Understand the structure of amino acids. Draw the structure of given amino acids in acidic solution, alkaline solution and as zwitterions.	0.3 weeks	**Students should be able to:** • draw the structure of given amino acids in acidic solution, alkaline solution and as zwitterions.	• Given the structure of the amino acid, students show draw the structure of the species formed in acidic solution, alkaline solution and as a zwitterion (AO2 - Apply knowledge and understanding).	• June 2013 Unit 4 Question 6 (QS13.4.06) • January 2012 Unit 4 Question 7 (QS12.4.07) • January 2005 Unit 4 Question 2 (QW05.4.02)	Structure of amino acids (rotatable) https://undergrad-ed.chemistry.ohio-state.edu/jmol-viewer/# RSC resource on basic biochemistry http://www.rsc.org/Education/Teachers/Resources/cfb/proteins.htm

3.3.13.2 Proteins

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the structure of proteins. Understand how peptide links can be hydrolysed to release amino acids. Know how to use thin-layer chromatography to separate and identify amino acids.	0.5 weeks	**Students should be able to:** • describe the primary, secondary and tertiary structure of proteins, including the importance of hydrogen bonds and S-S bonds • draw the structure of peptides formed from amino acids • know that peptide link can be hydrolysed producing amino acids • identify the amino acids given when a peptide is hydrolysed	• Draw the structure of peptides formed from joining amino acids together (AO2 - Apply knowledge and understanding). • Identify amino acids formed when peptides are hydrolysed (AO2 - Apply knowledge and understanding). • Identify the primary, secondary and tertiary parts of the structure of some proteins (AO2 - Apply knowledge and understanding). • Students can carry out some thin-layer chromatography of some amino acids to identify an unknown amino acid (AO2 - Apply knowledge and understanding; AT i - Use thin-layer or paper chromatography).	• January 2010 Unit 4 Question 6 (QW10.4.06) • SAMS A level Paper 2 Questions 5 • June 2011 Unit 4 Question 4c (QS11.4.04) • January 2011 Unit 4 Question 4f (QW11.4.04)	Structure of amino acids and proteins (rotatable) https://undergrad-ed.chemistry.ohio-state.edu/jmol-viewer/# RSC resource on basic biochemistry http://www.rsc.org/Education/Teachers/Resources/cfb/proteins.htm

		• know that amino acids can be separated and identified by thin-layer chromatography, including the use of R_f values.			

3.3.13.3 Enzymes

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the structure of enzymes. Understand the action of enzymes in terms of active sites. Understand the principle of drug action and the use of computer aided design.	0.2 weeks	**Students should be able to:** • explain that enzymes are proteins which act through a stereospecific active site that binds to a substrate • explain how drugs, which can be designed with the aid of computers, can act to inhibit enzymes by blocking active sites, but that the correct enantiomer is required.	• Use a right handed glove with their right/left hands to model enzyme action (AO2 - Apply knowledge and understanding).		RSC resource on basic biochemistry of enzymes http://www.rsc.org/Education/Teachers/Resources/cfb/enzymes.htm Useful animations on action of enzymes (eg hydrolysis of sucrose) http://doctorprodigious.wordpress.com/hd-animations/

3.3.13.4 DNA

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the structure of the components of DNA (given on data sheet). Understand the nature of nucleotides. Understand the structure of single DNA strands and the arrangement of these together in the double helix structure.	0.3 weeks	**Students should be able to:** • identify the components of DNA • explain how the two DNA strands interact with hydrogen bonds between base pairs.	• Make a 2D or 3D model of DNA using cut out components (AO2 - Apply knowledge and understanding). • Label a diagram of DNA to show the components and the hydrogen bonding between base pairs (AO1 - Demonstrate knowledge and understanding of scientific ideas).	• SAMs A-level Paper 2 (set 1) Question 8	How Stuff Works on the structure of DNA http://science.howstuffworks.com/life/cellular-microscopic/dna1.htm Simple animation showing the structure of DNA: http://www.youtube.com/watch?v=qy8dk5iS1f0 Useful animations on biochemistry http://doctorprodigious.wordpress.com/hd-animations/ *Chemistry review* article: Why is DNA helical? (Volume 1, edition 1)

3.3.13.5 Action of anti-cancer drugs

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how DNA replicates and how anti-cancer drug cisplatin prevents this.	0.2 weeks	**Students should be able to:** • describe how DNA replicates in simple terms • explain how the anti-cancer drug cisplatin prevents DNA replication • explain why some drugs can have adverse effects and appreciate the balance between benefits and adverse effects of any drug.	• Write notes to accompany a sequence of diagrams showing DNA replication (AO1 - Demonstrate knowledge and understanding of scientific ideas). • Write notes to accompany a diagram showing the action of cisplatin (AO1 - Demonstrate knowledge and understanding of scientific ideas). • Evaluate the benefits and adverse effects of using drugs such as cisplatin (AO3 - Analyse, interpret and evaluate scientific information).	• SAMs A-level Paper 2 (set 1) Question 8	Useful animations on biochemistry (DNA replication) http://doctorprodigious.wordpress.com/hd-animations/ Youtube video on action of cisplatin http://www.youtube.com/watch?v=Wq_up2uQRDo Cisplatin – molecule of the month http://www.chm.bris.ac.uk/motm/cisplatin/htmlonly/ *Chemistry review* article: Metals in medicine (Volume 8, edition 2) *Chemistry review* article: Curing cancer with chemistry (Volume 18, edition 3 *Chemistry review* article: Cisplatin: from accidental discovery to wonder drug (Volume 21, edition 4)

3.3.14 Organic synthesis

The formation of new organic compounds by multi-step syntheses using reactions included in the specification is covered in this section

Prior knowledge:

AS Chemistry

- All organic chemistry topics.

A-level Chemistry

- 3.3.8–3.3.13

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Devise synthetic routes to make specified compounds.	1.0 weeks	**Students should be able to:** • devise synthetic routes, with up to four steps, to make specific organic compounds using the reactions in the specification • explain why processes are designed to avoid solvents, non-hazardous starting materials and have steps with high atom economy.	• Devise synthetic routes, including reaction conditions, to make organic compounds using reactions in the specification (AO2 - Apply knowledge and understanding). • Describe features of processes that improve sustainability (A03 - Analyse, interpret and evaluate scientific information).	• Specimen Paper CHM4 Question 8 (QSP.4.08) • Specimen Paper CHM4 Question 9 (QSP.4.09) • June 2006 Unit 4 Question 6 (QS06.4.06) • January 2003 Unit 4 Question 7 (QW03.4.07) • June 2002 Unit 4 Question 7 (QS02.4.07)	RSC synthesis resource http://www.rsc.org/learn-chemistry/resource/res00000003/synthesis-explorer *Chemistry review* article: New tricks for stacking bricks: modern approaches to organic synthesis (Volume 12, edition 3) *Chemistry review* article: Salbutamol: saving your breath (Volume 18, edition 4)

3.3.15 Nuclear magnetic resonance spectroscopy

Chemists use a variety of techniques to deduce the structure of compounds. In this section, nuclear magnetic resonance spectroscopy is added to mass spectrometry and infrared spectroscopy as an analytical technique. The emphasis is on the use of analytical data to solve problems rather than on spectroscopic theory.

Prior knowledge:

AS Chemistry

- 3.3.1.1 – Nomenclature.

- 3.3.6 – Organic analysis.

This section could be taught before the A-level Organic Chemistry topics allowing the technique to be re-visited and to be part of practice questions throughout the teaching of the A-level Organic topics.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Using ^{1}H and ^{13}C NMR to deduce information about the structure of organic molecules. Understand similarities and differences between ^{1}H and ^{13}C NMR. Understand the use of TMS and suitable solvents.	2.0 weeks	**Students should be able to:** • understand the use of TMS and the δ scale for chemical shift • understand the use of deuterated solvents or CCl_4 • use the n+1 rule to deduce spin-spin splitting patterns of adjacent, non-equivalent	• Predict the number, position, relative intensity and splitting of signals in the ^{1}H NMR spectrum of compounds (AO2 - Apply knowledge and understanding). • Predict the number and position of signals in the ^{13}C NMR spectrum of compounds (AO2 - Apply knowledge and understanding). • Use data from NMR, and other analytical methods on the	• June 2013 Unit 4 Question 7 (QS13.4.07) • January 2013 Unit 4 Question 5 (QS13.4.05) • June 2012 Unit 4 Question 8 (QS12.4.08)	RSC Spectral School: http://www.rsc.org/learn-chemistry/collections/spectroscopy?uol_r=3ae0be55 RSC Spectroscopy resource: http://www.rsc.org/learn-chemistry/resource/res00000847/spectroscopy Database of spectra for organic compounds

		protons in aliphatic compounds • deduce the structure of compounds using ^{1}H NMR to deduce structures including the number, position, relative intensity and splitting of signals • deduce the structure of compounds using ^{13}C NMR to deduce structures including the number and position of signals.	specification, to deduce the structure of compounds (AO2 - Apply knowledge and understanding; MS3.1 Translate information between graphical, numerical and algebraic forms).	• January 2011 Unit 4 Question 5 (QW11.4.05) • January 2003 Unit 4 Question 5 (QW03.4.05) • January 2002 Unit 4 Question 4 (QW02.4.04)	http://sdbs.db.aist.go.jp/sdbs/cgi-bin/cre_index.cgi CLEAPSS Spectra (Secondary Science Guide L202) http://www.cleapss.org.uk/secondary/secondary-science/secondary-science-guides?start=20 (Subscription required)

3.3.16 Chromatography

Chromatography provides an important method of separating and identifying components in a mixture. Different types of chromatography are used depending on the composition of mixture to be separated

Prior knowledge:

AS level Chemistry

- 3.3.13 Amino acids, proteins and DNA (this section requires use of thin-layer chromatography for analysis of amino acids – it could be taught before or after this section)

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Describe the similarities and differences between thin-layer, column and gas chromatography. Explain how chromatography works. Use chromatography to separate and identify substances. **Required practical 12** Separation of species by thin-layer chromatography Research method for TLC	0.6 weeks	**Students should be able to:** • describe the similarities and differences between thin-layer, column and gas chromatography • explain how chromatography works • use retention times and R_f values to identify substances • describe the use of mass spectroscopy to analyse substances separated by gas chromatography.	• Produce a summary to compare similarities and differences between thin-layer, column and gas chromatography (AO1 - Demonstrate knowledge and understanding of scientific ideas). • Separate mixtures and identify substances (eg amino acids) by thin-layer chromatography (AO2 - Apply knowledge and understanding; AT i - Use thin-layer or paper chromatography). • Use retention time and R_f data to identify substances separated by chromatography.	• January 2011 Unit 4 Question 4f (QW11.4.04)	AQA Chromatography Teachers' Notes: http://filestore.aqa.org.uk/resources/chemistry/AQA-7405-TN-CHROMATOGRAPHY.PDF RCS video on TLC http://www.rsc.org/learn-chemistry/resource/res00001074/thin-layer-chromatography Modern Chemical Techniques RSC resource: http://www.rsc.org/learn-chemistry/resource/res00001301/chromatography

					Chemistry Review articles: How pure is your aspirin? (Volume 6, edition 3) What is chromatography? (Volume 8, edition 2) Antarctic atmospheric chemistry (Volume 13, edition 2) Drugs on money (Volume 13, edition 4) Thin-layer chromatography (Volume 14, edition 3) Body oddities: the chemical reactions of eating (Volume 21, edition 1) Body oddities: the chemical reactions of eating (Volume21, edition 4)

3.1.9 Rate Equations

In rate equations, the mathematical relationship between rate of reaction and concentration gives information about the mechanism of a reaction that may occur in several steps

Prior knowledge:

AS Chemistry

- 3.1.5 – Kinetics.

3.1.9.1 Rate Equations

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand rate equations and order of reaction. Deduce order of reaction, rate equations and rate constants from rate data. Describe how the rate constant changes with temperature. Use the Arrhenius equation.	0.5 week	**Students should be able to:** • define the terms order of reaction and rate constant • describe how changing concentration of a reagent affects the rate when the order with respect that reagent is 0, 1 or 2 • determine the values and units for rate constants given appropriate data • describe how rate constants change with temperature • perform calculations using the Arrhenius equation • plot straight line graphs of ln k versus 1/T to determine the activation energy of a reaction.	• Describe how changes in concentration will affect reaction rates given the rate equation (AO2 - Apply knowledge and understanding). • Use rate equations to determine reaction rates or rate constants (with units) using initial rate data (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in calculation; MS2.3 – substitute numerical values into algebraic equations; MS2.4 - Solve algebraic equations). • Students use a graph of concentration–time and calculate the rate constant of a zero-order reaction by determination of the gradient. (AO2 - Apply knowledge and understanding; MS3.3 - Determine the slope of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship). • Students can measure the activation energy for the catalysed and uncatalysed reaction of iodine with peroxodisulphate(VI) ions by experiment and plotting graphs (AO2 - Apply knowledge and understanding; MS3.3 - Determine the slope of a linear graph).	• June 2006 Unit 4 Question 5a and 5b (QS06.4.05) • June 2003 Unit 4 Question 1 (QS03.4.01)	Calculations in AS / A Level Chemistry (Clark) ISBN 9780582411272 *Chemistry Review* article: Establishing a rate equation (Volume 14, edition 2) Many suitable calculations can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ Advanced Practical Chemistry (ILPAC) ISBN 0719575079

3.1.9.2 Determination of rate equation

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand that rate equations have to be determined by experiment. Link rate equations to mechanisms. Determine rate using concentration-time graphs. Use rate-concentration graphs to deduce order for a reagent. **Required practical 7** Measure the rate of a reaction by an initial rate method, and a continuous monitoring method. Students could research the method. Students could also do practical 3 here and use Arrhenius equation.	2.0 weeks	**Students should be able to:** • explain that rate equations can only be determined by experiment • use concentration-time graphs to find rates (including initial rates) • use initial rate data to determine rate equations • use rate-concentration data/graphs to find orders of reaction with respect to a reagent • link rate equations to mechanism and determine rate determining steps.	• Determine rate equations, rate constants (with units) using initial rate data (AO2 - Apply knowledge and understanding; MS0.0 - Recognise and make use of appropriate units in calculation; MS2.3 – substitute numerical values into algebraic equations; MS2.4 - Solve algebraic equations). • Students do the iodine clock reaction and determine the order of reaction for a reactant (AO2 - Apply knowledge and understanding; PS 2.4 - Identify variables including those that must be controlled; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph AT a, k, l). • Students can react calcium carbonate or magnesium with acid of different concentrations and plot volume of gas formed against time for continuous monitoring. Initial rates could be found from these plots and compared (AO2 - Apply knowledge and understanding; PS	• SAMs A-level paper 2 (set 1) Q2 • June 2013 Unit 4 Question 1 (QS13.4.01) • January 2013 Unit 4 Question 1 (QW13.4.01) • January 2011 Unit 4 Question 1 (QW11.4.01) • January 2010 Unit 4 Question 3 (QW10.4.03) • January 2006 Unit 4 Question 1 (QW06.4.01) • January 2003 Unit 4 Question 1 (QW03.4.01)	Calculations in AS / A Level Chemistry (Clark) ISBN 9780582411272 *Chemistry Review* article: Establishing a rate equation (Volume 14, edition 2) ILPAC Unit P5: Chemical Kinetics (free download from www.nationalstemcentre.org.uk) Avogadro web site on rate equations: http://www.avogadro.co.uk/kinetics/rate_equation.htm

			2.4 - Identify variables including those that must be controlled; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change; AT a, k, l). • Students can use colorimetry for continuous monitoring experiments (eg bromine + methanoic acid; propanone + iodine) to determine order (AO2 - Apply knowledge and understanding; PS 3.1 - Plot and interpret graphs; PS 3.2 - Process and analyse data using appropriate mathematical skills; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change; AT a, k, l).		

			• Students could be given data to plot and interpret in terms of order with respect to a reactant. Alternatively, students could just be given appropriate graphs and asked to derive order(s) (AO2 - Apply knowledge and understanding; MS3.1 - Translate information between graphical, numerical and algebraic forms; MS3.2 - Plot two variables from experimental or other data; MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship; MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change). • Students calculate the rate constant of a zero-order reaction by determining the gradient of a concentration–time graph (MS3.3 - Determine the slope and intercept of a linear graph; MS3.4 - Calculate rate of change from a graph showing a linear relationship). • Students plot concentration–time graphs from collected or supplied data and draw an appropriate best-fit curve. Students draw tangents to such curves to deduce rates at different times (MS3.5 - Draw and use the slope of a tangent to a curve as a measure of rate of change).		

3.1.10 Equilibrium constant K_p for homogeneous systems

The further study of equilibria considers how the mathematical expression for the equilibrium constant K_p enables us to calculate how an equilibrium yield will be influenced by the partial pressures of reactants and products. This has important consequences for many industrial processes.

Prior knowledge:

AS Chemistry

- 3.1.6 – Chemical equilibria, Le Châtelier's principle and K_c

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the concept of and calculate partial pressures using mole fractions. Write expressions for and calculate K_p including units. Perform calculations involving K_p. Predict how changes in conditions affect the position of an equilibrium and the value of K_p. The effect of a catalyst affects an equilibrium and K_p.	2.0 weeks	**Students should be able to:** • calculate equilibrium quantities, mole fractions and partial pressures for equilibrium mixtures • write an expression for K_p for a reaction and calculate the value of K_p with units • predict and justify how changes in temperature and pressure affect the position of an equilibrium, and how this may or may not affect the value of K_p • understand how a catalyst affects an equilibrium and the value of K_p.	• Given initial amounts of substances and one substance at equilibrium, find the quantity of each reagent at equilibrium (AO2 - Apply knowledge and understanding). • Calculate mole fractions and then partial pressures in order to determine K_p, with units (AO2 - Apply knowledge and understanding; MS2.3 - Substitute numerical values into algebraic equations using appropriate units for physical quantities). • For given equilibria with enthalpy change data, predict the effect on the position of an equilibrium and the value of K_p (AO2 - Apply knowledge and understanding).	• January 2007 Unit 4 Question 2 (QW04.4.02) • June 2007 Unit 4 Question 1 (QS07.4.01) • January 2008 Unit 4 Question 3 (QW08.4.03) • June 2008 Unit 4 Question 3 (QS08.4.03) • January 2009 Unit 4 Question 3 (QW09.4.03) • June 2009 Unit 4 Question 2 (QS09.4.02)	Calculations for A level Chemistry (Ramsden) ISBN 9780748758395 Many suitable calculations can be found at http://www.docbrown.info/ and http://www.chemsheets.co.uk/ (subscription required)