OXFORD
INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL A-LEVEL CHEMISTRY

(9620)

OUTLINE SCHEME OF WORK

For teaching from September 2016 onwards
For A2 exams in June 2018 onwards

CONTENTS

INTRODUCTION

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

The scheme of work is designed to be a flexible medium term plan for the teaching of content and development of the skills that will be assessed. It covers the needs of the specification for the international A2 units of Chemistry 9620.

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

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

The majority of the prior knowledge listed in this scheme of work will come from the AS units of the course. Where GCSE prior knowledge is referred to, this comprises knowledge from the current double science (ie Core and Additional Science) International GCSE specifications. Students who studied the separate Science International GCSE courses will have this knowledge but may also have been introduced to other topics which are relevant to the International A-level content. Topics only found in separate sciences are not included in the prior knowledge section.

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

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

SCHEME OF WORK

3.1 Physical chemistry

This could be taught alongside topics from Organic and/or Inorganic Chemistry. Prior knowledge required from other topics on the specification will be highlighted at the start of each section of the Scheme of Work.

3.1.8 Thermodynamics

The further study of thermodynamics builds on the Energetics section and is important in understanding the stability of compounds and why chemical reactions occur. Enthalpy change is linked with entropy change enabling the free-energy change to be calculated.

Prior knowledge:

International AS Chemistry

- 3.1.4 - Energetics

3.1.8.1 Born-Haber Cycles

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Definitions of enthalpy changes used in Born-Haber and solution enthalpy cycles. Using Born-Haber cycles for ionic compounds. Considering covalent character of ionic compounds.	1.5 weeks	**Students should be able to:** • define lattice enthalpy (formation and dissociation), enthalpy of formation, ionisation enthalpy, enthalpy of atomisation, bond enthalpy, electron affinity, enthalpy of solution, hydration enthalpy	• Write equations to represent enthalpy changes. • Construct Born-Haber cycles and use them to calculate missing enthalpy change values. • Compare and comment on values of enthalpy changes from Born-Haber cycles with those calculated theoretically using the perfect ionic model.	• June 2013 Unit 5 Question 1 (QS13.5.01) • June 2013 Unit 5 Question 2 (QS13.5.02) • January 2013 Unit 5 Question 2 (QW13.5.02) • June 2011 Unit 5 Question 1 (QS11.5.01)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 Many suitable calculations can be found at docbrown.info

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Using solution enthalpy cycles for ionic compounds.		• draw and use Born-Haber cycles to find missing values of enthalpy changes • comment on the covalent character of an ionic compounds by comparing lattice enthalpies found using Born-Haber cycles with those calculated theoretically using the perfect ionic model. • draw enthalpy of solution cycles to calculate values of missing enthalpy changes.	• Construct and use cycles involving the solution of ionic compounds in water to find missing enthalpy change values. • Rich question – predict the relative magnitude of the lattice enthalpy of the following compounds: aluminium oxide, potassium oxide, sodium chloride, sodium oxide. • Rich question – for an ionic compound with covalent character, deduce whether the lattice enthalpy will have a greater or smaller magnitude than that calculated theoretically from the perfect ionic model.	• January 2010 Unit 5 Question 4 (QW10.5.04)	

3.1.8.2 Gibbs free-energy change ΔG and entropy change ΔS

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
To calculate entropy changes for reactions. To calculate Gibbs free-energy changes and determine whether reactions are feasible at various temperatures.	1.5 weeks	**Students should be able to:** • describe entropy in terms of disorder • predict whether reactions have an increase or decrease in entropy • calculate the entropy change for a reaction • calculate the Gibbs free-energy change for a reaction at a given temperature • determine whether a reaction is feasible at a given temperature • calculate the temperature at which a reaction becomes feasible • use entropy changes to explain why some endothermic reactions are feasible.	• Rank given substances in terms of entropy. • Use entropy values to calculate the entropy change for a reaction. • Predict, where possible, whether reactions have an increase or decrease in entropy. • Use the equation $\Delta G = \Delta H - T\Delta S$ to determine whether reactions are feasible at given temperatures, and determine the temperature at which reactions become feasible. • Plot graphs of ΔG versus T to determine ΔH and ΔS. • Forecast how temperature affects the feasibility of reactions given the sign of the enthalpy and entropy changes. • Apply the equation $\Delta G = \Delta H - T\Delta S$ to state changes to find ΔH, ΔS, melting and/or boiling points. • Determine ΔH and ΔS for the vaporization of water using a kettle.	• June 2013 Unit 5 Question 3 (QS13.5.03) • January 2012 Unit 5 Question 2 (QW12.5.02) • June 2011 Unit 5 Question 2 (QS11.5.02) • June 2010 Unit 5 Question 6 (QS10.5.06)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 Many suitable calculations can be found at docbrown.info

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		- Use the relationship $\Delta G = \Delta H - T\Delta S$ to determine how ΔG varies with temperature			

3.1.9 Electrode potential and electrochemical cells

Redox reactions take place in electrochemical cells where electrons are transferred from the reducing agent to the oxidising agent indirectly via an external circuit. A potential difference is created that can drive an electric current to do work. Electrochemical cells have very important commercial applications as a portable supply of electricity to power electronic devices such as mobile phones, tablets and laptops. On a larger scale, they can provide energy to power a vehicle.

Prior knowledge:

International AS Chemistry

- 3.1.5 – Oxidation, reduction and redox equations

3.1.9.1 Electrode potentials and cells

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The idea of a cell that has a potential difference being made by combining two half cells (electrodes). How potentials are measured relative to the Standard Hydrogen Electrode and under standard conditions. Use the electrochemical series to calculate the EMF of cells and predict the direction of simple redox reactions.	1. 0 week	**Students should be able to:** • understand that there is a potential difference between two half cells (electrodes) that are joined • use cell notation to represent cells • understand that potentials are measured relative to the Standard Hydrogen Electrode • understand that the potential of an electrode is affected by conditions	• Students make simple cells and use them to measure EMF and unknown electrode potentials. • Students write the standard cell notation for cells. • Students predict how changes in conditions will affect EMF. • Students could be asked to plan and carry out an experiment to investigate the effect of changing conditions, such as concentration or temperature, in a voltaic cell such as $Zn\|Zn^{2+}\|\|Cu^{2+}\| Cu$.	• January 2013 Unit 5 Question 7 (QW13.5.07) • January 2012 Unit 5 Question 4 (QW12.5.04) • June 2006 Unit 5 Question 5 (QS06.5.05) • January 2004 Unit 5 Question 4 (QW04.5.04)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 *Chemistry Review* articles: Understanding electrode potentials (Volume 12, edition 1) Electrode potentials (Volume 15, edition 3)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Cell Representation. **Required practical 6** Measuring the EMF of an electrochemical cell.		• know the standard conditions under which potentials are measured • know that electrode potentials are listed in order in the electrochemical series • use the electrochemical series to predict the direction of simple redox reactions.	• Students could use *E* values to predict the direction of simple redox reactions, and then test these predictions by simple test-tube reactions.		Some suitable problems can be found at docbrown.info

3.1.9.2 Commercial applications of electrochemical cells

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
That cells can be used as a source of energy. That cells can be non-rechargeable or rechargeable. That fuel cells can be used to generate an electric current. That there are benefits and risks associated with using these cells.	1.0 week	**Students should be able to:** • know the reactions occurring in a lithium cell and in an alkaline fuel cell. • classify cells as non-rechargeable, rechargeable or fuel cells. • use given electrode data to deduce the reactions occurring in cells and deduce the EMF of a cell • explain how the electrode reactions can be used to generate an electric current.	• Explain the differences between different types of cells. • Write half equations for a variety of different examples and calculate the EMF in each case.	• June 2013 Unit 5 Question 5 • June 2012 Unit 5 Question 5	Nuffield Science Data Book (free download): nationalstemcentre.org.uk Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 **Toyota fuel cell video** youtube.com/watch?v=g35I61FjKiI **Fuel cell article** rsc.org/chemistryworld/Issues/2006/March/FuelCells.asp

3.1.10 Acids and bases

Acids and bases are important in domestic, environmental and industrial contexts. Acidity in aqueous solutions is caused by hydrogen ions and a logarithmic scale, pH, has been devised to measure acidity. Buffer solutions, which can be made from partially neutralised weak acids, resist changes in pH and find many important industrial and biological applications.

Prior knowledge:

International AS Chemistry

- 3.1.7 – Chemical equilibria, Le Châtelier's principle and Kc

3.1.10.1 Brønsted-Lowry acid-base equilibria in aqueous solutions

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The idea of acids as proton donors and bases as proton acceptors.	0.2 weeks	**Students should be able to:** • define Brønsted-Lowry acids and bases • identify species as Brønsted-Lowry acids or bases in proton transfer reactions.	• Identify which species acts as the acid and which as the base in Brønsted-Lowry acid-base reactions.	• June 2012 Unit 4 Question 3ab (QS12.4.03)	Theory of acids history websites: bbc.co.uk/dna/ptop/plain/A708257 pubs.acs.org/subscribe/archive/tcaw/12/i03/pdf/303chronicles.pdf RSC acid-base simulator: rsc.org/learn-chemistry/resource/res00001457/acid-base-solutions-rsc-funded

3.1.10.2 Definition and determination of pH

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Calculate the pH of strong acids from concentration and vice versa.	0.4 weeks	**Students should be able to:** • calculate pH of a strong acid from its concentration • calculate the concentration of a strong acid from its pH • calculate the pH when a strong acid is diluted.	• Identify acids as being strong or weak and monoprotic or diprotic. • Calculate the pH of strong acids from the acid concentration, including examples where the acids are diluted. • Calculate the concentration of strong acids from the pH.	• June 2009 Unit 4 Question 3a (QS09.4.03)	RSC pH simulator: rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded Some suitable problems can be found at docbrown.info
Extension					Estimate the number of H^+ ions in a drop of water rsc.org/learn-chemistry/resource/res00000665/h-ions-in-water

3.1.10.3 The ionic product of water K_w

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Use K_w to calculate the pH of strong bases.	0.3 weeks	**Students should be able to:** • show that $K_w = [H^+][OH^-]$ • use K_w to find the pH of strong bases from its concentration, and vice versa • calculate the pH of water at different temperatures	• Derive the expression $K_w = [H^+][OH^-]$ • Calculate the pH of strong bases from the base concentration and vice versa, including dilutions. • Calculate the pH of water at different temperatures. • Explain how the pH and neutrality of water is or is not affected by changes in temperature.	• January 2013 Unit 4 Question 2a (QW13.4.02) • June 2011 Unit 4 Question 2a (QS11.4.02) • June 2010 Unit 4 Question 5ab (QS10.4.05)	RSC pH simulator: rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded Some suitable problems can be found at docbrown.info

3.1.10.4 Weak acids and bases; K_a for weak acids

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the term *weak* in relation to acids and bases. Use K_a to find the pH of weak acids from the concentration and vice versa. Relate K_a to pK_a	0.3 weeks	**Students should be able to:** • write expressions for K_a for stated weak acids • perform calculations linking K_a to concentration and pH • convert K_a values to pK_a and vice versa • calculate the pH of water at different temperatures.	• Explain the difference between strong and weak acids and bases. • Derive expressions for K_a for stated acids. • Perform calculations linking K_a to concentration and pH. • Convert K_a values to pK_a and vice versa, and use these values to rank acids in order of strength. • Measure K_a of a weak acid by measuring pH at half neutralisation.	• January 2012 Unit 4 Question 4b (QW12.4.04) • January 2006 Unit 4 Question 2ab (QW06.4.02)	RSC acid-base simulator: rsc.org/learn-chemistry/resource/res00001457/acid-base-solutions-rsc-funded RSC pH simulator: rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded Creative problem solving in Chemistry – weak acids: rsc.org/learn-chemistry/resource/res00000677/a-weak-acid Some suitable problems can be found at docbrown.info

3.1.10.5 pH curves, titrations and indicators

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Calculate the pH of the solution formed when strong or weak acids react with strong bases. Sketch pH curves and choose suitable indicators for titrations. **Required practical 7** Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base.	1.0 weeks	**Students should be able to:** • calculate pH of a mixture of a strong acid with a strong base • calculate the pH of a mixture of a weak acid with a strong base • sketch pH curves for titrations of strong/weak acids with strong/weak bases • choose a suitable indicator for acid-base titrations.	• Perform calculations to find the pH of mixtures of strong/weak acids with strong bases, with either excess acid or base. • Produce pH curves by experiment. • Sketch pH curves for given acid and base combinations, and choose a suitable indicator.	• June 2013 Unit 4 Question 3 (QS13.4.03) • June 2011 Unit 4 Question 1 (QS11.4.01) • June 2005 Unit 4 Question 2 (QS05.4.02) • June 2005 Unit 5 Question 2 (QS05.5.02) • June 2003 Unit 4 Question 3 (QW03.4.03)	RSC pH simulator: rsc.org/learn-chemistry/resource/res00001458/ph-scale-simulation-rsc-funded pH curve simulator: terpconnect.umd.edu/~toh/models/TitrationDemo.html Some suitable problems can be found at docbrown.info
Extension			Write spreadsheets to calculate the pH during a titration and to plot the pH curve.		

3.1.10.6 Buffer action

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know what buffer solutions are, how they are made and what they are used for. Explain how acidic and basic buffer solutions work. Calculate the pH of acidic buffer solutions.	0.6 weeks	**Students should be able to:** • describe what a buffer solution is and how it is made • explain qualitatively how acidic/basic buffer solutions work • know some uses of buffer solutions • calculate the pH of a buffer solution.	• Describe how buffer solutions are made, how they work and what they are used for. • Calculate the pH of a buffer solution given details about quantities of the reagents it is made from, and changes in pH when small amounts of acid/alkali are added to buffer solutions. • Students could prepare a solution of a specific pH and then test the solution to check its pH and buffer action.	• January 2013 Unit 4 Question 2 (QW13.4.02) • January 2011 Unit 4 Question 2 (QW11.4.02) • January 2005 Unit 4 Question 8 (QW05.4.08) • January 2002 Unit 4 Question 3 (QW02.4.03)	Sandcastles and mud huts – buffering action in blood (Hancock) ISBN 9780340543696 Some suitable problems can be found at docbrown.info

3.1.11 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:

International AS Chemistry

- 3.1.6 - Kinetics

3.1.11.1 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 to 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	• Describe how changes in concentration will affect reaction rates given the rate equation. • Use rate equations to determine reaction rates or rate constants (with units) using initial rate data. • Students use a graph of concentration–time and calculate the rate constant of a zero-order reaction by determination of the gradient. • Students can measure the activation energy for the catalysed and uncatalysed reaction of iodine with peroxodisulphate (VI) ions by experiment and plotting graphs.	• June 2006 Unit 4 Question 5 a) b) (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 docbrown.info Advanced Practical Chemistry (ILPAC) ISBN 0719575079

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• plot straight line graphs of ln *k* versus 1/*T* to determine the activation energy of a reaction.			

3.1.11.2 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 8** Measure the rate of a reaction by an initial rate method, and a continuous monitoring method.	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. • Practical Opportunity: Students do the iodine clock reaction and determine the order of reaction for a reactant. • Practical Opportunity: 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. • Practical Opportunity: Students can use colorimetry for continuous monitoring experiments (e.g. bromine + methanoic acid; propanone + iodine) to determine order. • 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).	• SAMS A level paper 2 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 nationalstemcentre.org.uk)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			• Students calculate the rate constant of a zero-order reaction by determining the gradient of a concentration–time graph. • 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.		

3.1.12 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:

International AS Chemistry

- 3.1.7 – Chemical equilibria, Le Châtelier's principle and Kc

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. • Calculate mole fractions and then partial pressures in order to determine K_p, with units. • For given equilibria with enthalpy change data, predict the effect on the position of an equilibrium and the value of K_p.	• 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 docbrown.info

3.2 Inorganic chemistry

3.2.4 Properties of Period 3 elements and their oxides

The reactions of the Period 3 elements with oxygen are considered. The pH of the solutions formed when the oxides react with water illustrates further trends in properties across this period. Explanations of these reactions offer opportunities to develop an in-depth understanding of how and why these reactions occur.

Prior knowledge:

International AS Chemistry
- 3.1.3 – Bonding
- 3.2.1 – Periodicity

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The reaction of Na and Mg with water. Reactions of Na, Mg, Al, Si, P and S with oxygen. Reactions of Na, Mg, Al, Si, P and S with chlorine. Melting points of Period 3 oxides and chlorides. Reactions of Period 3 oxides with water.	1.2 weeks	**Students should be able to:** • describe and write equations for the reactions of Na and Mg with water (and Mg with steam) • describe and write equations for reactions of Na, Mg, Al, Si, P and S with oxygen and with chlorine • describe and explain the trend in melting points of Period 3 oxides and chlorides	• Practical/Demo opportunity: react Na and Mg with cold water and Mg with steam. Write equations and record observations for reactions occurring. • Practical/Demo opportunity: react specified Period 3 elements with oxygen; react Period 3 elements with chlorine; react specified oxides and chlorides with water. Write equation and record observations for reactions occurring. • Plot a graph of melting points of Period 3 oxides and annotate it with explanation of the relative melting points.	• June 2013 Unit 5 Question 4 (QS13.5.04) • January 2013 Unit 5 Question 4 (QW13.5.04) • January 2012 Unit 5 Question 3 (QW12.5.03) • January 2011 Unit 5 Question 3 (QW11.5.03) • January 2004 Unit 5 Question 2 (QW04.5.02)	Youtube video on Period 3 oxides Youtube video of reaction of phosphorus with oxygen

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Reactions of Period 3 chlorides with water.		• write equations for the reactions of Period 3 oxides and chlorides with water and describe the pH of the solutions formed • describe the structure and bonding of Period 3 oxides and chlorides, and link this to how they react with water.	• Plot a graph of melting points of Period 3 chlorides and annotate it with explanation of the relative melting points. • Complete tables including equations to show how Period 3 elements react with oxygen, and how Period 3 oxides and chlorides react with water. • Draw structures of the anions formed when oxides and chlorides react with water.	• June 2004 Unit 5 Question 2 (QS04.5.02)	

3.2.5 Transition metals

The 3d block contains 10 elements, all of which are metals. Unlike the metals in Groups 1 and 2, the transition metals Ti to Cu form coloured compounds and compounds where the transition metal exists in different oxidation states. Some of these metals are familiar as catalysts. The properties of these elements are studied in this section with opportunities for a wide range of practical investigations.

Prior knowledge:

International AS Chemistry

- 3.1.1 – Atomic structure (electron structure)
- 3.1.5 – Oxidation, reduction and redox reactions (oxidation states, oxidation, reduction, redox equations)

3.2.5.1 General properties of the transition metals

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Give the electron structure of transition metals and their ions. Know the characteristic properties of transition metals. Understand the terms complex, ligand co-ordinate bond, and co-ordination number.	0.2 weeks	**Students should be able to:** • write the electron structure of first row transition metals and their ions • describe what a transition metal is in terms of electron structure • describe the characteristic properties of transition metals • define the terms ligand, complex, co-ordinate bond and co-ordination number.	• State the electron structure of first row transition metals and their ions. • Explain why the elements Ti to Cu have properties characteristic of transition metals, and what those characteristics are. • Identify the oxidation state of the metal, the ligands and co-ordination number in a series of complexes. • Identify an element from the series Ti to Cu and find examples for that element to confirm its characteristic properties.	• January 2005 Unit 5 Question 6a (QW05.5.06) • June 2010 Unit 5 Question 4ab (QS10.5.06) • January 2011 Unit 5 Question 4ab (QW11.5.04)	*Chemistry Review* article: Vanadium (Volume 19, edition 4)

3.2.5.2 Substitution reactions

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the different types of ligands. Understand ligand exchange. Know about oxygen transfer by haemoglobin. Understand the chelate effect.	1.0 weeks	**Students should be able to:** • explain the difference between, and give examples of monodentate, bidentate and multidentate ligands • explain what happens in a ligand substitution (exchange) reaction and why there may be a change in co-ordination number • describe what haem is, how oxygen is carried in blood and why carbon monoxide is toxic • describe and explain the chelate effect in terms of enthalpy and entropy changes.	• Give examples of monodentate, bidentate and multidentate ligands. • Students should carry out substitution reactions of metal aqua complexes with monodentate ligands (from ammonia and concentrated hydrochloric acid) to consider whether there is a change in co-ordination number and whether all the water ligands are substituted. • Students could carry out test-tube reactions of complexes with monodentate, bidentate and multidentate ligands to compare ease of substitution.	• June 2010 Unit 5 Question 4abde (QS10.5.06) • January 2005 Unit 5 Question 6b (QW05.5.06) • June 2004 Unit 5 Question 4b (QS04.5.04) • June 2002 Unit 5 Question 6 (QS02.5.06)	Molecule of month article on EDTA chm.bris.ac.uk/motm/edta/edtah.htm - Practical Uses of EDTA

3.2.5.3 Shapes of complex ions

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know the shapes of complexes with 2/4/6 ligands. Understand how complexes can show *cis-trans (E-Z)* or optical isomerism.	0.3 weeks	**Students should be able to:** • sketch examples of octahedral, tetrahedral, square planar and linear complexes • know how some complexes can show *cis-trans (E-Z)* or optical isomerism • know the complexes in cisplatin and Tollen's reagent.	• Give examples of and sketch the shape of octahedral, tetrahedral, square planar and linear complexes. • Explain how *cis-trans (E-Z)* isomerism arises in some octahedral and square planar complexes, including cisplatin, and draw the isomers. • Explain how optical isomerism arises in some octahedral complexes with bidentate ligands, and draw the isomers. • Students can use Molymod kits to make models of isomers.	• January 2011 Unit 5 Question 4 abc (QW11.5.04) • January 2004 Unit 5 Question 10b (QW04.5.10) • June 2003 Unit 5 Question 3abc (QS03.5.03)	Molymod molecular models. Shapes viewer (including inorganic complexes) undergrad-ed.chemistry.ohio-state.edu/jmol-viewer

3.2.5.4 Formation of coloured ions

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand why transition metal ions are coloured and what affects the colour. Use colorimetry to measure concentration of solutions.	0.6 weeks	**Students should be able to:** • explain why transition metal complexes are coloured • describe factors that affect the colour of transition metal ions • describe how colorimetry can be used to find the concentration of coloured ions in solution.	• Explain using diagrams and the equation $\Delta E = hv\ (= hc/\lambda)$ why transition metal complexes are coloured and what factors affect the colour. • Use a graph of absorption versus concentration to determine the concentration of the solution. • Use a colorimeter to produce a calibration curve and then find the concentration of a coloured solution, e.g. containing copper (II) ions.	• June 2013 Unit 5 Question 6 (QS13.5.06) • January 2012 Unit 5 Question 7ab (QW12.5.07) • June 2002 Unit 5 Question 3 (QW02.5.03)	Colorimetric determination of a copper ore: nuffieldfoundation.org/practical-chemistry/colorimetric-determination-copper-ore *Chemistry Review* article: Colorimetry (Volume 12, edition 3) RSC booklet on colorimetry from Gifted and Talented Chemistry: rsc.org/learn-chemistry/resource/res00000847/spectroscopy RSC Spectral School with range of resources: rsc.org/learn-chemistry/collections/spectroscopy

3.2.5.5 Variable oxidation states

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know what happens when vanadate (V) is reduced by zinc in acidic solution. How the redox potential for a transition metal is affected by the pH and ligand. The reduction of silver (I) in Tollen's reagent to test for aldehydes. Redox titrations, including calculations, of MnO_4^- with Fe^{2+} and $C_2O_4^{2-}$ in acidic solution.	2.5 weeks	**Students should be able to:** • describe and explain what happens when vanadate (V) ions are reduced by zinc in acidic solution • understand how the redox potential of a transition metal ion is affected by changes in pH and ligand • describe and explain the use of $Ag(NH_3)^{2+}$ in Tollen's reagent to distinguish between aldehydes and ketones • perform titrations and associated calculations for redox reactions of MnO_4^- with Fe^{2+} and $C_2O_4^{2-}$ in acidic solution.	• Students should react an acidified solution of ammonium vanadate (V) with zinc to observe colour changes, identify vanadium species and write redox reactions for each reduction reaction. • Compare redox potentials for Cr^{3+} at different pH values and different ligands. • Test aldehydes and ketones with Tollen's reagent. • Carry out redox titrations, including associated titrations, of Fe^{2+} with MnO_4^- in acidic solution (e.g. analysis of iron in iron tablets, analysis of iron in lawn sand, analysis of iron in steel, finding the M_r of hydrated ammonium (II) sulfate). • Carry out redox titrations, including associated titrations, of $C_2O_4^{2-}$ with MnO_4^- in acidic solution (e.g. finding the M_r of ethanedioic acid).	• June 2006 Unit 5 Question 1 (QW06.5.01) • June 2005 Unit 5 Question 4b (QS05.5.04) • June 2003 Unit 5 Question 2 (QS03.5.02) • January 2003 Unit 5 Question 7b (QW03.5.07)	Nuffield Science Data Book (free download): nationalstemcentre.org.uk Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510 ILPAC Advanced Practical Chemistry ISBN 9780719575075

3.2.5.6 Catalysts

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand what heterogeneous catalysts are and how they work, including examples and how they can become poisoned. Understand what homogeneous catalysts are, with specific examples.	1.0 weeks	**Students should be able to:** • describe what a heterogeneous catalyst is and the role of active sites and the support medium • explain, with the aid of equations, how V_2O_5, acts as a catalyst in the Contact Process • describe the use of Fe in the Haber process • explain how heterogeneous catalysts can become poisoned • describe what a homogeneous catalyst is and how reactions proceed through an intermediate species • describe, with the aid of equations, how Fe^{2+} catalyses the reaction between I^- and $S_2O_8^{2-}$ • describe, with the aid of equations, how Mn^{2+} catalyses the reaction between $C_2O_4^{2-}$ and MnO_4^-.	• Create a set of notes on how heterogeneous and homogeneous catalysts work, including the specific examples required: • V_2O_5 in the contact process. • Fe^{2+} ions in the reaction of I^- with $S_2O_8^{2-}$. • Mn^{2+} ions in the reaction of $C_2O_4^{2-}$ and MnO_4^-. • Students could investigate Mn^{2+} as the autocatalyst in the reaction between ethanedioic acid and acidified potassium manganate (VII).	• January 2013 Unit 5 Question 6 (QW13.5.06) • January 2012 Unit 5 Question 6 (QW12.5.06) • January 2011 Unit 5 Question 4d) (QW11.5.04) • January 2010 Unit 5 Question 1 (QW10.5.01) • June 2006 Unit 5 Question 9a (QS06.5.09)	*Chemistry Review* article: Catalysts: getting chemistry going (Volume 20, edition 3) *Chemistry Review* article: Catalysts: heterogeneous catalysis (Volume 23, edition 1) *Chemistry Review* article: Catalysts: homogeneous catalysis (Volume 23, edition 3)

3.2.6 Reactions of ions in aqueous solution

The reactions of transition metal ions in aqueous solution provide a practical opportunity for students to show and to understand how transition metal ions can be identified by test-tube reactions in the laboratory.

Prior knowledge:

International AS Chemistry

- 3.1.5 – Oxidation, reduction and redox reactions (oxidation states, oxidation, reduction, redox equations)

International A level Chemistry

- 3.2.5 – Transition metals

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The nature of meta-aqua ions. The relative acidity of metal-aqua ions. The reaction of metal-aqua ions (Fe^{2+}, Cu^{2+}, Al^{3+}, Fe^{3+}) with bases OH^-, NH_3, CO_3^{2-} The character of metal hydroxides as basic or amphoteric.	1 week	**Students should be able to:** • understand that metal ions exist as metal-aqua ions in aqueous solution • the hydrolysis of metal-aqua ions in aqueous solution giving acidic solutions • explain why $[M(H_2O)_6]^{3+}$ ions are more acidic than $[M(H_2O)_6]^{2+}$ ions • describe and explain reactions of $[M(H_2O)_6]^{2+}$ (M = Cu, Fe) and $[M(H_2O)_6]^{3+}$ (M = Al, Fe) with the bases OH^-, NH_3,	• Students could measure the pH of solution of metal aqua ions (of equal concentration) and explain the difference in pH. • Students could complete a series of test tube reactions of iron(II) and iron(III) ions with reagents such as Mg, Na_2CO_3 to exemplify the difference in pH. • Students carry out test-tube reactions of metal-aqua ions with NaOH, NH_3 and Na_2CO_3. • Students could identify unknown substances (containing cations and anions on the specification) using reagents.	• January 2013 Unit 5 Question 8 (QW13.5.08) • June 2004 Unit 5 Question 4 (QW04.5.04) • January 2011 Unit 5 Question 6 (QW11.5.06) • January 2012 Unit 5 Question 8 (QW12.5.08) • June 2014 Unit 5 Question 4 (QS14.5.04)	Complexes and First Row Transition Metals (Nicholls) ISBN 9780333170885

Required practical 9 Carry out some simple test-tube reactions to identify transition metal ions in solution.		CO_3^{2-} • describe if and how metal hydroxides (Cu(II), Fe(II), Al(III), Fe(III)) react with H^+ and OH^-, and so whether these metal hydroxides are basic or amphoteric.	• Students could produce precipitates of metal hydroxides and then test how they react with acid and alkali to determine whether they are basic or amphoteric.		

3.3 Organic chemistry

3.3.7 Optical isomerism

Compounds that contain an asymmetric carbon atom form stereoisomers that differ in their effect on plane polarised light. This type of isomerism is called optical isomerism.

Prior knowledg**e:**

International AS Chemistry

- 3.3.1.3 – Isomerism

International A level Chemistry

- 3.3.8 – Aldehydes and ketones (the best example of how a racemic mixture forms comes from the reaction of many aldehydes and ketones with HCN; two alternative strategies are (a) teach 3.3.7 first but teach the point about formation of racemic mixtures during 3.3.8, or (b) teach 3.3.8 before 3.3.7)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The cause and nature of optical isomerism. The similarities and differences in the properties of enantiomers. The formation of racemic mixtures.	0.4 weeks	**Students should be able to:** • explain the cause of optical isomerism • identify molecules that exhibit optical isomerism/that are optically active • draw pairs of optical isomers in 3D	• Students make models of mirror image molecules of some chiral and non-chiral molecules to see if they are non-superimposable or not. • Students identify whether molecules exhibit optical isomerism and, where they do, draw the two enantiomers in 3D. • Students could see how passing polarised light through a solution of sucrose affects the plane of the light.	• January 2005 Unit 4 Question 3d (QW05.4.03) • June 2002 Unit 4 Question 5a (QW02.4.05)	Molymod models. *Chemistry Review* article: Looking in the mirror (Volume 10, edition 3)

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• describe how enantiomers affect plane polarised light • explain what a racemic mixture is, how they can be formed, and their effect on plane polarised light.	• Students could use Molymod models to show how a racemic mixture is formed when ethanal reacts with HCN.		

3.3.8 Aldehydes and ketones

Aldehydes, ketones, carboxylic acids and their derivatives all contain the carbonyl group which is attacked by nucleophiles. This section includes the addition reactions of aldehydes and ketones.

Prior knowledge:

International AS Chemistry

- 3.3.1.1 – Nomenclature
- 3.3.1.2 – Reaction mechanisms
- 3.3.5.2 – Oxidation of alcohols

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know about the oxidation of aldehydes. Know about the reduction of aldehydes and ketones with $NaBH_4$, including mechanism. Know about the reaction of aldehydes and ketones with KCN then acid, including mechanism.	0.6 weeks	**Students should be able to:** • write equations and know reagents and conditions to oxidise aldehydes to carboxylic acids • know how to distinguish aldehydes and ketones • write equations, know reagents and conditions and outline the mechanism to reduce aldehydes and ketones to alcohols with $NaBH_4$	• Students write equations for the oxidation of aldehydes (using reagents acidified potassium dichromate (VI) / Tollen's reagent / Fehling's solution). • Students could carry out test-tube reactions of Tollen's reagent and Fehling's solution to distinguish aldehydes and ketones. • Students write equations and mechanisms for the reduction of aldehydes and ketones using $NaBH_4$. • Students write equations and mechanisms for the reaction of aldehydes and ketones with KCN followed by acid.	• January 2010 Unit 4 Question 4 ab (QW10.4.04) • June 2005 Unit 4 Question 3a (QS05.4.03) • June 2004 Unit 4 Question 6de (QS04.4.06) • January 2002 Unit 4 Question 6a (QW02.4.06)	Molymod models. Giant silver mirror nuffieldfoundation.org/practical-chemistry/giant-silver-mirror RSC mechanisms resource: rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions Mechanism animations science.jbpub.com/organic/movies/

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• write equations, know reagents and conditions and outline the mechanism for reaction of aldehydes and ketones with KCN and acid • understand why reaction of aldehydes and ketones with KCN followed by acid can form a racemic mixture • students understand the hazards of using KCN.	• Students could use Molymod models to show how a racemic mixture is formed when ethanal reacts with HCN. • Students could research why KCN/HCN are highly toxic.		

3.3.9 Carboxylic acids and derivatives

Carboxylic acids are weak acids but strong enough to liberate carbon dioxide from carbonates. Esters occur naturally in vegetable oils and animal fats. Important products obtained from esters include biodiesel, soap and glycerol.

Prior knowledge:

International AS Chemistry

- 3.3.1.1 – Nomenclature
- 3.3.1.2 – Reaction mechanisms
- 3.3.5.2 – Oxidation of alcohols

3.3.9.1 Carboxylic acids and esters

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Draw the structure of and name carboxylic acids and esters. Know that carboxylic acids are weak acids. Know how esters are made from carboxylic acids. Know some uses of esters. Know how esters are hydrolysed.	1.5 weeks	**Students should be able to:** • draw the structure of and name carboxylic acids and esters • know how carboxylic acids react with carbonates • write equations for the reaction of carboxylic acids with alcohols to form esters • know some common uses of esters • write equations for the hydrolysis of esters in acidic or alkaline conditions	• Students draw and name carboxylic acids and esters. • Students write equations for, and make esters by reactions of alcohols with carboxylic acids in test tubes; or an ester could be collected and purified using a separating funnel and distillation. • Students research uses of esters and the presence of esters in fruit. • Students write equations for the hydrolysis of given esters in acidic and alkaline conditions. • Students make soap by hydrolysis of castor oil. • Students make biodiesel.	• January 2013 Unit 4 Question 3a) (QW13.4.03) • June 2010 Unit 4 Question 7ad (QS10.4.07) • January 2010 Unit 4 Question 5 (QW10.4.05) • June 2005 Unit 1 Question 1a) d) (QS05.4.01)	Making soap from castor oil: nuffieldfoundation.org/practical-chemistry/making-soaps-and-detergents Method and guidance for making biodiesel – CLEAPSS leaflet PS 67-10 Molecule of the month: Esters in fruits chm.bris.ac.uk/motm/ethylacetate/ethylv.htm Biofuels website: biofuels.co.uk

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know that vegetable oils and animal fats are esters of fatty acids and glycerol. Know how soap and biodiesel are made from vegetable oil and animals fats.		• understand the structure of animals fats and vegetable oils • know how soap and biodiesel are made and write equations for these reactions for specified fats/oils.	• Students write equations for production of soap and/or biodiesel from specified fats/oils. • Students could identify an unknown ester by determination of boiling point followed by hydrolysis and then purifying and finding the melting point of the carboxylic acid formed (e.g. for example methyl benzoate).		

3.3.9.2 Acylation

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Draw the structure of and name acid anhydrides, acyl chlorides and amides. Understand acylation reactions of water, alcohols, ammonia and amines with acyl chlorides and acid anhydrides, including the mechanism for acyl chlorides. **Required practical 10** Preparation of a pure organic solid and test of its purity.	2.0 weeks	**Students should be able to:** • draw the structure of and name acid anhydrides, acyl chlorides and amides • identify the products of and write equations for acylation reactions of water, alcohols, ammonia and primary amines with acyl chlorides and acid anhydrides • outline the mechanism for the acylation reactions of acyl chlorides • state advantages of using ethanoic anhydride rather than ethanoyl chloride in the production of aspirin • prepare and purity an organic solid and test its purity.	• Students draw and name acid anhydrides, acyl chlorides and amides. • Students write equations and outline mechanisms for acylation reactions of water, alcohols, ammonia and amines with acyl chlorides and acid anhydrides; some of these reactions could be demonstrated. • Students prepare, purify and test the purity of aspirin by melting point determination.	• January 2012 Unit 4 Question 10a (QW12.4.10) • June 2006 Unit 4 Question 1 abcd (QS06.4.01) • June 2005 Unit 4 Question 7 ac (QS05.4.07) • June 2003 Unit 5 Question 8b (QS03.5.08)	RSC resource on aspirin: rsc.org/learn-chemistry/resource/res00000056/aspirin Aspirin Pre-lab Screen Experiment: rsc.org/learn-chemistry/resource/res00001644/aspirin-screen-experiment RSC mechanisms resource: rsc.org/learn-chemistry/resource/res00000638/curly-arrows-and-stereoselectivity-in-organic-reactions Mechanism animations science.jbpub.com/organic/movies

3.3.10 Aromatic chemistry

Aromatic chemistry takes benzene as an example of this type of molecule and looks at the structure of the benzene ring and its substitution reactions.

Prior knowledge:

International AS Chemistry

- 3.3.1.1 – Nomenclature
- 3.3.1.2 – Reaction mechanisms

3.3.10.1 Bonding

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand the structure of benzene and evidence for delocalisation.	0.2 weeks	**Students should be able to:** • describe the structure of benzene and explain how delocalisation makes benzene more stable than the theoretical cyclohexa-1,3,5-triene • use thermochemical evidence from enthalpies of hydrogenation to account for this extra stability • explain why benzene undergoes substitution reactions in preference to addition reactions.	• Name a range of aromatic compounds with common functional groups. • Draw enthalpy diagrams to show the relative stability of cyclohexane, cyclohexene, cyclohexa-1,4-diene, benzene and the theoretical cyclohexa-1,3,5-triene.	• June 2011 Unit 4 Question 8a (QS11.4.08) • January 2004 Unit 4 Question 7a (QW04.4.07)	*Chemistry Review* article: The structure of benzene (Volume 1, edition 1) *Chemistry Review* article: Who discovered the structure of benzene (Volume 5, edition 1)

3.3.10.2 Electrophilic substitution

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know nitration, sulfonation and Friedel-Crafts alkylation and acylation reactions of aromatic compounds, including the mechanism and usefulness. Know the free-radical reactions of chlorine on benzene and methylbenzene. Understand the relative reactivities of chlorine when substituted in the ring and in the side chain.	1.5 weeks	**Students should be able to:** • write equations and outline mechanisms for nitration, sulfonation and Friedel-Crafts alkylation and acylation reactions of aromatic compounds. (including equations for the formation of electrophiles) • understand the usefulness of nitration and Friedel-Crafts acylation reactions • write equations and outline the mechanism for the reaction of chlorine with benzene and with methylbenzene. • Explain the relative reactivities of chlorine substituted in the ring and in the side chain.	• Write equations (including for the formation of electrophiles) and mechanisms for nitration, sulfonation and Friedel-Crafts alkylation and acylation reactions given the starting material and products. • Write equations and mechanisms for the reaction of chlorine with benzene and with methylbenzene. • Students could carry out the preparation of methyl 3-nitrobenzoate by nitration of methyl benzoate, purification by recrystallisation and determination of melting point.	• January 2012 Unit 4 Question 9a (QW12.4.09) • January 2011 Unit 4 Question 6 (QW11.4.06) • June 2010 Unit 4 Question 8 (QS10.4.08) • January 2006 Unit 4 Question 7 (QW06.4.07) • June 2011 Unit 4 Question 8b	*Chemistry review* article: Probably the most important reactions in the world (Volume 15, edition 2)

3.3.11 Amines

Amines are compounds based on ammonia where hydrogen atoms have been replaced by alkyl or aryl groups. This section includes their reactions as nucleophiles

Prior knowledge:

International AS Chemistry

- 3.3.1.1 – Nomenclature
- 3.3.1.2 – Reaction mechanisms
- 3.3.3.1 – Nucleophilic substitution

3.3.11.1 Preparation

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Know how primary aliphatic amines are made from halogenoalkanes and from nitriles. Know how aromatic amines are produced and their use in making dyes.	0.2 weeks	**Students should be able to:** • write equations and give conditions for the preparation of primary aliphatic amines from both halogenoalkanes and nitriles • write equations and give conditions for the production of aromatic amines and identify their use in making dyes.	• Identify reagents and conditions and write equations to make specified primary aliphatic amines from halogenoalkanes and nitriles. • Identify reagents and conditions and write equations to make specified aromatic amines. • Research the use of aromatic amines in making.	• June 2013 Unit 4 Question 8 (QS13.4.08) • June 2005 Unit 4 Question 5b) (QS05.4.05) • January 2005 Unit 4 Question 1 (QW05.4.01) • June 2004 Unit 4 Question 4a)b) (QS04.4.04) • January 2004 Unit 4 Question 8 (QW04.4.08)	*Chemistry Review* article: Get real: chemistry in fashion (Volume 11, edition 3)

3.3.11.2 Base properties

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Compare the base strength of amines.	0.2 weeks	**Students should be able to:** • place amines in order of base strength and explain this order.	• Given pairs of amines, students should identify the stronger base giving reasons for their answer.	• January 2005 Unit 4 Question 1d (QW05.4.01) • June 2004 Unit 4 Question 4c (QS04.4.04) • January 2003 Unit 4 Question 6 (QW03.4.06) • June 2013 Unit 4 Question 9a)	Data books with base strength values: Nuffield Science Data Book (free download): nationalstemcentre.org.uk Chemistry Data Book (Starck, Wallace, McGlashan) ISBN: 9780719539510

3.3.11.3 Nucleophilic properties

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how amines react with halogenoalkanes, acyl chlorides and acid anhydrides, including mechanisms.	0.5 weeks	**Students should be able to:** • identify the various amines and quaternary ammonium salts formed when ammonia and amines react with halogenoalkanes • give the mechanism for reactions of ammonia and amines with halogenoalkanes • recognise the use of quaternary ammonium salts • identify the products of and write equations for acylation reactions of ammonia and amines with acyl chlorides and acid anhydrides • outline the mechanism for the acylation reactions	• Identify the amines and quaternary ammonium salts that can be formed when ammonia and amines react with halogenoalkanes and how changing conditions can affect the main product; outline the mechanism to form these products. • Students could research the use of quaternary ammonium salts. • Students write equations and mechanisms for acylation reactions of water, alcohols, ammonia and amines with acyl chlorides and acid anhydrides; some of these reactions could be demonstrated. • Practical opportunity: The preparation of N-phenylethanamide.	• January 2006 Unit 4 Question 5 (QW06.4.05) • January 2004 Unit 4 Question 8 (QW04.4.08) • January 2003 Unit 4 Question 7 (QW06.4.07)	*Chemistry Review* article: Two in one: the chemistry of shampoo and conditioner (Volume 22, edition 3)

3.3.12 Polymers

The study of polymers is extended to include condensation polymers. The ways in which condensation polymers are formed are studied, together with their properties and typical uses. Problems associated with the reuse or disposal of both addition and condensation polymers are considered.

Prior knowledge:

International AS Chemistry

- 3.3.1.1 – Nomenclature
- 3.3.4.3 – Addition polymers

3.3.12.1 Condensation polymers

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand how condensation polymers are formed including linkages in polyesters and polyamides. Identify the repeating unit given monomer(s) and vice versa.	1.0 weeks	**Students should be able to:** • identify the repeating unit and linkages in polyesters and polyamides given the monomer(s) • identify monomer(s) needed the make a condensation polymer given the repeating unit • know the repeating units in Terylene, nylon 6,6 and Kevlar • know some uses of condensation polymers	• Draw the structure of repeating units in polyesters and polyamides given the monomer(s) and vice versa • Students could make nylon 6,6 • Students could each make a model of a monomer using Molymods and then students collectively join them together to make a long polymer chain.	• January 2012 Unit 4 Question 8b (QW12.4.08) • June 2011 Unit 4 Question 4a (QS11.4.04) • June 2006 Unit 4 Question 4a (QS06.4.04) • June 2003 Unit 4 Question 5 (QS03.4.05)	Molymods. RSC resource on nylon: rsc.org/learn-chemistry/resource/res00000026/nylon Video on discovery of nylon: rsc.org/learn-chemistry/resource/res00001346/invention-of-nylon The discovery of Nylon rsc.org/learn-chemistry/resource/res00000034/anecdotes-nylon

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		- explain the nature of the intermolecular forces between molecules of condensation polymers.			Making nylon: rsc.org/learn-chemistry/resource/res00000755/making-nylon-the-nylon-rope-trick Sandcastles and mudhuts section 27 – Spare Parts (Hancock) ISBN 9780340543696 *Chemistry Review* article: Tougher than a speeding bullet (Volume 13, edition 4) *Chemistry Review* article: Polyesters: plastics of the future (Volume 17, edition 1) *Chemistry Review* article: Kevlar and composites (Volume 20, edition 2) *Chemistry Review* article: Kevlar – miracle material (Volume 22, edition 4)

3.3.12.2 Biodegradability and disposal of polymers

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Understand why polyalkenes are not biodegradable. Understand why polyesters and polyamides are biodegradable. Evaluate different methods of disposing of polymers.	0.2 weeks	**Students should be able to:** • explain why polyalkenes are non-biodegradable • explain why polyesters and polyamides are biodegradable • evaluate the advantages and disadvantages of different methods of disposing of polymers.	• Students can create a summary table to compare and explain the biodegradability of different types of polymers. • Students can research and summarise different methods of disposing of polymers, including recycling, considering advantages, disadvantages and sustainability.	• January 2013 Unit 4 Question 4 b c d (QW13.4.04) • June 2002 Unit 4 Question 7 (QS02.4.07) • June 2004 Unit 4 Question 5 a c (QS04.4.05) • SAMS A level Paper 2 Question 7	*Chemistry Review* article: Reclaiming plastic waste (Volume 23, edition 2). Video on recycling plastics: rsc.org/learn-chemistry/resource/res00001347/recycling-plastics

3.3.13 Amino acids, proteins and DNA

Amino acids, proteins and DNA are the molecules of life. In this section, the structure and bonding in these molecules and the way they interact is studied. Drug action is also considered.

Prior knowledge:

International AS level Chemistry

- 3.1.3.7 – Forces between molecules
- 3.3.1.1 – Nomenclature

International A level Chemistry

- 3.3.9 – Carboxylic acids
- 3.3.11 – Amines
- 3.3.16 – Chromatography (you might wish to teach this section before using it to test amino acids by thin-layer chromatography here)

3.3.13.1 Amino acids

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
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.	• 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 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 • know that amino acids can be separated and identified by thin-layer chromatography, including the use of R_f values.	• Draw the structure of peptides formed from joining amino acids together. • Identify amino acids formed when peptides are hydrolysed. • Identify the primary, secondary and tertiary parts of the structure of some proteins. • Students can carry out some thin-layer chromatography of some amino acids to identify an unknown amino acid.	• 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 rsc.org/Education/Teachers/Resources/cfb/proteins.htm

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. • Write notes to accompany a diagram showing the action of cisplatin. • Evaluate the benefits and adverse effects of using drugs such as cisplatin.	• SAMS A level Paper 2 Questions 8	Useful animations on biochemistry (DNA replication) doctorprodigious.wordpress.com/hd-animations Youtube video on action of cisplatin youtube.com/watch?v=Wq_up2uQRDo Cisplatin – molecule of the month 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

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

International AS level Chemistry

- All organic chemistry topics

International 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. • Describe features of processes that improve sustainability. • Produce a flow chart which links all the functional groups studied and lists reagents and conditions required for each transformation.	• 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 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:

International AS level Chemistry
- 3.3.1.1 – Nomenclature
- 3.3.6 – Organic analysis

This section could be taught before the International A level Organic Chemistry topics allowing the technique to be re-visited and to be part of practice questions throughout the teaching of the International 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 tetramethylsilane (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 protons in aliphatic compounds	• Predict the number, position, relative intensity and splitting of signals in the ^{1}H NMR spectrum of compounds. • Predict the number and position of signals in the ^{13}C NMR spectrum of compounds. • Use data from NMR, and other analytical methods on the specification, to deduce the structure of compounds.	• 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) • January 2011 Unit 4 Question 5 (QW11.4.05) • January 2003 Unit 4 Question 5 (QW03.4.05)	RSC Spectral School: rsc.org/learn-chemistry/collections/spectroscopy?uol_r=3ae0be55 RSC Spectroscopy resource: rsc.org/learn-chemistry/resource/res00000847/spectroscopy Database of spectra for organic compounds sdbs.db.aist.go.jp/sdbs/cgi-bin/cre_index.cgi

Learning objective	Time taken	Learning outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• 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.		• January 2002 Unit 4 Question 4 (QW02.4.04)	

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:

International 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.	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. • Separate mixtures and identify substances (e.g. amino acids) by thin-layer chromatography. • Use retention time and R_f data to identify substances separated by chromatography.	• January 2011 Unit 4 Question 4f (QW11.4.04) • June 2014 Unit4 Questions 6e (QS14.4.06)	RCS video on TLC rsc.org/learn-chemistry/resource/res00001074/thin-layer-chromatography Modern Chemical Techniques RSC resource: 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)

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