Scheme of work A

**AS Chemistry 7404**

## v1.2

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Scheme of work A

## 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 schools and colleges that use two teachers teach topics 3.1.1 Atomic Structure and 3.1.3 Structure 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:

**GCSE Chemistry**

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

**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**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The structure of atoms. | 0.2 weeks | **Students should be able to:*** 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 research how the model of the atom changed over time (examples of key contributions could include the Ancient Greeks, Dalton, Thompson, Rutherford, Bohr, Chadwick) (AO1 - Knowledge and understanding of atomic structure; AO3 - Evaluate how and why atomic structure model developed over time).
* Rich question – How can we tell what is inside an atom if we can’t see it?
 |  | RSC timeline:<http://www.rsc.org/chemsoc/timeline>RSC: Chemists in a social & historical context: <http://www.rsc.org/learn-chemistry/resource/res00001332/the-atom-detectives?cmpid=CMP00002843> RI Christmas Lecture – section on atomic structure <http://www.rsc.org/learn-chemistry/resource/res00001119/ri-christmas-lectures-2012-atomic-structure>  |

**3.1.1.2 Mass number and isotopes**

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| **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 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 (AO2 - Apply knowledge and understanding).
* 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 (AO2 - Apply knowledge and understanding; MS1.1 - Use an appropriate number of significant figures to find relative masses; MS1.2 - Find arithmetic means to find relative masses.
* Students look at the mass spectra of compounds to determine the relative formula mass (AO2 - Apply knowledge and understanding).
 | * SAM AS Paper 1 (set 1) Q2
* June 2013 Unit 1 Question 1a, 1b, 1c and 1f (QS13.1.01)
* January 2012 Unit 1 Question 7a (QW12107)
* June 2010 Unit 1 Question 8a (QS10.1.8A)
 | RSC: Build an atom simulation:<http://www.rsc.org/learn-chemistry/resource/res00001433/build-an-atom-simulation-rsc-funded>RSC Spectral School: <http://www.rsc.org/learn-chemistry/collections/spectroscopy>Isotope data:<http://www.chem.ualberta.ca/~massspec/atomic_mass_abund.pdf> Data on isotopes in meteorites: ‘The Elements: Their Origin, Abundance, and Distribution' by P. A. CoxAQA Time of flight mass spectrometry Teachers’ Notes and Student guide:<http://filestore.aqa.org.uk/resources/chemistry/AQA-7404-7405-TN-MASS-SPECTROMETRY.PDF><http://filestore.aqa.org.uk/resources/chemistry/AQA-7404-7405-SG-TOFMS.PDF><http://filestore.aqa.org.uk/resources/chemistry/AQA-7404-7405-SG-TOFMS-QA.PDF> |
| Extension |  |  | Students investigate the use of mass spectroscopy in drug testing athletes (AO3 - Analyse, interpret and evaluate scientific information). |  |  |

**3.1.1.3 Electron configuration**

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| **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
* explain how data from ionisation energies provides evidence for electron structure.
 | * Students write the electron structure of atoms and ions with *Z*=1-36 (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students research values of first ionisation energies for elements *Z*=1–36 and plot them on a graph and then explain trends (AO2 - Apply knowledge and understanding; MS3.2 - Plot two variables from experimental or other data).
* Students write explanations for trends in ionisation energies down a group and across a period (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students determine which Group an element is in using successive ionisation energy data (AO2 - Apply knowledge and understanding).
 | * January 2012 Unit 1 Question 5a and 5b (QW12.01.05)
* June 2013 Unit 1 Question 6b, 6c and 6d (QS13.01.06)
* January 2010 Unit 1 Question 2 (QW10.01.02)
* June 2009 Unit 1 Question 1a and 1b (QS09.01.01)
* January 2002 Unit 1 Question 4d (QW02.01.04)
 | Orbitron (shows shapes of orbitals):<http://winter.group.shef.ac.uk/orbitron/> Ionisation energy data (1st and successive)<http://en.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 dm3 of a solution of known concentration and by volume in dm3 of a gas.

Prior knowledge:

**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**

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| **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 weeks | **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.
 | * The relative mass of different substances is calculated from the formula (AO2 - Apply knowledge and understanding)
* The mass of everyday objects could be measured relative to a specific object of known mass (AO2 - Apply knowledge and understanding)
* Determine the relative formula mass (*Mr*) of substances using relative atomic mass values (AO2 - Apply knowledge and understanding)
 | * Students can calculate *M*r given the formula of compounds
 | Suitable resources can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required) |
| Extension |  |  | * Students could research why 12C was chosen as the standard (AO3 - Analyse, interpret and evaluate scientific information).
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**3.1.2.2 The mole and Avogadro constant**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Calculations using moles for solids and solutions. | 1.0 weeks | **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 masses sub atomic particles, quoting answers to a suitable number of significant figures for data provided (AO2 - Apply knowledge and understanding).
* Practical opportunity: Students measure out 1 mole (and other mole quantities) of different substances (eg sucrose, salt, water) (AO2 - Apply knowledge and understanding).
* 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 (AO2 - Apply knowledge and understanding; MS1.1 - Use an appropriate number of significant figures to find relative masses).
* Students find the concentration of NaCl in intravenous saline (9 g per dm3), glucose in isotonic sports drinks (17 g in 500 cm3) and other similar calculations for everyday solutions. (AO2 - Apply knowledge and understanding).
 | * Calculating the mass (in g) of atoms/ions using the masses 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.
* Calculations using Avogadro’s number to determine the number of particles in a solution or given mass.
 | Sports drink data from <http://www.lucozadesport.com/products/sport/>Many suitable calculations can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required) |
| Extension |  |  | Students research how Avogadro determined the value of his constant (AO3 - Analyse, interpret and evaluate scientific information). |  |  |

**3.1.2.3 The ideal gas equation**

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| **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 weeks | **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 (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in ideal gas calculations MS2.2 - Change the subject of the ideal gas equation; MS2.3 - Substitute numerical values into the ideal gas equation using appropriate units for physical quantities).
* Practical opportunity: Students find the *M*r of a volatile liquid (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in ideal gas calculations ; MS2.2 - Change the subject of the ideal gas equation; MS2.3 - Substitute numerical values into the ideal gas equation using appropriate units for physical quantities; PS 3.2 - Process and analyse data; PS 4.1 - Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques).
* Students find the mass of argon inside a gas cylinder (23 MPa pressure, 146 × 23 cm dimensions) (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in ideal gas calculations MS2.2 - Change the subject of the ideal gas equation; MS2.3 - Substitute numerical values into the ideal gas equation using appropriate units for physical quantities).
 | * 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:<http://www.nuffieldfoundation.org/practical-chemistry/determining-relative-molecular-mass-butane>Data on gas cylinders:<http://www.boconline.co.uk/en/index.html>Many suitable calculations can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required) |
| 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) (AO3 - Analyse, interpret and evaluate scientific information) |  |  |

**3.1.2.4 Empirical and molecular formula**

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| **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 weeks | **Students should be able to:*** explain the difference between empirical and molecular formulae
* carry out calculations:
* to find empirical formula from data giving composition by mass or percentage by mass
* to 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) (AO2 - Apply knowledge and understanding; PS 3.2 – process & analyse data using appropriate mathematical skills).
* Students find empirical formulae (and molecular formulae where relevant) from data (AO2 - Apply knowledge and understanding; MS0.2 - Use ratios, fractions and percentages).
 | * June 2010 Unit 1 Question 4a (QS10.1.04)
* June 2009 Unit 1 Question 2c (QS09.1.02)
 | Finding empirical formula of copper oxide<http://www.nuffieldfoundation.org/practical-chemistry/finding-formula-copper-oxide> Many suitable calculations can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required) |
| Extension |  |  | Students look at some further information about elemental microanalysis using the RSC resource (this is beyond the specification but relevant) (AO3 - Analyse, interpret and evaluate scientific information) |  | RSC resource on elemental microanalysis: <http://www.nationalstemcentre.org.uk/elibrary/resource/9890/elemental-microanalysis> |

**3.1.2.5 Balanced equations and associated calculations**

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| **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, atom economies, volumes of gases, concentrations & volumes of solutions.To understand the importance of processes having a high 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, • atom economies, • volumes of gases, • concentrations & 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 (AO2 - Apply knowledge and understanding).
* Students write ionic equations from given equations (AO2 - Apply knowledge and understanding).
* Students practise calculations to find masses, percentage yields, atom economies, volumes of gases, concentrations & volumes of solutions (AO2 - Apply knowledge and understanding; MS1.1 - Use an appropriate number of significant figures; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities).
* Practical opportunity: the yield for the conversion of magnesium to magnesium oxide (AO2 - Apply knowledge and understanding; PS 3.2 - Process and analyse data using appropriate mathematical skills).
* Practical opportunity: Students find the *M*r of a hydrated salt (eg copper sulfate or magnesium sulfate) by heating to constant mass (AO2 - Apply knowledge and understanding; PS 3.2 - Process and analyse data using appropriate mathematical skills).
* Practical opportunity: Students find the percentage conversion of a Group 2 carbonate to its oxide by heat (AO2 - Apply knowledge and understanding; PS 3.2 - Process and analyse data using appropriate mathematical skills).
* **Required practical 1** - Make up a volumetric solution and carry out a simple acid–base titration (AO2 - Apply knowledge and understanding; PS 3.2 - Process and analyse data using appropriate mathematical skills); PS 3.3 - Consider margins of error, accuracy and precision of data; AT d - Use laboratory apparatus for a variety of experimental techniques including titration, using burette and pipette; AT f - Use acid–base indicators in titrations of weak/strong acids with weak/strong alkalis).
* 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 *M*r of a group 2 hydrogencarbonate• the *M*r of succinic acidAnalysis of coffee descaler• the mass of aspirin in an aspirin tablet.(AO2 - Apply knowledge and understanding; PS 3.2 - Process and analyse data using appropriate mathematical skills); PS 3.3 - Consider margins of error, accuracy and precision of data; AT d - Use laboratory apparatus for a variety of experimental techniques including titration, using burette and pipette ; AT f - Use acid–base indicators in titrations of weak/strong acids with weak/strong alkalis). | * 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:<http://www.nuffieldfoundation.org/practical-chemistry/finding-formula-hydrated-copperii-sulfate>Many suitable calculations and practical activities can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required)*Chemistry Review* article: Atom Economy (Volume 19, edition 2) |

### 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:

**GCSE Chemistry**

- Structure and bonding (re-visited here).

**3.1.3.1 Ionic bonding**

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| **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
* write the formula of ionic compounds.
 | * Students explain the properties of ionic compounds (AO2 - Apply knowledge and understanding).
* Students write the formula of ionic compounds, including those with common compound ions (AO2 - Apply knowledge and understanding).
* 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): <http://www.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**

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| **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 (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students describe similarities and differences between covalent and co-ordinate bonds (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students draw diagrams of molecules showing covalent and co-ordinate bonds as lines/arrows respectively (“stick” diagrams) (AO2 - Apply knowledge and understanding).
* Students explain the properties of molecular substances (AO2 - Apply knowledge and understanding).
* 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.
 | Animation showing covalent bonding <http://www.chemit.co.uk/resource/Details/87> |

**3.1.3.3 Metallic bonding**

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| **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 (AO2 - Apply knowledge and understanding).
* Students explain the properties of metals (AO2 - Apply knowledge and understanding).
* Rich question: Which metals have the highest and lowest melting points – sodium, potassium, magnesium – explain your reasoning?
 |  | Nuffield Science Data Book (free download): <http://www.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**

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| **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. | 1.0 weeks | **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 (AO2 - Apply knowledge and understanding; PS 1.1 - Solve problems set in practical contexts).
* Students create a summary table to describe and explain the structure and properties of ionic, molecular, giant covalent and metallic substances (AO2 - Apply knowledge and understanding).
* 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 (AO2 - Apply knowledge and understanding).
* 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 (AO2 - Apply knowledge and understanding).
 | * 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): <http://www.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**

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| **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 weeks | **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 (AO2 - Apply knowledge and understanding; MS4.3 - Understand the symmetry of 2D and 3D shapes).
* Use balloons to represent electron pairs to demonstrate shapes (AO2 - Apply knowledge and understanding).
* Deduce, sketch and name the shapes of given molecules and ions, including bond angles (AO2 - Apply knowledge and understanding; MS4.1 - Use angles and shapes in regular 2D and 3D structures; MS4.2 - Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects; MS4.3 - Understand the symmetry of 2D and 3D shapes).
 | * 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)
* January 2004 Unit 1 Question 6a (QW04.1.06)
 | Rotatable shapes<https://people.ok.ubc.ca/wsmcneil/vsepr.htm> Molymod molecular modelsRSC exercise on VSEPR theory:<http://www.rsc.org/learn-chemistry/resource/res00000648/shapes-of-molecules-and-ions>  |

**Content Opportunities for skills development**

**Content Opportunities for skills development**

**3.1.3.6 Bond polarity**

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| **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 weeks | **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 (AO2 - Apply knowledge and understanding).
* Predict whether covalent bonds are polar or not (AO2 - Apply knowledge and understanding).
* Predict whether molecules have permanent dipoles or not (AO2 - Apply knowledge and understanding; MS4.3 - Understand the symmetry of 2D and 3D shapes).
 | * January 2013 Unit 1 Question 3 (QW13.1.03)
* June 2004 Unit 1 Question 6a (QS04.1.06A)
 | Rotatable shapes<https://people.ok.ubc.ca/wsmcneil/vsepr.htm>Molymod molecular models. |

**3.1.3.7 Forces between molecules**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| The three types of intermolecular force: van der Waals’ 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 weeks | **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 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 (AO2 - Apply knowledge and understanding).
* 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 van der Waals’ forces) (AO2 - Apply knowledge and understanding).
* 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 (AO2 - Apply knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 1.2 - Apply scientific knowledge to practical contexts).
* Students explain why ice floats on water by reference to hydrogen bonding (AO2 - Apply knowledge and understanding).
 | * 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): <http://www.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: <http://www.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)RSC Kitchen Chemistry: The Structure of Ice and Waterhttp://www.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 NH3 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:

**GCSE Chemistry**

- Exothermic and endothermic reactions.

**3.1.4.1 Enthalpy change**

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| **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 and is and about 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 (AO2 - Apply knowledge and understanding).
* Students draw enthalpy profiles for exothermic and endothermic reactions (AO2 - Apply knowledge and understanding).
* Write balanced chemical equations, to include state symbols, to represent the changes shown by standard enthalpy changes of formation and combustion (AO2 - Apply knowledge and understanding).
 | * June 2002 Unit 2 Question 1a and 1b (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**

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| **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∆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∆T* * Calculate *∆H* for reactions using calorimetry experiment data.
 | * Students calculate molar enthalpy changes using provided data from calorimetry experiments (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in calculation ; MS1.1 - Use an appropriate number of significant figures; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities).
* Practical opportunity: Students find *∆H* for a reaction by calorimetry eg

• dissolution of potassium chloride• dissolution of sodium carbonate• neutralising NaOH with HCl• displacement reaction between CuSO4 + Zn* Combustion of alcohols

(AO2 - Apply knowledge and understanding; MS1.3 - Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined; MS3.2 – Plot two variables from experimental data; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; PS 3.3 - Consider margins of error, accuracy and precision of data).* Students could research how accurate values are found for the energy content in food and fuels.
 | * January 2011 Unit 2 Question 9b and 9d (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): <http://www.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**

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| **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. | 1.5 weeks | **Students should be able to:*** Recall the equation

*q = mc∆T* * Calculate *∆H* for reactions using calirometry experiment data
 | * Students calculate Hess’s law plus enthalpies of formation and enthalpies of combustion (AO2 - Apply knowledge and understanding).
* 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(AO2 - Apply knowledge and understanding; AT a - Use appropriate apparatus to record a range of measurements (to include mass, time, volume of solutions, temperature); MS1.3 - Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined; MS3.2 – Plot two variables from experimental data; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; PS 3.3 - Consider margins of error, accuracy and precision of data). | * 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)
* June 2002 Unit 2 Question 1 (QS02.2.02)
 | Nuffield Science Data Book (free download): <http://www.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**

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| **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 *∆H* for reactionsUnderstand why most bond enthalpies are mean values. | 0.5 weeks | **Students should be able to:*** calculate enthalpy changes using mean bond enthalpies
* understand why most bond enthalpies are mean values.
 | * Students calculate *∆H* for reactions using mean bond enthalpies (AO2 - Apply knowledge and understanding).
 | * 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): <http://www.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 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:

**GCSE Chemistry**

- Reaction rates.

**3.1.5.1 Collision theory**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Collision theory. | 0.1 weeks | **Students should be able to:*** 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 (AO1 - Demonstrate knowledge and understanding).
 |  | Collision theory simulator: <http://www.kscience.co.uk/animations/collision.htm> |

**3.1.5.2 Maxwell–Boltzmann distribution**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Drawing Maxwell–Boltzmann distribution curves. | 0.1 weeks | **Students should be able to:*** draw and interpret Maxwell–Boltzmann distribution curves.
 | * Students draw and Maxwell–Boltzmann curves at different temperatures, pressures and number of particles, identifying the most probable energy and particles with *E* ≥ *E*a (AO2 - Demonstrate knowledge and understanding; MS3.1 - Translate information between graphical, numerical and algebraic forms).
 | * 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: <http://www.docbrown.info/BBCbasic/kpts.htm>  |

**3.1.5.3 Effect of temperature on reaction rate**

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| **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.**Required practical 3**Investigation of how the rate of a reaction changes with temperature. | 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 (AO2 - Demonstrate knowledge and understanding).
* 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 (AO2 - Demonstrate knowledge and understanding).
* 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 (AO2 - Demonstrate knowledge and understanding; PS 2.4 - Identify variables including those that must be controlled; PS 3.1 - Plot and interpret graphs; MS3.2 – Plot two variables from experimental data; AT l - Measure rates of reaction by at least two different methods, for example 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: <http://www.rsc.org/learn-chemistry/resource/res00000448/the-effect-of-temperature-on-reaction-rate>Collision theory simulator: <http://www.kscience.co.uk/animations/collision.htm> |

**3.1.5.4 Effect of concentration and pressure**

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| **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 (AO2 - Demonstrate knowledge and understanding).
* Use collision theory, including diagrams, to explain why an increase in gas pressure leads to an increase in reaction rate (AO2 - Demonstrate knowledge and understanding).
* 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 (AO2 - Demonstrate knowledge and understanding; AT l - Measure rates of reaction by at least two different methods, for example a continuous monitoring method; PS 2.4 - Identify variables including those that must be controlled; PS 3.1 - Plot and interpret graphs; MS3.2 – Plot two variables from experimental data; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change)
 | * June 2012 Unit 2 Question 1a, 1b, 1c and 1d (QS12.2.01)
 | Collision theory simulator: <http://www.kscience.co.uk/animations/collision.htm> |

**3.1.5.5 Effect of catalysts**

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| **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 (AO2 - Demonstrate knowledge and understanding).
* Students could research the use of catalysts in catalytic converters in cars (AO3 - Analyse, interpret and evaluate scientific information).
* Practical opportunity: Students could use Co2+ as a catalyst in the oxidation of potassium sodium tartrate by hydrogen peroxide (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
 | * 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 <http://www.rsc.org/learn-chemistry/resource/res00000378/faces-of-chemistry-catalysts>RSC AfL activity on catalysis <http://www.rsc.org/learn-chemistry/resource/res00000123/afl-how-do-catalysts-affect-reaction-rates>Practical showing the catalyst is involved in the reaction (using Co2+ as a catalyst in the oxidation of potassium sodium tatrate by hydrogen peroxide) <http://www.nuffieldfoundation.org/practical-chemistry/involvement-catalysts-reactions>  |

### 3.1.6 Chemical equilibria, Le Chatelier’s principle and *K*c

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:

**GCSE Chemistry**

- Reaction rates.

- Exothermic and endothermic reactions.

- Equilibria (Separate Science but re-visited here).

**AS Chemistry**

- Energetics (useful to do this first, but not essential as GCSE knowledge would suffice).

- Kinetics (useful to do this first, but not essential as GCSE knowledge would suffice).

**3.1.6.1 Chemical equilibria and Le Chatelier’s principle**

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| **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 the term dynamic equilibrium
* explain 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 (AO2 - Demonstrate knowledge and understanding).
* Practical opportunity: Students carry out test-tube equilibrium shifts to show the effect of concentration and temperature (eg Cu(H2O)62+ with concentrated HCl). (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Students explain how conditions in temperature and pressure are a compromise in examples of industrial processes (AO3 - Analyse, interpret and evaluate scientific information).
 | * 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 <http://www.rsc.org/learn-chemistry/resource/res00000843/equilibria> RSC AfL exercise <http://www.rsc.org/learn-chemistry/resource/res00000117/afl-equilibrium-reactions> Many suitable resources can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required)Co2+ equilibrium experiment:<http://www.rsc.org/learn-chemistry/resource/res00000001/cobalt-equilibrium>  |

**3.1.6.2 Equilibrium constant *K*c for homogeneous systems**

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| **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 equilibria (AO2 - Demonstrate knowledge and understanding).
* Calculate the moles and concentration of reagents at equilibrium given initial quantities and the quantity of one reagent at equilibrium (AO2 - Demonstrate knowledge and understanding).
* Calculate *K*c from data (AO2 - Demonstrate knowledge and understanding; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities.
* 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 (AO2 - Demonstrate knowledge and understanding; AT d - Use laboratory apparatus for a variety of experimental techniques including titration, using burette and pipette ; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 3.2 - Process and analyse data using appropriate mathematical skills).
* 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 <http://www.rsc.org/learn-chemistry/resource/res00000843/equilibria> Many suitable resources can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required)  |

### 3.1.7 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:

**AS Chemistry**

- Writing equations (3.1.2).

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| **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 (AO2 - Demonstrate knowledge and understanding).
* Determine and then combine redox half equations (AO2 - Demonstrate knowledge and understanding).
* Determine and then combine redox half equations for the reaction of a brass 2p coin with concentrated nitric acid (AO2 - Demonstrate knowledge and understanding).
 | * June 2013 Unit 2 Question 4a (QS13.2.04)
* January 2012 Unit 2 Question 5a and 5b (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 <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required) |

## 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:

**AS Chemistry**

- Electron structure (3.1.1).

- Ionisation energy (3.1.1).

- Bonding (3.1.3).

**3.2.1.1 Classification**

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| **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 electron structure.
 | * Write the electron structure of elements and state which block they belong to (AO2 - Demonstrate knowledge and understanding).
* Rich question: Is helium an s or p block element?
 | * June 2003 Unit 1 Question 1b (QS03.1.01)
* June 2002 Unit 1 Question 6a (QS02.1.06)
 |  |

**3.2.1.2 Physical properties of the Period 3 elements**

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| **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 (AO1 - Demonstrate knowledge and understanding of scientific ideas; AO2 - Demonstrate knowledge and understanding; MS3.2 – Plot two variables from experimental or other data).
 | * 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:

**GCSE Chemistry**

- Writing formulas of ionic compounds.

Prior knowledge:

**AS Chemistry**

- Ionisation energy (3.1.1.3).

- Bonding (3.1.3).

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| **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.Uses of Mg in the extraction of Ti and CaO/CaCO3 in removing SO2 from flue gases. | 1.0 weeks | **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 hydroxides
* know uses of Mg(OH)2 and BaSO4 in medicine; BaSO4 in testing for sulfate ions; Ca(OH)2 in agriculture; Mg in the extraction of Ti; CaO/CaCO3 in removing SO2 from flue gases.
 | * Students plot data on graphs for atomic radius, first ionisation energy and melting point and explain those trends (AO1 - Demonstrate knowledge and understanding of scientific ideas; AO2 - Demonstrate knowledge and understanding; MS3.2 – Plot two variables from experimental or other data).
* Practical opportunity: Students test the reactions of Mg–Ba with water and Mg with steam and record their results (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* 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 (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* 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 (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Practical opportunity: Students test for sulfate ions using acidified barium chloride and record their results (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Students research uses of the following: Mg(OH)2 and BaSO4 in medicine; BaSO4 in testing for sulfate ions; Ca(OH)2 in agriculture; Mg in the extraction of Ti; CaO/CaCO3 in removing SO2 from flue gases (AO3 - Analyse, interpret and evaluate scientific information).
* Practical opportunity: Students identify some “unknown” group 2 compounds by their reactions with NaOH and sulfate ions. (AO2 - Demonstrate knowledge and understanding; AT d - Use laboratory apparatus for qualitative tests for ions; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
 | * 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: <http://www.rsc.org/learn-chemistry/resource/res00000118/afl-group-2>Royal College of Radiologists leaflet on barium meals:<https://www.rcr.ac.uk/docs/patients/worddocs/CRPLG_meal.doc> Newspaper story about changes to recipe of milk of magnesia in 2013:<http://www.dailymail.co.uk/news/article-2352139/Milk-Magnesia-disappears-British-shelves-ingredients-fall-foul-EU-meddlers.html>  |

### 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:

**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 (3.1.7).

**3.2.3.1 Trends in properties**

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| **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 4**Carry out simple test-tube reactions in aqueous solution to identify cations (Group 2, NH4+) and anions (Group 7 (halide), OH-, CO32-, SO42-). | 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 (AO1 - Demonstrate knowledge and understanding of scientific ideas; AO2 - Demonstrate knowledge and understanding; MS3.2 – Plot two variables from experimental or other data).
* Practical opportunity: Students carry out test-tube reactions of solutions of the halogen (Cl2, Br2, I2) with solutions containing their halide ions (eg KCl, KBr, KI) (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 2.2 - Present results of test-tube reactions in appropriate ways).
* Practical opportunity: Students record observations from reactions of NaCl, NaBr and NaI with concentrated sulfuric acid. (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 2.2 - Present results of test-tube reactions in appropriate ways).
* 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 (AO2 - Demonstrate knowledge and understanding; AT d - Use laboratory apparatus for qualitative tests for ions; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 2.2 - Present results of test-tube reactions in appropriate ways).
* Required practical 4: Students complete a series of test-tube reactions to identify some anions and cations (AO2 - Demonstrate knowledge and understanding; AT d - Use laboratory apparatus for qualitative tests for ions; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 2.2 - Present results of test-tube reactions in appropriate ways).
 | * 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 F2 displacing other halides <http://www.rsc.org/learn-chemistry/resource/res00000791/displacement-of-halogens>Use of silver halides in non-digital photography <http://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)**

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| **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 (AO3 - Analyse, interpret and evaluate scientific information).
* Students investigate and evaluate the addition of sodium fluoride to water supplies (AO3 - Analyse, interpret and evaluate scientific information).
 | * January 2013 Unit 2 Question 10 (QW13.2.10)
* January 2010 Unit 2 Question 10a, 10b and 10c (QW10.2.10)
 | Review by University of York of fluoridation of water <http://www.york.ac.uk/inst/crd/fluores.htm>Detailed information about chlorination of water [http://www.safewater.org/PDFS/resourcesknowthefacts/What+is+Chlorination.pdf](http://www.safewater.org/PDFS/resourcesknowthefacts/What%2Bis%2BChlorination.pdf)Some information about treatment of water in swimming pools <http://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:

**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**

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| **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.Draw and name organic molecules with chains and rings with up to six carbonatoms each. | 1.0 weeks | **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 (AO2 - Demonstrate knowledge and understanding; MS 4.2 – visualise and represent 2D and 3D forms including 2D representations of 3D objects).
* Make models of organic compounds (AO2 - Demonstrate knowledge and understanding; MS 4.2 – visualise and represent 2D and 3D forms including 2D representations of 3D objects).
* Name molecules given their structure, or draw the structure given the name (AO2 - Demonstrate knowledge and understanding).
 | * 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 modelsNaming hydrocarbons AfL activity<http://www.rsc.org/learn-chemistry/resource/res00000110/afl-naming-hydrocarbons>Shows interactive organic molecules <http://chemtube3d.com/Organic%20Structures%20and%20Bonding.html>Chemsketch Freeware allows drawing of molecules and then 3D viewer provides shape.<http://www.acdlabs.com/resources/freeware/chemsketch/> |

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

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| **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 weeks | **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 (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students suggest a mechanistic step in an unfamiliar reaction (AO2 - Demonstrate knowledge and understanding).
 | * 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 modelsRSC mechanisms resource: <http://www.rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions> RSC resource of misconceptions about mechanisms: <http://www.rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms> RSC AfL task on nucleophilic substitution <http://www.rsc.org/learn-chemistry/resource/res00000115/afl-nucleophilic-substitution-reaction-mechanisms> Mechanism animations <http://science.jbpub.com/organic/movies/> Interactive mechanisms <http://www.chem.ox.ac.uk/vrchemistry/iom/>  |

**3.3.1.3 Isomerism**

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| **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 CIP priority rules. | 1.0 weeks | **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 (AO2 - Demonstrate knowledge and understanding; MS 4.2 – visualise and represent 2D and 3D forms including 2D representations of 3D objects).
* Draw and name isomers, including using CIP rules to name *E–Z­* isomers (AO2 - Demonstrate knowledge and understanding; MS 4.2 – visualise and represent 2D and 3D forms including 2D representations of 3D objects).
* Identify pairs (or groups) of compounds which exhibit each type of isomerism (AO2 - Demonstrate knowledge and understanding).
 | * June 2011 Unit 2 Question 6a and 6b (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 modelsMany suitable exercises can be found at <http://www.docbrown.info/> and <http://www.chemsheets.co.uk/>(subscription required) |

### 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:

**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**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Understand what alkanes are.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) (AO2 - Demonstrate knowledge and understanding; MS 4.2 – visualise and represent 2D and 3D forms including 2D representations of 3D objects).
* Describe and explain how alkanes in crude oil are separated by fractional distillation (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Practical opportunity: Separate some alkanes into fractions from a crude oil substitute mixture (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
 | * June 2005 Unit 3 Question 1a (QS05.3.01)
* January 2009 Unit 1 Question 6a and 6b (QW09.1.06)
 | Molymod molecular modelsRSC Videos and animations on fractional distillation of crude oil <http://www.rsc.org/learn-chemistry/resource/res00000027/oil-refining#!cmpid=CMP00002022> Animations of fractional distillation <http://science.howstuffworks.com/environmental/energy/oil-refining2.htm> <http://bpes.bp.com/secondary-resources/science/ages-14-to-16/chemical-and-material-behaviour/hydrocarbons-from-crude-oil/>Practical: fractional distillation of crude oil <http://www.nuffieldfoundation.org/practical-chemistry/fractional-distillation-crude-oil> |

**3.3.2.2 Modification of alkanes by cracking**

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| **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. | 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 (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Construct a table to compare thermal and catalytic cracking in terms of conditions and products (AO1 - Demonstrate knowledge and understanding of scientific ideas).
 | * January 2009 Unit 1 Question 6c (Qw09.1.06)
* January 2004 Unit 3 Question 5 (QW04.03.05)
* June 2001 Unit 3 Question 7 (QS01.03.07)
 | Molymod molecular modelsPractical: cracking <http://www.nuffieldfoundation.org/practical-chemistry/cracking-hydrocarbons> RSC Videos and animations on cracking <http://www.rsc.org/learn-chemistry/resource/res00000027/oil-refining#!cmpid=CMP00002022> Animation of cracking <http://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**

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| **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 NOx, CO, C and unburned hydrocarbons are formed in the internal combustion engine and how their emissions can be reduced
* why SO2 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 (AO2 - Demonstrate knowledge and understanding).
* Construct a table to show why pollutants may be formed when fuels are burned and how these can be reduced (AO1 - Demonstrate knowledge and understanding of scientific ideas; AO3 - Analyse, interpret and evaluate scientific information).
 | * 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 6d and 6e (QW09.01.06)
 | Animations and information about how the internal combustion works <http://www.howstuffworks.com/engine.htm>Statistics on a flue gas desulfurisation plant<http://www.eon-uk.com/FGD.pdf>Anecdote about a plane running out of fuel<http://www.rsc.org/learn-chemistry/resource/res00000037/anecdotes-gimli-glider>Videos about catalytic converters <http://www.rsc.org/learn-chemistry/resource/res00000378/faces-of-chemistry-catalysts> *Chemistry Review* article: Catalysis: heterogeneous catalysis (volume 23, edition 1) |

**3.3.2.4 Chlorination of alkanes**

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| **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 (AO2 - Demonstrate knowledge and understanding).
* Write balanced equations to show the steps in the mechanism for these reactions (AO2 - Demonstrate knowledge and understanding).
* Students could look at the usefulness of halogenoalkanes as anaesthetics (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Demonstration: the reaction of chlorine with methane (AO2 - Demonstrate knowledge and understanding).
 | * June 2003 Unit 3 Question 2 (QS03.3.02)
* June 2012 Unit 2 Question 6a (QS12206)
* January 2006 Unit 3 Question 3 (QW06.3.03)
 | RSC mechanisms resource: <http://www.rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions> RSC resource of misconceptions about mechanisms: <http://www.rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms> Mechanism animations <http://science.jbpub.com/organic/movies/> Interactive mechanisms <http://www.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:

**AS Chemistry**

- Nomenclature of organic compounds (3.3.1).

- Principles of curly arrow mechanisms (3.3.1).

**3.3.3.1 Nucleophilic substitution**

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| **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 NH3.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 NH3
* explain the relative rate of reaction of halogenoalkanes
 | * Draw and name halogenoalkanes (AO2 - Demonstrate knowledge and understanding).
* Write equations and mechanisms for reactions of halogenoalkanes with OH-‑, CN– and NH3 (AO2 - Demonstrate knowledge and understanding).
* Practical opportunity: Students carry out test-tube hydrolysis of halogenoalkanes to show their relative rates of reaction (AO2 - Demonstrate knowledge and understanding; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Practical opportunity: Students prepare a chloroalkane, purifying the product using a separating funnel and distillation (AO2 - Demonstrate knowledge and understanding; AT a - Use appropriate apparatus to record mass, and boiling points ; AT b - Use water bath or electric heater or sand bath for heating ; AT d - Use laboratory apparatus for a variety of experimental techniques including distillation and heating under reflux, including setting up glassware using retort stand and clamps; AT g - Purify a liquid product, including use of separating funnel; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
 | * January 2011 Unit 2 Question 8a and 8b (QW11.2.08)
* June 2010 Unit 2 Question 2 (QW10.2.02)
 | RSC mechanisms resource: <http://www.rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions> RSC AfL task on nucleophilic substitution <http://www.rsc.org/learn-chemistry/resource/res00000115/afl-nucleophilic-substitution-reaction-mechanisms> Mechanism animations <http://science.jbpub.com/organic/movies/> Interactive mechanisms <http://www.chem.ox.ac.uk/vrchemistry/iom/>   |

**3.3.3.2 Elimination**

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| **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 (AO2 - Demonstrate knowledge and understanding).
 | * 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: <http://www.rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions> Mechanism animations <http://science.jbpub.com/organic/movies/> Interactive mechanisms <http://www.chem.ox.ac.uk/vrchemistry/iom/>  |

**3.3.3.3 Ozone depletion**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| What ozone is and its role in the atmosphere.How Cl free radicals are formed in the atmosphere and how they destroy ozone.How research evidence led to the end of use of CFCs and alternatives found. | 0.4 weeks | **Students should be able to:*** understand the role of ozone in the atmosphere
* understand how chlorine free radicals can be formed in the atmosphere from compounds such as CFCs
* understand the mechanism for the depletion of ozone by chlorine free radicals
* evaluate the role of chemists in the introduction of legislation to ban the use of CFCs and to find replacements.
 | * Students investigate the presence and role of ozone in the atmosphere (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Write equations and mechanisms for the formation of chlorine free radicals and the destruction of ozone (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Understand why suitable replacements for CFCs do not destroy ozone (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students investigate the role of chemists in the introduction of legislation to ban the use of CFCs and in finding replacements (AO3 - AO3 - Analyse, interpret and evaluate scientific information).
* Rich question – CFCs are still used in some countries – how can we stop this?
 | * January 2013 Unit 2 Question 7 (QW13.2.07)
* June 2011 Unit 2 Question 7 (QS11.2.07)
* June 2009 Unit 2 Question 11 (QS09.2.11)
 | RSC resource on CFCs and ozone: <http://www.rsc.org/learn-chemistry/resource/res00000779/mario-molina-puts-ozone-on-the-political-agendas>US EPA information<http://www.epa.gov/ozone/science/sc_fact.html>Nobel Prize 1995<http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1995/press.html>*Chemistry Review* article: Do ants destroy the ozone layer (Volume 20, edition 4)*Chemistry Review* article: Thomas Midgley (Volume 15, edition 2)*Chemistry Review* article: The Antarctic ozone hole (Volume 17, edition 2) |

### 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 n 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:

**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**

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| **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 (AO2 - Demonstrate knowledge and understanding; MS4.1 - Use angles and shapes in regular 2D and 3D structures of alkenes).
 | * Draw and name alkenes.
 |  |

**3.3.4.2 Addition reactions of alkenes**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Electrophilic addition reactions of alkenes with HBr, H2SO4 and Br2 | 1.0 weeks | **Students should be able to:*** write equations and mechanisms for reactions of alkenes with HBr, H2SO4 and HBr
* explain the potential formation of major and minor products in these reactions.
 | * Write equations for reactions of alkenes with HBr, H2SO4 and HBr (AO2 - Apply knowledge and understanding of scientific ideas).
* Draw mechanisms for reactions of alkenes with HBr, H2SO4 and HBr, including explaining why there may be major and minor products (AO2 - Apply knowledge and understanding of scientific ideas).
* Practical opportunity: Students test organic compounds for unsaturation using bromine water and record their observations (AO2 - Apply knowledge and understanding of scientific ideas; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
 | * June 2012 Unit 2 Question 7 (QS12.2.07)
* June 2010 Unit 2 Question 6a (QS10.2.06)
 | RSC resource of misconceptions about mechanisms: <http://www.rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms> Mechanism animations <http://science.jbpub.com/organic/movies/>   |

**3.3.4.3 Addition polymers**

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| **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 (AO2 - Apply knowledge and understanding).
* 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 (AO2 - Apply knowledge and understanding of scientific ideas).
* Students should consider how polymer technology has developed over time (AO3 -Analyse, interpret and evaluate scientific information).
* Students should research uses of PVC and how plasticisers change its properties (AO3 - Analyse, interpret and evaluate scientific information).
* Practical opportunity: Students make poly(phenylethene) (AO2 - Apply knowledge and understanding of scientific ideas; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
 | * June 2012 Unit 2 Question 7 (QS12.2.07)
* June 2010 Unit 2 Question 6a (QS10.2.06)
 | Molymods RSC Polymers resource <http://www.rsc.org/learn-chemistry/resource/res00000846/polymers>Nuffield Practical Chemistry method to polymerise phenylethene <http://www.nuffieldfoundation.org/practical-chemistry/addition-polymerisation> |

### 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:

**GCSE Chemistry**

- What are biofuels?

- Production of ethanol.

- Addition polymers.

**AS Chemistry**

- Alkenes (3.3.4).

**3.3.5.1 Alcohol production**

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| **Learning objective** | **Time taken** | **Learning outcome** | **Learning activity with opportunity to develop skills** | **Assessment opportunities** | **Resources** |
| Alcohols can be made by hydration of alkenes.Ethanol can be produced by the reaction of ethene and steam using a phosphoric acid catalyst.Ethanol can also be made by fermentation of glucose and is used as a biofuel.Compare the two methods of producing ethanol. | 0.2 weeks | **Students should be able to:*** write equations and give conditions for the production of alcohols by hydration of alkenes
* outline the mechanism for formation of ethanol from reaction of ethene with steam with an acid catalyst
* write an equation, give and justify conditions for the production of ethanol by fermentation of glucose
* compare the two methods of producing ethanol
* explain the meaning of the term biofuel
* evaluate the use of ethanol as a biofuel
* show using equations how ethanol made by fermentation can be regarded as carbon neutral but that in reality it is not.
 | * Write equations for the production of alcohols from alkenes (AO2 - Apply knowledge and understanding of scientific ideas).
* Produce a summary table to compare and contrast the two methods of making ethanol (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Outline the mechanism to make ethanol from reaction of ethene with steam with an acid catalyst (AO1 - Demonstrate knowledge and understanding of scientific ideas).
* Students could produce ethanol by fermentation, followed by purification by fractional distillation (AO2 - Apply knowledge and understanding of scientific ideas; AT d - Use laboratory apparatus for a variety of experimental techniques including distillation and setting up glassware using retort stand and clamps; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Evaluate the use of biofuels (AO3 - Analyse, interpret and evaluate scientific information).
* Show by use of chemical equation that the formation of ethanol by fermentation can be thought of as being carbon neutral, but why it is not in reality (AO1 - Demonstrate knowledge and understanding of scientific ideas).
 | * January 2005 Unit 3 Question 5a, 5b and 5c (QW.05.3.05)
* January 2002 Unit 3 Question 7 (QW02.3.07)
 | Making ethanol by fermentation: <http://www.nuffieldfoundation.org/practical-chemistry/fermentation-glucose-using-yeast>Biofuels website: <http://www.thesolarspark.co.uk/the-science/renewable-energy/bio/> Biofuels website: <http://www.biofuels.co.uk/>Press report about problems with biofuels: <http://www.telegraph.co.uk/earth/energy/biofuels/10520736/The-great-biofuels-scandal.html> BP biofuels resources: <http://bpes.bp.com/secondary-resources/science/ages-14-to-16/energy-electricity-and-forces/biofuels-and-the-future/> |

**3.3.5.2 Oxidation of alcohols**

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| **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 (AO2 - Apply knowledge and understanding of scientific ideas).
* Write equations to show oxidation reactions of alcohols (AO2 - Apply knowledge and understanding of scientific ideas).
* Practical opportunity: Carry out test-tube reactions to distinguish tertiary alcohols from primary and secondary by reaction with acidified potassium dichromate(VI) (AO2 - Apply knowledge and understanding of scientific ideas; AT b - Use water bath or electric heater or sand bath for heating; AT d - Use laboratory apparatus for qualitative tests for organic functional groups; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Practical opportunity: Carry out test-tube reactions to distinguish aldehydes from ketones by reaction with Tollens’ reagent and Fehling’s solution (AO2 - Apply knowledge and understanding of scientific ideas; AT b - Use water bath or electric heater or sand bath for heating; AT d - Use laboratory apparatus for qualitative tests for organic functional groups; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Practical opportunity: The preparation of ethanal (AO2 - Apply knowledge and understanding of scientific ideas; AT b - Use water bath or electric heater or sand bath for heating; AT d - Use laboratory apparatus for a variety of experimental techniques including distillation and heating under reflux, including setting up glassware using retort stand and clamps; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances).
* Giant silver mirror demonstration. (AO2 - Apply knowledge and understanding of scientific ideas).
 | * January 2013 Unit 2 Question 5 (QW13.02.05)
* 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:<http://www.nuffieldfoundation.org/practical-chemistry/oxidation-alcohols>Disposal breathalysers are available (legal requirement for driving in France)The breathalyser reaction <http://www.nuffieldfoundation.org/practical-chemistry/%E2%80%98breathalyser%E2%80%99-reaction> Giant silver mirror <http://www.nuffieldfoundation.org/practical-chemistry/giant-silver-mirror> *Chemistry Review* article: Oxidation of alcohols (Volume 10, edition 4) |
| Extension |  |  | Students investigate how a roadside breathalyser works (AO3 - Analyse, interpret and evaluate scientific information). |  |  |

**3.3.5.3 Elimination**

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| **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 5**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 (AO2 - Apply knowledge and understanding of scientific ideas).
* Practical opportunity: Students could carry out the preparation of cyclohexene from cyclohexanol, including purification using a separating funnel and by distillation (AO2 - Apply knowledge and understanding of scientific ideas; AT b - Use water bath or electric heater or sand bath for heating; AT d - Use laboratory apparatus for a variety of experimental techniques including distillation and heating under reflux, including setting up glassware using retort stand and clamps; AT g - Purify a liquid product, including use of separating funnel; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances.
 | * June 2003 Unit 3 Question 4b (QS03.3.4B)
* SAMs AS Paper 2 (set 1) Question 1
 | Preparation of cyclohexene [http://www.chemsheets.co.uk/Chemsheets%20AS%20079%20(Preparation%20of%20cyclohexene).pdf](http://www.chemsheets.co.uk/Chemsheets%20AS%20079%20%28Preparation%20of%20cyclohexene%29.pdf) *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:

**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**

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| **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 6**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 (AO2 - Apply knowledge and understanding of scientific ideas; AT b - Use water bath or electric heater or sand bath for heating; AT d - Use laboratory apparatus for qualitative tests for organic functional groups; AT k - Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances; PS 2.2 - Present results of reactions in appropriate ways; PS 2.3 - Evaluate results and draw conclusions).
* Write equations for the reactions occurring. (AO2 - Apply knowledge and understanding of scientific ideas).
 | * June 2012 Unit 4 Question 7 (QS12.4.07)
* January 2013 Unit 4 Question 6a (QW13.4.06)
 | Test-tube oxidation reactions of alcohols:<http://www.nuffieldfoundation.org/practical-chemistry/oxidation-alcohols>*Chemistry Review* article: Identifying an unknown compound (Volume 17, edition 3) |

**3.3.6.2 Mass spectrometry**

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| **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 (AO2 - Apply knowledge and understanding of scientific ideas; MS1.1 - Use an appropriate number of significant figures).
 | * June 2012 Unit 2 Question 3c (QS12.2.03)
* January 2010 Unit 2 Question 6e (QW10.2.06)
 | Mass spectrometry calculator: <http://www.sisweb.com/mstools/isotope.htm>  |

**3.3.6.4 Infrared spectroscopy**

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| **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 CO2, methane and water vapour and global warming.
 | * Students identify functional groups from infra-red spectra (AO2 - Apply knowledge and understanding of scientific ideas).
* Students research the relative effect of different gases on global warming (AO3 - Analyse, interpret and evaluate scientific information).
 | * 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 from RSC (including potential visit to your school/college by a university team with IR spectrometer):<http://www.rsc.org/learn-chemistry/resource/res00000283/spectroscopy-in-a-suitcase-ir-student-resources> IR spectroscopy resources: <http://www.chemsheets.co.uk/page3.html> Greenhouse gas IR spectra: <http://www.chem.wisc.edu/middlecamp/108-Fall08/work/IR_spec5.swf>*Chemistry Review* article: Infrared spectrometers (Volume 21, edition 2) |