6 (QW10.1.06) • June 2006 Unit 1 Question 5B (QS06.1.05B) • June 2005 Unit 1 Question 4 (QS05.1.04)	Molymod molecular models RSC exercise on VSEPR theory: rsc.org/learn-chemistry/resource/res00000648/shapes-of-molecules-and-ions

3.1.3.6 Bond polarity

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Definition of electronegativity. How polar covalent bonds originate and deducing whether a bond is polar. How polar molecules originate and deducing whether a molecule has a permanent dipole.	0.4 week	**Students should be able to:** • define and understand the concept of electronegativity • understand why some covalent bonds are polar and deduce whether a bond is polar • understand why some molecules are polar and deduce whether a molecule has a permanent dipole.	• Predict and explain the trend in electronegativity down a Group and across a period. • Predict whether covalent bonds are polar or not. • Predict whether molecules have permanent dipoles or not.	• January 2013 Unit 1 Question 3 (QW13.1.03) • June 2004 Unit 1 Question 6A (QS04.1.06A)	Molymod molecular models.

3.1.3.7 Forces between molecules

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The three types of intermolecular force: induced dipole forces, permanent dipole-dipole forces; and hydrogen bonds. How melting and boiling points of molecular substances depend on the relative strength of intermolecular forces. The impact of hydrogen bonding on the density of ice and melting/boiling points.	0.4 week	**Students should be able to:** • understand that there are three types of intermolecular force • explain how each of the intermolecular forces arise • explain how the melting points and boiling points are influenced by these intermolecular forces • explain the anomalous nature of ice and how its low density can be explained through a knowledge of hydrogen bonding.	• Students produce a summary to compare the three types of intermolecular force. • Students explain trends in Group 4, 5, 6 and 7 hydrides (to show relative strength of the three types of force and the effect of M_r on induced dipole forces). • Practical opportunity: Students could try to deflect jets of various liquids from burettes to investigate the presence of different types and relative size of intermolecular forces. • Students explain why ice floats on water by reference to hydrogen bonding.	• June 2013 Unit 1 Question 4 (QS13.1.04) • January 2012 Unit 1 Question 1 (QS12.1.01) • June 2011 Unit 1 Question 3 (QS11.1.03) • January 2011 Unit 1 Question 1 (QW11.1.01) • January 2010 Unit 1 Question 3 (QW10.1.01) • June 2005 Unit 1 Question 5 (QS05.1.05) • June 2004 Unit 1 Question 6b (QS04.01.06)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 RSC AfL exercise on hydrogen bonding: rsc.org/learn-chemistry/resource/res00000129/afl-what-are-hydrogen-bonds-and-where-are-they-found *Chemistry Review* article: All things Ice (Volume 22, edition 3)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
					RSC Kitchen Chemistry: The Structure of Ice and Water rsc.org/learn-chemistry/resource/res00000813/kitchen-chemistry-the-structure-of-ice-and-water *Chemistry Review* article: Gecko glue (Volume 21, edition 1)
Extension			Rich question – Why is there no hydrogen bonding between molecules of HCl gas even though Cl is more electronegative than N yet NH_3 has hydrogen bonding?		

3.1.4 Energetics

The enthalpy change in a chemical reaction can be measured accurately. It is important to know this value for chemical reactions that are used as a source of heat energy in applications such as domestic boilers and internal combustion engines.

Prior knowledge:

International GCSE Chemistry
- Exothermic and endothermic reactions

3.1.4.1 Enthalpy change

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know that reactions can be exothermic or endothermic. Know what an enthalpy change is and know the standard conditions. Define standard enthalpies of formation and combustion.	0.2 weeks	**Students should be able to:** • define *enthalpy change* and standard conditions • define standard enthalpy changes of combustion and formation.	• Students list examples of endothermic and exothermic reactions. • Students draw enthalpy profiles for exothermic and endothermic reactions. • Write balanced chemical equations, to include state symbols, to represent the changes shown by standard enthalpy changes of formation and combustion.	• June 2002 Unit 2 Question 1a, b (QS02.2.01)	Some everyday examples of exothermic and endothermic reactions: http://antoine.frostburg.edu/chem/senese/101/thermo/faq/exothermic-endothermic-examples.shtml

3.1.4.2 Calorimetry

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources

Understand and be able to use the equation $q = mc\Delta T$ to calculate molar enthalpy changes.
 	
Required practical 2
Measurement of an enthalpy change.
	1.5 weeks	**Students should be able to:**
		• recall the equation $q = mc\Delta T$
		• Calculate ΔH for reactions using calorimetry experiment data.
			• Students calculate molar enthalpy changes using provided data from calorimetry experiments.
			• Practical Opportunity: Students find ΔH for a reaction by calorimetry, eg
			  • dissolution of potassium chloride
			  • dissolution of sodium carbonate
			  • neutralising NaOH with HCl
			  • displacement reaction between CuSO4 + Zn
			• Practical Opportunity: The enthalpy of combustion of a series of fuels
			• Students could research how accurate values are found for the energy content in food and fuels.
				• January 2011 Unit 2 Question 9b,d (QW11.2.09)
				• June 2009 Unit 2 Question 3 (QS09.2.03)
				• June 2006 Unit 2 Question 1d (QS06.2.01)
				• June 2002 Unit 2 Question 2 (QS02.2.02)
					Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition
					
					Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510

3.1.4.3 Applications of Hess's law

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources

Understand Hess's law.
 	
Use Hess's law to calculate enthalpy changes using enthalpies of formation and combustion.
 	
Required practical 2
Measurement of an enthalpy change.
(May be completed in Section 3.1.4.2)
	1.5 weeks	**Students should be able to:**
		• Recall the equation $q = mc\Delta T$
		• Calculate ΔH for reactions using calirometry experiment data.
			• Students calculate Hess's law plus enthalpies of formation and enthalpies of combustion.
			• Practical Opportunity: Students could be asked to find ΔH for a reaction using Hess's law and calorimetry, then present data in appropriate ways. Examples of reactions could include:
			  • thermal decomposition of NaHCO3
			  • hydration of MgSO4
			  • Enthalpy of formation of CaCO3
				• January 2013 Unit 2 Question 3a (QW13.02.03)
				• January 2013 Unit 2 Question 4 (QW12.2.04)
				• June 2012 Unit 2 Question 2a (QS12.2.02)
				• June 2011 Unit 2 Question 2 (QS11.2.02)
				• June 2009 Unit 2 Question 2a (QS09.2.02)
					Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition
					
					Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510

3.1.4.4 Bond enthalpies

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the term mean bond enthalpy. Use mean bond enthalpies to calculate approximate values for ΔH for reactions. Understand why most bond enthalpies are mean values.	0.5 weeks	**Students should be able to:** • define the term mean bond enthalpy • calculate enthalpy changes using mean bond enthalpies • understand why most bond enthalpies are mean values.	• Students calculate ΔH for reactions using mean bond enthalpies.	• January 2013 Unit 2 Question 6 (QW13.2.06) • January 2006 Unit 2 Question 1 (QW06.2.01) • June 2005 Unit 2 Question 1 (QS05.2.01) • January 2003 Unit 2 Question 2 (QW03.2.02) • January 2011 Unit 2 Question 9d	Nuffield Science Data Book (free download): nationalstemcentre.org.uk/elibrary/resource/3402/nuffield-advanced-science-book-of-data-second-edition Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510

3.1.5 Oxidation, reduction and redox equations

Redox reactions involve a transfer of electrons from the reducing agent to the oxidising agent. The change in the oxidation state of an element in a compound or ion is used to identify the element that has been oxidised or reduced in a given reaction. Separate half-equations are written for the oxidation or reduction processes. These half-equations can then be combined to give an overall equation for any redox reaction.

Prior knowledge:

International AS Chemistry

- Writing equations (3.1.2)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Oxidation and reduction in terms of electron transfer. Oxidation states. Writing redox half equations and full equations.	1.0 weeks	**Students should be able to:** • determine oxidation states • write redox half equations • combine redox half equations to produce full equations • identify reduction and oxidation processes.	• Determine the oxidation state of each element in substances and ions. • Determine and then combine redox half equations. • Determine and then combine redox half equations for the reaction of a brass coin with concentrated nitric acid.	• June 2013 Unit 2 Question 4a (QS13.2.04) • January 2012 Unit 2 Question 5ab (QW12.2.05) • June 2011 Unit 2 Question 5a (QS11.2.05) • January 2005 Unit 2 Question 2 (QW05.2.02) • January 2002 Unit 2 Question 4 (QW02.2.04)	Many suitable resources can be found at docbrown.info

3.1.6 Kinetics

The study of kinetics enables chemists to determine how a change in conditions affects the speed of a chemical reaction. Whilst the reactivity of chemicals is a significant factor in how fast chemical reactions proceed, there are variables that can be manipulated in order to speed them up or slow them down.

Prior knowledge:

International GCSE Chemistry
- Reaction rates

3.1.6.1 Collision theory

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Collision theory. Understand the term activation energy.	0.1 week	**Students should be able to:** • define the term activation energy • explain that reactions can only take place when particles collide with energy greater than or equal to the activation energy.	• Students should be able to explain why reacts do or do not take place using collision theory.		Collision theory simulator: kscience.co.uk/animations/collision.htm

3.1.6.2 Maxwell–Boltzmann distribution

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Drawing Maxwell-Boltmann distribution curves.	0.1 week	**Students should be able to:** • draw and interpret Maxwell-Boltmann distribution curves.	• Students draw Maxwell-Boltzmann curves at different temperatures, pressures and number of particles, identifying the most probable energy, the mean energy and particles with $E \geq E_a$	• June 2013 Unit 2 Question 3 (QS13.2.03) • January 2012 Unit 2 Question 3 (QW12.2.03) • June 2006 Unit 2 Question 2 (QS06.2.02) • January 2002 Unit 2 Question 7 (QW02.2.07)	Maxwell-Boltzmann curve simulator: docbrown.info/BBCbasic/kpts.htm

3.1.6.3 Effect of temperature on reaction rate

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how and why temperature affects the rate of chemical reactions.	0.4 weeks	**Students should be able to:** • define the term rate of reaction • explain how and why temperature affects the rate of reactions using Maxwell-Boltzmann distributions.	• Use Maxwell-Boltzmann curves to explain why a small increase in temperature leads to a large increase in reaction rate. • Students could investigate how knowledge and understanding of the factors that affect the rate of chemical reaction have changed methods of storage and cooking of food. • Practical Opportunity: Students could investigate the effect of temperature on the rate of reaction of sodium thiosulfate and hydrochloric acid by an initial rate method.	• June 2006 Unit 2 Question 2 (QS06.2.02) • January 2004 Unit 2 Question 2 (QW04.2.02) • January 2012 Unit 2 Question 3 (QW12.2.03)	Sodium thiosulfate practical: rsc.org/learn-chemistry/resource/res00000448/the-effect-of-temperature-on-reaction-rate Collision theory simulator: kscience.co.uk/animations/collision.htm

3.1.6.4 Effect of concentration and pressure

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how and why concentration and pressure affect the rate of chemical reactions.	0.3 weeks	**Students should be able to:** • explain how and why concentration of solutions affects the rate of reactions • explain how and why pressure of gases affects the rate of reactions.	• Use collision theory, including diagrams, to explain why an increase in solution concentration leads to an increase in reaction rate. • Use collision theory, including diagrams, to explain why an increase in gas pressure leads to an increase in reaction rate. • Students could investigate the effect of changing the concentration of acid on the rate of a reaction of calcium carbonate and hydrochloric acid by a continuous monitoring method.	• June 2012 Unit 2 Question 1abcd (QS12.2.01)	Collision theory simulator: kscience.co.uk/animations/collision.htm

3.1.6.5 Effect of catalysts

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how and why a catalyst affects the rate of chemical reactions.	0.2 weeks	**Students should be able to:** • state what a catalyst is • explain how and why a catalyst affects the rate of reactions.	• Use a Maxwell-Boltzmann curve to explain how a catalyst increases the rate of a reaction. • Students could research the use of catalysts in catalytic converters in cars. • Practical Opportunity: Students could use Co^{2+} as a catalyst in the oxidation of potassium sodium tartrate by hydrogen peroxide.	• June 2012 Unit 2 Question 1 (QS12.2.01) • June 2011 Unit 2 Question 1 (QS11.2.01) • January 2003 Unit 2 Question 3 (QW03.203) • January 2011 Unit 2 Question 2b	RSC resources on catalysts rsc.org/learn-chemistry/resource/res00000378/faces-of-chemistry-catalysts RSC AfL activity on catalysis rsc.org/learn-chemistry/resource/res00000123/afl-how-do-catalysts-affect-reaction-rates Practical showing the catalyst is involved in the reaction (using Co^{2+} as a catalyst in the oxidation of potassium sodium tatrate by hydrogen peroxide) nuffieldfoundation.org/practical-chemistry/involvement-catalysts-reactions

3.1.7 Chemical equilibria, Le Chatelier's principle and Kc

In contrast with kinetics, which is a study of how quickly reactions occur, a study of equilibria indicates how far reactions will go. Le Chatelier's principle can be used to predict the effects of changes in temperature, pressure and concentration on the yield of a reversible reaction. This has important consequences for many industrial processes. The further study of the equilibrium constant, K_c, considers how the mathematical expression for the equilibrium constant enables us to calculate how an equilibrium yield will be influenced by the concentration of reactants and products.

Prior knowledge:

International GCSE Chemistry
- Reaction rates
- Exothermic and endothermic reactions
- Equilibria (Separate Science but re-visited here)

International AS Chemistry
- Energetics (useful to do this first, but not essential as International GCSE knowledge would suffice)
- Kinetics (useful to do this first, but not essential as International GCSE knowledge would suffice)

3.1.7.1 Chemical equilibria and Le Chatelier's principle

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how reversible reactions can reach a state of dynamic equilibrium. Understand Le Chatelier's principle. Understand why a compromise temperature and pressure may be used for a reversible reaction in an industrial process. Understand the effect of a catalyst on an equilibrium.	1.0 weeks	**Students should be able to:** • describe what is meant by the term dynamic equilibrium • explain, in terms of Le Chatelier's principle, how changes in temperature, pressure and concentration affect the position of a system at equilibrium • explain why compromise conditions of temperature and pressure may be used for a reversible reaction in an industrial process.	• Predict and explain the effect of changes in temperature, pressure and concentration on the position of an equilibrium. • Practical Opportunity: Students carry out test-tube equilibrium shifts to show the effect of concentration and temperature (eg $Cu(H_2O)_6^{2+}$ with concentrated HCl). • Students explain how conditions in temperature and pressure are a compromise in examples of industrial processes.	• June 2013 Unit 2 Question 10a (QS13.2.10) • June 2013 Unit 2 Question 1a (QS13.2.01) • January 2013 Unit 2 Question 2 (QW13.2.02) • January 2012 Unit 2 Question 2 (QW12.2.02)	RSC Resource pack on equilibria rsc.org/learn-chemistry/resource/res00000843/equilibria RSC AfL exercise rsc.org/learn-chemistry/resource/res00000117/afl-equilibrium-reactions Many suitable resources can be found at docbrown.info Co^{2+} equilibrium experiment: rsc.org/learn-chemistry/resource/res00000001/cobalt-equilibrium

3.1.7.2 Equilibrium constant K_c for homogeneous systems

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Write an expression for and calculate K_c including units. Predict the effect, if any, of changes in conditions on the value of K_c.	1.0 weeks	**Students should be able to:** • write an expression for K_c for a homogeneous equilibrium, including its units • calculate the moles and concentration of reagents at equilibrium • calculate the value of K_c • predict qualitatively how the value of K_c will change, if at all, as the position of an equilibrium moves as conditions are changed.	• Write expressions for K_c and derive units for a variety of chemical equilibria. • Calculate the moles and concentration of reagents at equilibrium given initial quantities and the quantity of one reagent at equilibrium. • Calculate K_c from data. • Practical Opportunity: Students set up a reaction between ethanol and ethanoic acid with acid catalyst and leave to reach equilibrium before titrating and using the results to determine K_c • Students predict qualitatively how the value of K_c will change, if at all, as the position of an equilibrium moves as conditions are changed.	• June 2013 Unit 4 Question 2 (QS13.4.02) • January 2010 Unit 4 Question 1 (QW10.04.01) • June 2006 Unit 4 Question 2 (QS06.4.02) • January 2003 Unit 4 Question 2 (QW03.04.02)	RSC Resource pack on equilibria rsc.org/learn-chemistry/resource/res00000843/equilibria Microscale Experiment rsc.org/learn-chemistry/resource/res00000537/measuring-an-equilibrium-constant Many suitable resources can be found at docbrown.info

3.2 Inorganic chemistry

3.2.1 Periodicity

The Periodic Table provides chemists with a structured organisation of the known chemical elements from which they can make sense of their physical and chemical properties. The historical development of the Periodic Table and models of atomic structure provide good examples of how scientific ideas and explanations develop over time.

Prior knowledge:

International AS Chemistry

- Electron structure (3.1.1)
- Ionisation energy (3.1.1)
- Bonding (3.1.3)

3.2.1.1 Classification

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
How elements are classified as s, p, d or f block elements.	0.1 weeks	**Students should be able to:** • classify an element as an s, p, d or f block element using its proton number and/or electron structure.	• Write the electron structure of elements and state in which block they should be classified. • Rich question: Is helium an s or p block element?	• June 2003 Unit 1 Question 1a (QS03.1.01) • June 2002 Unit 1 Question 6a (QS02.1.06)	

3.2.1.2 Physical properties of the Period 3 elements

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Trends in atomic radius, ionisation energy and melting point across Period 3.	0.4 weeks	**Students should be able to:** • describe and explain the trends across Period 3 in atomic radius, ionisation energy, melting points.	• Students plot data on graphs for atomic radius, first ionisation energy and melting point and explain those trends.	• January 2011 Unit 1 Question 5 (QW11.1.05) • January 2009 Unit 1 Question 4 (QW09.1.04) • June 2003 Unit 1 Question 1c (QS03.01.01)	

3.2.2 Group 2, the alkaline earth metals

The elements in Group 2 are called the alkaline earth metals. The trends in the solubilities of the hydroxides and the sulfates of these elements are linked to their use. Barium sulfate, magnesium hydroxide and magnesium sulfate have applications in medicines whilst calcium hydroxide is used in agriculture to change soil pH, which is essential for good crop production and maintaining the food supply.

Prior knowledge:

International GCSE Chemistry

- Writing formulas of ionic compounds

International AS Chemistry

- Ionisation energy (3.1.1.3)
- Bonding (3.1.3)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Trends in atomic radius, first ionisation energy and melting point. How elements Mg-Ba react with water. Solubility and some uses of Group 2 sulfates and hydroxides.	1 week	**Students should be able to:** • know and explain trends in atomic radius, first ionisation energy and melting point from Mg-Ba • know the role of Mg in the extraction of Ti • describe and write equations for the reactions of Mg-Ba with water • know the solubility of Group 2 sulfates and	• Students plot data on graphs for atomic radius, first ionisation energy and melting point and explain those trends. • Practical Opportunity: Students test the reactions of Mg–Ba with water and Mg with steam and record their results. • Practical Opportunity: Students test the solubility of Group 2 hydroxides by mixing solutions of soluble Group 2 salts with sodium hydroxide and record their results.	• June 2012 Unit 2 Question 5 (QS12205) • June 2006 Unit 1 Question 5A (QS06.1.5A) • January 2005 Unit 1 Question 5B (QW05.1.5B) • January 2012 Unit 2 Question 7 (QW12207)	RSC AfL exercise on Group 2: rsc.org/learn-chemistry/resource/res00000118/afl-group-2

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Uses of Mg in the extraction of Ti and $CaO/CaCO_3$ in removing SO_2 from flue gases.		hydroxides • know uses of $Mg(OH)_2$ and $BaSO_4$ in medicine; $BaSO_4$ in testing for sulfate ions; $Ca(OH)_2$ in agriculture; Mg in the extraction of Ti; $CaO/CaCO_3$ in removing SO_2 from flue gases.	• Practical Opportunity: students test the solubility of Group 2 sulfates by mixing solutions of soluble Group 2 salts with sulfuric acid and record their results. • Practical Opportunity: Students test for sulfate ions using acidified barium chloride and record their results. • Students research uses of the following: $Mg(OH)_2$ and $BaSO_4$ in medicine; $BaSO_4$ in testing for sulfate ions; $Ca(OH)_2$ in agriculture; Mg in the extraction of Ti; $CaO/CaCO_3$ in removing SO_2 from flue gases. • Practical Opportunity: Students identify some ‘unknown’ Group 2 compounds by their reactions with NaOH and sulfate ions.		

3.2.3 Group 7(17), the halogens

The halogens in Group 7 are very reactive non-metals. Trends in their physical properties are examined and explained. Fluorine is too dangerous to be used in a school laboratory but the reactions of chlorine are studied. Challenges in studying the properties of elements in this group include explaining the trends in ability of the halogens to behave as oxidising agents and the halide ions to behave as reducing agents.

Prior knowledge:

International AS Chemistry

- Ionisation energy (3.1.1)
- Ionic equations (3.1.2)
- Electronegativity (3.1.3)
- Bonding (3.1.3)
- Oxidation states and redox equations (3.1.5)

3.2.3.1 Trends in properties

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Trends in electronegativity and boiling point down Group 7. Trends in oxidising power of halogens and reducing power of halide ions. Use of acidified silver nitrate to identify halide ions. **Required practical 3** Carry out simple test-tube reactions in aqueous solution to identify cations (Group 2, NH_4^+) and anions (Group 7 (halide), OH^-, CO_3^{2-}, SO_4^{2-}).	1.5 weeks	**Students should be able to:** • describe and explain the trends down Group 7 in electronegativity and boiling points • describe and explain the trends in oxidising power of the halogens, illustrated by displacement reactions of halide ions • describe and explain the trends in reducing power of the halide ions, illustrated by reactions of concentrated sulfuric acid with solid sodium halides • describe and explain how halide ions can be identified using acidified silver nitrate and the solubility of silver halides in ammonia • explain why the silver nitrate used is acidified.	• Students plot data on graphs for electronegativity and boiling point and explain those trends. • Practical Opportunity: Students carry out test-tube reactions of solutions of the halogen (Cl_2, Br_2, I_2) with solutions containing their halide ions (eg KCl, KBr, KI). • Practical Opportunity: Students record observations from reactions of NaCl, NaBr and NaI with concentrated sulfuric acid. • Practical Opportunity: Students could carry out tests for halide ions using acidified silver nitrate, including the use of ammonia to distinguish the silver halides formed. • Required practical 3: Students complete a series of test tube reactions to identify some anions and cations.	• June 2002 Unit 2 Question 4 (QS02.2.04) • June 2002 Unit 2 Question 3 (QS02.02.03) • January 2002 Unit 2 Question 8 (QW02.2.08) • January 2013 Unit 2 Question 9 (QW13.2.09) • June 2012 Unit 2 Question 9 (QS12209) • January 2010 Unit 2 Question 3	Video showing F_2 displacing other halides rsc.org/learn-chemistry/resource/res00000791/displacement-of-halogens Use of silver halides in non-digital photography electronics.howstuffworks.com/film7.htm *Chemistry Review* article: Iodine in medicine (Volume 23, edition 1)

3.2.3.2 Uses of chlorine and chlorate(I)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Reactions of chlorine with water and use of chlorine in water treatment. Reaction of chlorine with sodium hydroxide and use of this reaction.	0.2 weeks	**Students should be able to:** • know the reactions of chlorine with water • know how and why chlorine is used in water treatment • evaluate advantages and disadvantages of adding chemicals to water • know the reaction of sodium hydroxide with water and uses of the solution formed.	• Students investigate and evaluate the treatment of drinking water with chlorine. • Students investigate and evaluate the addition of sodium fluoride to water supplies.	• January 2013 Unit 2 Question 10 (QW13.2.10) • January 2010 Unit 2 Question 10abc (QW10.2.10)	Some information about treatment of water in swimming pools home.howstuffworks.com/swimming-pool5.htm

3.3 Organic chemistry

3.3.1 Introduction to organic chemistry

Organic chemistry is the study of the millions of covalent compounds of the element carbon. These structurally diverse compounds vary from naturally occurring petroleum fuels to DNA and the molecules in living systems. Organic compounds also demonstrate human ingenuity in the vast range of synthetic materials created by chemists. Many of these compounds are used as drugs, medicines and plastics.

Organic compounds are named using the International Union of Pure and Applied Chemistry (IUPAC) system and the structure or formula of molecules can be represented in various different ways. Organic mechanisms are studied, which enable reactions to be explained.

In the search for sustainable chemistry, safer agrochemicals and for new materials to match the desire for new technology, chemistry plays a vital role.

Prior knowledge:

International GCSE Chemistry
- Some simple organic chemistry, eg alkanes and alkenes (although this is revisited here).
- Empirical and molecular formulas (although this is revisited here).

Rather than teaching Section 3.3.1.2 on mechanisms here, each mechanism could be taught as they are encountered during teaching of specific organic reactions.

3.3.1.1 Nomenclature

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the different types of formulas used in organic chemistry. Understand what is meant by a homologous series and functional group. Draw and name organic molecules with chains and rings with up to six carbon atoms each.	1 week	**Students should be able to:** • give the empirical, molecular, general, structural, displayed and skeletal structure of organic molecules • describe the characteristics of a homologous series • draw the structure of, and name organic molecules with chains and rings with up to six carbon atoms each.	• Give the empirical, molecular, general, structural, displayed and skeletal structure of organic. molecules given one or more of these for each molecule. • Make models of organic compounds • Name molecules given their structure, or draw the structure given the name.	• For various molecules students can complete the molecular, empirical, structural, displayed and skeletal formulas as well as the name where only one or more of these is given for each molecule.	Molymod molecular models. Naming hydrocarbons AfL activity rsc.org/learn-chemistry/resource/res00000110/afl-naming-hydrocarbons Shows interactive organic molecules chemtube3d.com/Organic%20Structures%20and%20Bonding.html Chemsketch Freeware allows drawing of molecules and then 3D viewer provides shape. acdlabs.com/resources/freeware/chemsketch/

3.3.1.2 Reaction mechanisms (could be taught throughout the organic chemistry section)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
For both free radical and curly arrow mechanisms write/draw the mechanisms and understand what they represent. Understand the concept of the curly arrow.	0.5 week	**Students should be able to:** • write mechanisms for free radical reactions (free radical substitution of alkanes) • draw mechanisms with curly arrow diagrams (electrophilic addition, nucleophilic addition and nucleophilic substitution at AS level).	NB: It may be best to teach mechanisms as each one is met during the course rather than together here • Write mechanisms for the reactions shown. • Students suggest a mechanistic step in an unfamiliar reaction.	• June 2013 Unit 2 Question 7a (QS13.2.07) • January 2011 Unit 2 Question 7 (QW11.2.07) • January 2002 Unit 3 Question 5 (QW03.2.05) • January 2005 Unit 3 Question 4 (QW03.5.04) • June 2011 Unit 2 Question 9	Molymod molecular models. RSC mechanisms resource: rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions RSC resource of misconceptions about mechanisms: rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms RSC AfL task on nucleophilic substitution rsc.org/learn-chemistry/resource/res00000115/afl-nucleophilic-substitution-reaction-mechanisms

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
					Mechanism animations science.jbpub.com/organic/movies Interactive mechanisms chem.ox.ac.uk/vrchemistry/iom/

3.3.1.3 Isomerism

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the difference between structural and stereoisomerism. Understand the three types of structural isomerism: chain, position and functional group. Understand the cause of E-Z isomerism. Draw and name E-Z isomers using Cahn-Ingold-Prelog (CIP) priority rules.	1 week	**Students should be able to:** • define structural isomerism and stereoisomerism • draw the structure of and name chain, position and functional group isomers • explain the cause of E-Z isomerism • draw the structure of and name E-Z isomers (using Cahn-Ingold-Prelog priority rules).	• Make models of isomers. • Draw and name isomers, including using CIP rules to name E-Z isomers. • Identify pairs (or groups) of compounds which exhibit each type of isomerism.	• June 2011 Unit 2 Question 6a,b (QS11.2.06) • June 2003 Unit 3 Question 3a (QS03.3.03) • June 2003 Unit 3 Question 4A (QS03.3.4A) • January 2003 Unit 3 Question 1c (QW03.3.01)	Molymod molecular models. Many suitable exercises can be found at docbrown.info

3.3.2 Alkanes

Alkanes are the main constituent of crude oil, which is an important raw material for the chemical industry. Alkanes are also used as fuels and the environmental consequences of this use are considered in this section.

Prior knowledge:

International GCSE Chemistry

- Some simple organic chemistry, eg alkanes and alkenes (although this is revisited here).
- Fractional distillation of crude oil (although this is revisited here).
- Empirical and molecular formulae (although this is revisited here).

3.3.2.1 Fractional distillation of crude oil

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand that alkanes are saturated hydrocarbons. Understand how fractional distillation can be used to separate the alkanes in crude oil.	0.3 weeks	**Students should be able to:** • explain that alkanes are saturated hydrocarbons • explain how the alkanes in crude oil are separated by fractional distillation.	• Draw and name alkanes – (opportunity here to reinforce isomerism). • Describe and explain how alkanes in crude oil are separated by fractional distillation. • Practical Opportunity: Separate some alkanes into fractions from a crude oil substitute mixture.	• June 2005 Unit 3 Question 1a (QS05.3.01) • January 2009 Unit 1 Question 6a,b (QW09.1.06)	Molymod molecular models. RSC Videos and animations on fractional distillation of crude oil rsc.org/learn-chemistry/resource/res00000027/oil-refining#!cmpid=CMP00002022 Animations of fractional distillation science.howstuffworks.com/environmental/energy/oil-refining2.htm BP Resource bpes.bp.com/secondary-resources/science/ages-14-to-16/chemical-and-material-behaviour/hydrocarbons-from-crude-oil/

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
					Practical: fractional distillation of crude oil nuffieldfoundation.org/practical-chemistry/fractional-distillation-crude-oil

3.3.2.2 Modification of alkanes by cracking

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand why cracking is useful. Compare how thermal and catalytic cracking are completed and the types of compounds that are produced. (mechanisms not required).	0.3 weeks	**Students should be able to:** • explain the commercial benefits of cracking • describe how thermal and catalytic cracking are completed and the types of compounds that are produced.	• Practical Opportunity: Crack some kerosene/paraffin. • Construct a table to compare thermal and catalytic cracking in terms of conditions and products.	• January 2009 Unit 1 Question 6c (QW09.1.06) • June 2001 Unit 3 Question 7 (QS01.03.07)	Molymod molecular models. Practical: cracking nuffieldfoundation.org/practical-chemistry/cracking-hydrocarbons RSC Videos and animations on cracking rsc.org/learn-chemistry/resource/res00000027/oil-refining#!cmpid=CMP00002022 Animation of cracking bpes.bp.com/secondary-resources/science/ages-14-to-16/chemical-and-material-behaviour/hydrocarbons-from-crude-oil/

3.3.2.3 Combustion of alkanes

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know what is formed when alkanes are burned as fuels. Know/consider how pollution problems from burning alkanes can be reduced.	0.4 weeks	**Students should be able to:** • write equations for the complete and incomplete combustion of alkanes • explain how a number of pollutants including NO_x, CO, C and unburned hydrocarbons are formed in the internal combustion engine and how their emissions can be reduced • explain why SO_2 may be formed when fuels are burned and how it can be removed from flue gases.	• Write balanced equations for the complete and incomplete combustion of alkanes. • Construct a table to show why pollutants may be formed when fuels are burned and how these can be reduced.	• June 2010 Unit 1 Question 4 (QS10.1.04) • June 2010 Unit 1 Question 5 (QS10.1.05) • January 2004 Unit 3 Question 2 (QW04.3.02) • January 2009 Unit 1 Question 6de (QW09.01.06)	Animations and information about how the internal combustion works howstuffworks.com/engine.htm Statistics on a flue gas desulfurisation plant eon-uk.com/FGD.pdf Anecdote about a plane running out of fuel rsc.org/learn-chemistry/resource/res00000037/anecdotes-gimli-glider Videos about catalytic converters rsc.org/learn-chemistry/resource/res00000378/faces-of-chemistry-catalysts *Chemistry Review* article: Catalysis: heterogeneous catalysis (v23, e1)

3.3.2.4 Chlorination of alkanes

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Equations and mechanism for reaction of alkanes with halogens.	0.4 weeks	**Students should be able to:** • write equations for the reaction of halogens with alkanes • write equations to show the mechanism for the reaction of halogens with alkanes • represent the unpaired electron in a radical using a dot.	• Write balanced equations for reactions of alkanes with halogens. • Write balanced equations to show the steps in the mechanism for these reactions. • Extension: Students could look at the usefulness of halogenoalkanes as anaesthetics. • Demonstration: the reaction of chlorine with methane.	• June 2003 Unit 3 Question 2 (QS03.3.02) • June 2012 Unit 2 Question 6a (QS12.2.06) • January 2006 Unit 3 Question 3 (QW06.3.03)	RSC mechanisms resource: rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions RSC resource of misconceptions about mechanisms: rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms Mechanism animations science.jbpub.com/organic/movies/ Interactive mechanisms chem.ox.ac.uk/vrchemistry/iom/

3.3.3 Halogenoalkanes

Halogenoalkanes are much more reactive than alkanes. They have many uses, including as refrigerants, as solvents and in pharmaceuticals. The use of some halogenoalkanes has been restricted due to the effect of chlorofluorocarbons (CFCs) on the atmosphere.

Prior knowledge:

International AS Chemistry

- Nomenclature of organic compounds (3.3.1)
- Principles of curly arrow mechanisms (3.3.1)

3.3.3.1 Nucleophilic substitution

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The polar nature of the C-halogen bond. Nucleophilic substitution reactions with OH^-, CN^- and NH_3. Relative rate of reaction of halogenoalkanes.	1.5 weeks	Students should be able to: • draw and name halogenoalkanes • write equations and mechanisms for reactions of halogenoalkanes with OH^-, CN^- and NH_3 • explain the relative rate of reaction of halogenoalkanes.	• Draw and name halogenoalkanes. • Write equations and mechanisms for reactions of halogenoalkanes with OH^-, CN^- and NH_3 . • Practical Opportunity: Students carry out test-tube hydrolysis of halogenoalkanes to show their relative rates of reaction. • Practical Opportunity: Students prepare a chloroalkane, purifying the product using a separating funnel and distillation (Could be used as Required Practical 4)	• January 2011 Unit 2 Question 8ab (QW11.2.08) • June 2010 Unit 2 Question 2 (QW10.2.02)	RSC mechanisms resource: rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions RSC AfL task on nucleophilic substitution rsc.org/learn-chemistry/resource/res00000115/afl-nucleophilic-substitution-reaction-mechanisms Mechanism animations science.jbpub.com/organic/movies/ Interactive mechanisms chem.ox.ac.uk/vrchemistry/iom/

3.3.3.2 Elimination

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The concurrent substitution and elimination reactions of a halogenoalkane.	0.5 weeks	**Students should be able to:** • write equations and mechanisms for elimination reaction of halogenoalkanes using OH^- • understand the concurrent nature of elimination and substitution when halogenoalkanes react with OH^- • understand the different roles of the OH^- in these reactions.	• write equations and mechanisms for reactions of halogenoalkanes with OH^-, both for elimination and substitution reactions.	• June 2013 Unit 2 Question 5 (QS13.2.05) • January 2011 Unit 2 Question 8 (QW11.2.08) • January 2010 Unit 2 Question 7 (QW10.2.07) • June 2009 Unit 2 Question 8 (QS09.2.08) • June 2002 Unit 3 Question 6 (QS02.3.06)	RSC mechanisms resource: rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions Mechanism animations science.jbpub.com/organic/movies Interactive mechanisms chem.ox.ac.uk/vrchemistry/iom

3.3.4 Alkenes

In alkenes, the high-electron density of the carbon–carbon double bond leads to attack on these molecules by electrophiles. This section also covers the mechanism of addition to the double bond and introduces addition polymers, which are commercially important and have many uses in modern society.

Prior knowledge:

International AS Chemistry

- E-Z isomerism (3.3.1)
- Principles of curly arrow mechanisms (3.3.1)
- Shapes of molecules (3.1.3)

3.3.4.1 Structure, bonding and reactivity

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The structure of alkenes, with a focus on the C=C double bond.	0.1 weeks	**Students should be able to:** • draw alkenes • understand that the double bond is an area of high electron density.	• Draw and name alkenes, including E-Z isomers (useful opportunity to reinforce isomerism and CIP rules).	• Draw and name alkenes.	

3.3.4.2 Addition reactions of alkenes

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Electrophilic addition reactions of alkenes with HBr, H_2SO_4 and Br_2	1.0 weeks	**Students should be able to:** • write equations and mechanisms for reactions of alkenes with HBr, H_2SO_4 and Br_2 • explain the potential formation of major and minor products in these reactions.	• Write equations for reactions of alkenes with HBr, H_2SO_4 and Br_2 • Draw mechanisms for reactions of alkenes with HBr, H_2SO_4 and Br_2, including explaining why there may be major and minor products. • Practical Opportunity: Students test organic compounds for unsaturation using bromine water and record their observations.	• June 2012 Unit 2 Question 7b (QS12.2.07) • June 2010 Unit 2 Question 6a (QS10.2.06)	RSC resource of misconceptions about mechanisms: rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms Mechanism animations science.jbpub.com/organic/movies

3.3.4.3 Addition polymers

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The reaction of monomers to make addition polymers. The structure and name of the polymer. Some uses of polymers.	0.5 weeks	**Students should be able to:** • describe what a polymer is • identify the repeating unit of an addition polymer given the monomer structure and vice versa • name polymers from the name of the monomer • explain how polymers have developed over time • give some uses of PVC and how plasticisers can change its properties • explain why addition polymers are unreactive • explain the nature of the intermolecular forces between polyalkene molecules.	• Students could each make a model of a monomer using Molymods and then students collectively join them together to make a long polymer chain. • Draw the structure of the monomer, repeating unit of the polymer and a section of the polymer chain given one of the others; students should also be able to name the polymer from the monomer name and vice versa. • Students should consider how polymer technology has developed over time. • Students should research uses of PVC and how plasticisers change its properties. • Practical Opportunity: Students make poly(phenylethene).	• January 2013 Unit 4 Question 4c (QW13.4.04) • January 2010 Unit 2 Question 7d (QW10.2.07)	Molymods. RSC Polymers resource rsc.org/learn-chemistry/resource/res00000846/polymers Nuffield Practical Chemistry method to polymerise phenylethene nuffieldfoundation.org/practical-chemistry/addition-polymerisation

3.3.4.4 Epoxyethane

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The structure of epoxyethane and its high reactivity. Reactions of epoxyethane with water and with alcohols. .	0.5 weeks	**Students should be able to:** • explain the high reactivity of epoxyethane • write equations for the production of epoxyethane and recall the conditions for this partial oxidation • understand the hazards of the production of epoxyethane • write equations for the reactions of epoxyethane with water and with alcohols • outline mechanisms for the reactions of epoxyethane with water and with alcohols • explain the economic and environmental importance of the products of the reactions of epoxyethane • know the uses of these products as surfactants and antifreeze.	• Write equations for the reaction of epoxyethane with water and with alcohols. • Outline mechanisms for the reaction of epoxyethane with water and with alcohols. • Students could research the uses of the products of these reactions.	• June 2002 Unit 3 Question 5 • June 2001 Unit 3 Question 3 • June 2006 Unit 3 Question 2c	essentialchemicalindustry.org/chemicals/epoxyethane.html

3.3.5 Alcohols

Alcohols have many scientific, medicinal and industrial uses. Ethanol is one such alcohol and it is produced using different methods, which are considered in this section. Ethanol can be used as a biofuel.

Prior knowledge:

International GCSE Chemistry

- What are biofuels?
- Production of ethanol
- Addition polymers

International AS Chemistry

- Alkenes (3.3.4)

3.3.5.1 Oxidation of alcohols

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Oxidation reactions of primary, secondary and tertiary alcohols. Testing to distinguish aldehydes and ketones.	1.0 weeks	**Students should be able to:** • classify alcohols as primary, secondary or tertiary. • identify products and write equations for oxidation reactions of alcohols. • use chemical tests to distinguish aldehydes and ketones.	• Draw and name alcohols and classify them as primary, secondary or tertiary. • Write equations to show oxidation reactions of alcohols. • Practical Opportunity: Carry out test tube reactions to distinguish tertiary alcohols from primary and secondary by reaction with acidified potassium dichromate (VI) • Practical Opportunity: Carry out test tube reactions to distinguish aldehydes from ketones by reaction with Tollens' reagent and Fehling's solution. • Practical Opportunity: The preparation of ethanal (Could be used as **Required Practical 4**) • Giant silver mirror demonstration.	• January 2013 Unit 2 Question 5 (QW13.2.05) • June 2006 Unit 3 Question 5 (QS06.3.05) • January 2005 Unit 3 Question 3 (QW05.3.03) • June 2004 Unit 3 Question 3 (not part a)ii))(QS04.3.03)	Test tube oxidation reactions of alcohols: nuffieldfoundation.org/practical-chemistry/oxidation-alcohols Disposable breathalysers are available (legal requirement for driving in France) *Chemistry Review* article: Oxidation of alcohols (Volume 10, edition 4)
Extension			Students investigate how a roadside breathalyser works.		

3.3.5.3 Elimination

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Formation of alkenes by elimination reactions of alcohols (mechanism required). Making addition polymers from alkenes made from alcohols. **Required practical 4** Distillation of a product from a reaction.	1.0 weeks	**Students should be able to:** • identify products of alcohol elimination reactions • write equations and mechanism for alcohol elimination reactions • understand how addition polymers can be made from alkenes made this way without using monomers derived from crude oil.	• Students should identify alkenes formed from elimination of alcohols and write equations and mechanism for their production. • Practical Opportunity: Students could carry out the preparation of cyclohexene from cyclohexanol, including purification using a separating funnel and by distillation. (Could be used as **Required Practical 4 –** other opportunities exist in previous topics.)	• June 2003 Unit 3 Question 4B (QS03.3.4B) • June 2004 Unit 3 Question 1C • SAMS AS Paper 2 Question 1	*Chemistry Review* article: Heating under reflux (Volume 20, edition 2) *Chemistry Review* article: Distillation (Volume 14, edition 3)

3.3.6 Organic analysis

Our understanding of organic molecules, their structure and the way they react, has been enhanced by organic analysis. This section considers some of the analytical techniques used by chemists, including test-tube reactions and spectroscopic techniques.

Prior knowledge:

International AS Chemistry

- Mass spectrometry (3.1.1)
- Halogenoalkanes (3.3.3)
- Alkenes (3.3.4)
- Alcohols (3.3.5)

3.3.6.1 Identification of functional groups by test-tube reactions

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Use chemical tests to distinguish functional groups. **Required practical 5** Tests for alcohol, aldehyde, alkene and carboxylic acid.	0.8 weeks	**Students should be able to:** • carry out test-tube reactions in the specification to distinguish alcohols, aldehydes, alkenes and carboxylic acids, and interpret the observations from these reactions.	• Practical Opportunity: Students carry out test-tube reactions in the specification to distinguish alcohols, aldehydes, alkenes and carboxylic acids. • Write equations for the reactions occurring.	• June 2012 Unit 4 Question 7a (QS12.4.07) • January 2013 Unit 4 Question 6a,6c (QW13.4.06)	Test tube oxidation reactions of alcohols: nuffieldfoundation.org/practical-chemistry/oxidation-alcohols *Chemistry Review* article: Identifying an unknown compound (Volume 17, edition 3)

3.3.6.2 Mass spectrometry

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Use high resolution mass spectrometry to find molecular formulae.	0.2 weeks	**Students should be able to:** • use precise atomic masses and the precise molecular mass to determine the molecular formula of a compound.	• Students use precise atomic masses to calculate the precise molecular mass of a compound in order to determine the molecular formula.	• June 2012 Unit 2 Question 3c (QS12.2.03) • January 2010 Unit 2 Question 6e (QW10.2.06)	Mass spectrometry calculator: sisweb.com/mstools/isotope.htm

3.3.6.4 Infra-red spectroscopy

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Use infrared absorptions to identify functional groups. Know how the ‘fingerprint’ region can be used. The role of infrared absorption by molecule in global warming.	0.3 weeks	**Students should be able to:** • identify functional groups from infra-red spectra • understand how the ‘fingerprint’ region of a spectrum can be used • understand the link between absorption of infrared radiation by bonds in CO_2, methane and water vapour and global warming.	• Students identify functional groups from infra-red spectra. • Students research the relative effect of different gases on global warming.	• June 2012 Unit 2 Question 8bii (QS12.2.08) • June 2011 Unit 2 Question 6e (QS11.1.06) • January 2012 Unit 2 Question 10 (QS12.2.10) • June 2009 Unit 2 Question 9 (QS09.2.09)	Spectroscopy in a suitcase resources from RSC rsc.org/learn-chemistry/resource/res00000283/spectroscopy-in-a-suitcase-ir-student-resources *Chemistry Review* article: Infrared spectrometers (Volume 21, edition 2)