INTERNATIONAL ADVANCED LEVEL

CHEMISTRY

SCHEME OF WORK

Pearson Edexcel International Advanced Subsidiary in Chemistry (XCH11) Pearson Edexcel International Advanced Level in Chemistry (YCH11)

First teaching September 2018

First examination from January 2019

First certification from August 2019 (International Advanced Subsidiary) and August 2020 (International Advanced Level)

Pearson

Introduction

The following scheme of work provides an overview of the content of the 2018 International Advanced Level Chemistry and shows how the content could be taught as a guideline approach only. It should be adapted by schools to fit their timetabling and staffing arrangements.

It is based upon a two-year delivery model where all IAS content is being taught in the first year and the remaining IA2 content in the second year.

The scheme of work is broken up into units and topics, so that there is greater flexibility for moving topics around to meet planning needs. It includes:

- Recommended teaching time for topics, though of course this is adaptable according to individual teaching needs
- classroom activities, teaching points and suggested teaching resources
- Objectives for students at the end of the topic area and examples of integrated Transferable Skills* that are being developed

The number of guided learning hours for Advanced level is 360. Teachers should be aware that the estimated teaching hours are approximate and should be used as a guideline only.

IAL Chemistry Assessment structure

Unit Title	Assessment
Unit 1 Structure, Bonding and Introduction to Organic Chemistry	40% of IAS, 20% of IAL; 1 hour and 30 minutes, total marks 80
Unit 2 Energetics, Group Chemistry, Halogenoalkanes and Alcohols	40% of IAS, 20% of IAL; 1 hour and 30 minutes, total marks 80
Unit 3 Practical Skills in Chemistry I	20% of IA2, 10% of IAL; 1 hour and 20 minutes, total marks 50
Unit 4 Rates, Equilibria and Further Organic Chemistry	40% of IA2, 20% of IAL; 1 hour and 45 minutes, total marks 90
Unit 5 Transition Metals and Organic Nitrogen Chemistry	40% of IA2, 20% of IAL; 1 hour and 45 minutes, total marks 90
Unit 6 Practical Skills in Chemistry II	20% of IA2, 10% of IAL; 1 hour and 20 minutes, total marks 50

Assessment Objectives

AO1 Demonstrate knowledge and understanding of science.

AO2 (a) Application of knowledge and understanding of science in familiar and unfamiliar contexts.

(b) Analysis and evaluation of scientific information to make judgements and reach conclusions

AO3 Experimental skills in science, including analysis and evaluation of data and methods

Estimated teaching hours

Year 1: IAS (Please note more time is required for practical work, mock examination and examinations in addition to the 120 estimated teaching hours for the topics outlined below.)

Unit	Topic	Estimated teaching hours
1	1 Formulae, Equations and Amount of substance	**16**
	2 Atomic Structure and the Periodic Table	**12**
	3 Bonding and Structure	**12**
	4 Introductory Organic chemistry and Alkanes	**12**
	5 Alkenes	**8**
2	6 Energetics	**10**
	7 Intermolecular Forces	**4**
	8 Redox chemistry and Groups 1, 2 and 7	**20**
	9 Introduction to Kinetics and Equilibria	**8**
	10 Organic chemistry: Alcohols, Halogenoalkanes and Spectra	**18**
3	There is no specific content for this Unit and students are expected to develop experimental skills, and a knowledge and understanding of the necessary techniques, by carrying out a range of practicals while they study Units 1 and 2	
	Total	**120 hours**

Year 2: IA2

(Please note more time is required for practical work, mock examination and examinations in addition to the 120 estimated teaching hours for the topics outlined below.)

Unit	Topic	Estimated teaching hours
4	11 Kinetics	**16**
	12 Entropy and Energetics	**8**
	13 Chemical Equilibria	**4**
	14 Acid-base Equilibria	**12**
	15 Organic Chemistry: Carbonyls, Carboxylic acids and Chirality	**20**
5	16 Redox Equilibria	**16**
	17 Transition Metals and their Chemistry	**16**
	18 Organic Chemistry - Arenes	**8**
	19 Organic Nitrogen Compounds: Amines, Amides, amino Acids and Proteins	**8**
	20 Organic Synthesis	**12**
6	There is no specific content for this Unit and students are expected to develop experimental skills, and a knowledge and understanding of the necessary techniques, by carrying out a range of practicals while they study Units 4 and 5	
	Total	**120 hours**

*Why transferable skills?

In recent years, higher education institutions and global employers have consistently identified the need for students to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work. To support the design of our qualifications, we have mapped them to a transferable skills framework. The framework includes cognitive, intrapersonal skills and interpersonal skills and each skill has been interpreted for this specification as detailed below.

NRC framework skill	Skill interpretation in IAL Chemistry
Cognitive skills	
Cognitive Processes and Strategies	
Critical thinking	Discuss uncertainty of measurements in practical work
Problem solving	Calculate formulae from data
Analysis	Interpret mass spectra, infrared spectra and nmr spectra
Reasoning/argumentation	Analysis of unknown organic and inorganic compounds
Interpretation	Ability to interpret graphs
Decision making	Plan organic reaction schemes (with up to 4 steps)
Adaptive learning	Predictions from data Select equipment and methods for carrying out practical work
Executive function	
Creativity	
Creativity	Devising experimental procedures Identify errors and uncertainties and how to improve outcomes
Innovation	Suggest uses of new materials eg graphene
Intrapersonal skills	
Intellectual openness	
Adaptability	This occurs in any practical
Personal and social responsibility	Soluble laundry bags Catalytic converters
Continuous learning	
Intellectual interest and curiosity	Use of Chemistry in biological systems e.g. buffers in blood and food; Haemoglobin in blood; Cancer drugs *cis*-platin

Work ethic/conscientiousness	
Initiative	Investigation of chemical reactions
Self-direction	Preparations
Responsibility	Health and safety and the difference between hazard and risk
Perseverance	Purification of an organic compound
Productivity	Improving manufacturing processes
Self-regulation (metacognition, forethought, reflection)	Suggest ways to reduce risks when dealing with chemicals
Ethics	Use of chromatography in drug testing; Climate change; Carbon neutrality fuels; Pollution; Biodegradable polymers/ incineration of polymers
Integrity	
Positive Core Self Evaluation	
Self-monitoring/self-evaluation/self-reinforcement	Carrying out practical work individually
Interpersonal skills	
Teamwork and collaboration	
Communication	This occurs in any practical when working with a partner
Collaboration	This occurs in any practical when working with a partner
Teamwork	Preparation of aspirin in a group
Co-operation	This occurs in any practical when working with a partner
Interpersonal skills	This occurs in any practical when working with a partner
Empathy/perspective taking	This occurs in any practical when working with a partner
Negotiation	This occurs in any practical when working with a partner
Leadership	
Leadership	This occurs in any practical when working with a partner
Responsibility	This occurs in any practical when working with a partner
Assertive communication	This occurs in any practical when working with a partner
Self-presentation	This occurs in any practical when working with a partner

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
1	**Amount of substance** Know the terms atom, element, ion, molecule, compound, empirical formula and molecular formula Know that the mole (mol) is the unit for amount of a substance and be able to perform calculations using the Avogadro constant Be able to write balanced full and ionic equations, including state symbols, for chemical reactions Understand the terms: relative atomic mass, relative molecular mass, relative formula ,mass, molar mass, parts per million Be able to use experimental data to calculate empirical and molecular formulae	View video on Mole and Avogadro as part of 'Flip Learning' preparation, then use scaffolded worksheets to check understanding. e.g. http://www.youtube.com/watch?v=AsqEkF7hcII Students work in groups to carry out an experiment to confirm the empirical formula of a compound (e.g. copper oxide by reduction). Students work in groups to carry out an experiment to determine the number of water molecules in a hydrated salt (e.g. hydrated magnesium(II) sulfate). Play a 'spot the difference' game with cards showing all the key definitions. Design a spreadsheet to calculate relative molecular mass / relative formula mass from relative atomic masses.	Problem solving in calculations Analysis of results of experiments Interpretation of results of experiments Responsibility for carrying out practical work in a safe manner, following all safety requirements Teamwork and cooperation when working with others carrying out practical experiments Communication between members of a group carrying out experiments

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
2 and 3	**Calculating amounts of substance in equations using moles** Be able to use chemical equations to calculate reacting masses and vice versa using the concept of amount of substance and molar mass Be able to calculate volumes of gases and vice versa using: i the concepts of amount of substance ii molar volume of gases iii the expression $pV = nRT$ for gases and volatile liquids Be able to determine a formula or confirm an equation by experiment, including evaluation of the data **CORE PRACTICAL 1:** Measure the molar volume of a gas	Students work in groups to carry out an experiment to determine the molar ratio in a reaction e.g. lithium and water or the reaction between magnesium and an acid. Other possible practicals include: Add excess copper(II) sulfate solution to a known mass of iron and weigh the copper produced to deduce whether iron(II) sulfate or iron(III) sulfate is formed Measure the volume of hydrogen produced when excess sulfuric acid is added to a known mass of magnesium and use this to determine the molar volume of gas Mix different amounts of aqueous lead nitrate and aqueous potassium iodide, measure the heights of the precipitates formed and use this to determine the mole ratio and hence the balanced equation for the reaction. Assess progress of students using AfL sheet from RSC. http://www.rsc.org/education/teachers/resources/aflchem/resources/36/index.htm	Problem solving in calculations Analysis of results of experiments Interpretation of results of experiments Responsibility for carrying out practical work in a safe manner, following all safety requirements Teamwork and cooperation when working with others carrying out practical experiments Communication between members of a group carrying out experiments

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
4	**Solutions, yields, atom economy and test tube experiments** Be able to calculate the concentration of a solution in mol dm^{-3} and g dm^{-3} Be able to calculate percentage yields and percentage atom economies (by mass) in laboratory and industrial processes using chemical equations and experimental results Be able to relate ionic and full equations, with state symbols, to observations from simple test tube experiments, to include: i displacement reaction, ii typical reactions of acids iii precipitation reactions	Students work in groups to carry out an experiment to prepare a salt and calculate the percentage yield e.g. preparation of iron(II) ammonium sulfate from iron, ammonia and sulfuric acid. Students work in groups to carry out and interpret the results of simple test tube experiments for displacement reactions, reactions of acids and precipitation reactions. This is an opportunity for students to write balanced full and ionic equations, including state symbols, for the reactions they have carried out.	Problem solving in calculations Analysis of results of experiments Interpretation of results of experiments Responsibility for carrying out practical work in a safe manner, following all safety requirements Teamwork and cooperation when working with others carrying out practical experiments Communication between members of a group carrying out experiments

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
5	**Structure of atoms and mass spectrometry** Know the structure of an atom in terms of electrons, protons and neutrons Know the relative mass and charge of protons, neutrons and electrons Know what is meant by the terms 'atomic (proton) number' and 'mass number' Understand the term 'isotope' Understand the basic principles of a mass spectrometer and be able to analyse and interpret mass spectra to: i deduce the isotopic composition of a sample of an element ii calculate the relative atomic mass of an element from relative abundances of isotopes and vice versa iii determine the relative molecular mass of a molecule, and hence identify molecules in a sample iv understand that ions in a mass spectrometer may have a 2+ charge Be able to predict the mass spectra, including relative peak heights, for diatomic molecules, including chlorine, given the isotopic abundances	Revise work from IGCSE on Atomic structure. Students carry out research (in pairs or groups) to produce a timeline of events in the development of our current understanding of the structure of the atom. Present this research to the rest of the class. Build a model to represent Geiger and Muller's experiment to confirm most of an atom is empty space. Annotate a Periodic Table with key information, showing how to determine numbers of sub-atomic particles. 'Build an atom' simulation. e.g. http://tinyurl.com/buildanatomsim Notes on mass spectrometer. e.g. https://www.chemguide.co.uk/analysis/masspec/howitworks.html Video on mass spectrometer. e.g. https://www.youtube.com/watch?v=J-wao0O0_qM	Problem solving in calculations Analysis and interpretation of mass spectra Teamwork and cooperation when working with others to carry out research and produce a presentation Communication between members of a group carrying out research and producing a presentation Creativity in producing a presentation

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
6	**Ionisation energy and electron orbitals** Be able to define first, second and third ionisation energies and understand that all ionisation energies are endothermic Know that an orbital is a region within an atom that can hold up to two electrons with opposite spins. Understand how ionisation energies are influenced by the number of protons in the nucleus, the electron shielding and the sub-shell from which the electron is removed Be able to represent data, in a graphical form (including the use of logarithms of first ionisation energy on a graph) for elements 1 to 36 Know that ideas about electronic configuration developed from: i an understanding that successive ionisation energies provide evidence for the existence of quantum shells and the group to which the element belongs ii an understanding that the first ionisation energy of successive elements provides evidence for electron sub-shells Be able to describe the shape of *s* and *p* orbitals Know that orbitals in sub-shells: i each take a single electron before pairing up ii pair up with two electrons of opposite spin	Plot graphs of the log of successive ionisation energies of a selection of atoms and use these to predict the group to which the element belongs. Explain why a log graph is used. Ideas on misconceptions about ionisation energies e.g. http://tinyurl.com/IE-Misconceptions Plot a graph of first ionisation energy against atomic number for the first 20 elements Look at 3-dimensional models or diagrams of *s* and *p* orbitals	Analysis and interpretation of graphs of ionisation energy

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
7	**Electron configuration and the Periodic Table** Be able to predict the electronic configurations, using 1s notation and electrons-in-boxes notation, of: i atoms, given the atomic number, *Z*, up to *Z* = 36 ii ions, given the atomic number, *Z*, and the ionic charge, for s and p block ions only, up to Z = 36 Understand that electronic configuration determines the chemical properties of an element Know that the Periodic Table is divided into blocks, such as *s*, *p* and *d* and know the number of electrons that can occupy *s*, *p* and *d* sub-shells in the first four quantum shells Be able to represent data, in a graphical form (including the use of logarithms of first ionisation energy on a graph) for elements 1 to 36 and hence explain the meaning of the term 'periodic property' Be able to explain: i the trends in melting and boiling temperatures of the elements of Periods 2 and 3 of the Periodic Table in terms of the structures of the element and the bonding between its atoms or molecules ii the general increase and the specific trends in ionisation energy of the elements across Periods 2 and 3 of the Periodic Table iii the decrease in first ionisation energy down a group	Carry out a 'Whiteboard' or Pupil Response Unit Quiz on electronic configurations, using both '$1s^2$ etc.' and 'electrons in boxes' models. Use RSC 'Starter for Ten' in subsequent lessons. http://www.rsc.org/learn-chemistry/resource/res00000954/starters-for-ten-chapters-1-11#!cmpid=CMP00001407 Annotate a Periodic Table with key information, showing group and period numbers; how to determine numbers of sub-atomic particles; s, p and d blocks; relationship between electronic configuration and group and period numbers etc. Relate previous graphs to periodic properties. Plot melting and boiling temperatures of the elements in Periods 2 and 3. Annotate the graphs to explain trends in terms of structure. Use the graph of first ionisation energy against atomic number for the first 20 elements plotted last week. Plot a graph of first ionisation against atomic number for a group in the Periodic Table.	Analysis and interpretation of graphs of periodic properties

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
8	**Ionic bonding** Know and be able to interpret evidence for the existence of ions, limited to physical properties of ionic compounds, electron density maps and migration of ions Be able to describe the formation of ions in terms of loss or gain of electrons Be able to draw dot-and-cross diagrams to show electrons in cations and anions Be able to describe ionic crystals as giant lattices of ions Know that ionic bonding is the result of strong electrostatic attraction between ions Understand the effects of ionic radius and ionic charge on the strength of ionic bonding Understand reasons for the trends in ionic radii down a group in the Periodic Table, and for a set of isoelectronic ions, e.g. N^{3-} to Al^{3+} Understand the term polarisation as applied to ions Understand that the polarising power of a cation depends on its radius and charge, and the polarisability of an anion also depends on its radius and charge	Revise work on ionic bonding from IGCSE. Demonstrate the migration of ions in a U-tube using copper(II) chromate solution or on a piece of filter paper on a microscope slide using potassium manganate(VII) crystals. Study a dot-and-cross diagram of a known compound (e.g. sodium chloride) and use it to predict the dot-and-cross diagram for less familiar compounds (e.g. magnesium bromide). Look at models of giant structures of ionic compounds. Plot a graph of ionic radius against atomic number for Group 1 elements and explain the shape of the graph. Plot a graph of ionic radius against atomic radius for nitrogen to aluminium and explain the shape of the graph. Explain the concepts of polarisation, polarising power and polarizability (e,g, https://www.bestchoice.net.nz/chemistry/819/p13071.htm	Analysis and interpretation of dot-and-cross diagrams Analysis and interpretation of graphs of ionic radius

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
9	**Covalent bonding** Understand that covalent bonding is the strong electrostatic attraction between two nuclei and the shared pair of electrons between them, based on evidence: i the physical properties of giant atomic structures ii electron density maps for simple molecules Be able to draw dot-and-cross diagrams to show electrons in simple covalent substances, including: i molecules with single, double and triple bonds ii species exhibiting dative (coordinate) bonding, including Al_2Cl_6 and the ammonium ion Be able to discuss the different structures formed by giant lattices of carbon atoms, including graphite, diamond and graphene, and the application of these Understand the meaning of the term electronegativity as applied to atoms in a covalent bond Know that ionic and covalent bonding are the extremes of a continuum of bonding type and be able to explain this is terms of electronegativity differences leading to bond polarity in bonds and molecules, and to ionic bonding if the electronegativity difference is large enough Be able to distinguish between polar bonds and polar molecules and predict whether or not a given molecule is likely to be polar	Revise work on covalent bonding from IGCSE. Look at a model of diamond, a giant atomic structure, and discuss the physical properties of diamond, Look at electrons density maps of ionic and covalent compounds. Study a dot-and-cross diagrams of some compounds (e.g. chlorine, methane, oxygen) and use them to predict the dot-and-cross diagrams for other compounds (e.g. ammonia, water, nitrogen). Discuss dative bonding. Carry out research (in pairs or groups) to produce a presentation about the different forms of carbon, including their structures, physical properties and uses. Demonstration experiment to determine the effect of an electrostatic force on jets of liquids from a burette, including water, ethanol and cyclohexane, and use the results to determine whether the molecules are polar or non-polar. e.g. http://www.rsc.org/learn-chemistry/resource/res00000669/jets-of-liquids This resource from the RSC may be useful in teaching this topic: http://www.rsc.org/learn-chemistry/resource/res00001140/chemical-bonding	Analysis and interpretation of dot-and-cross diagrams Teamwork and cooperation when working with others to carry out research and produce a presentation Communication between members of a group carrying out research and producing a presentation Creativity in producing a presentation

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
10	**Shapes of molecules and metallic bonding** Understand the principles of the electron-pair repulsion theory, used to interpret and predict the shapes of simple molecules and ions Understand the terms 'bond length' and 'bond angle' Know and be able to explain the shapes of, and bond angles in, $BeCl_2$, BCl_3, CH_4, NH_3, NH_4^+, H_2O, CO_2, gaseous PCl_5, SF_6 and C_2H_4 Be able to apply the electron-pair repulsion theory to predict the shapes of, and bond angles in other molecules and ions Understand that metals consist of giant lattices of metal ions in a sea of delocalised electrons Know that metallic bonding is the strong electrostatic attraction between metal ions and the delocalised electrons Be able to use the models above to interpret simple properties of metals, e.g. electrical conductivity and high melting temperature	This RSC resource has useful information and ideas on this topic. http://www.rsc.org/learn-chemistry/resource/res00000648/shapes-of-molecules-and-ions Give students cards / models showing the shapes of a variety of molecules. They then draw a dot-and-cross diagram for each molecule and produce a summary that links number of electron pairs to shape. Self-assess against VSEPR rules. This RSC resource has useful information and ideas on metallic bonding. http://www.rsc.org/learn-chemistry/resource/res00000092/afl-what-is-the-bonding-like-in-iron Research metallic radii of metallic elements and compare to melting point. Use metallic bonding model to explain any trends.	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
11	**Introduction to Organic Chemistry and Alkanes** Understand the concepts of homologous series and functional group Be able to apply the rules of IUPAC nomenclature to: i name compounds relevant to this specification ii draw these compounds, as they are encountered in the specification, using structural, displayed and skeletal formulae Be able to classify reactions as addition, substitution, oxidation, reduction or polymerisation Understand that bond breaking can be: i homolytic, to produce free radicals ii heterolytic, to produce ions Know definitions of the terms 'free radical' and electrophile Know the general formula of alkanes and cycloalkanes and understand that they are hydrocarbons (compounds of carbon and hydrogen only) which are saturated (contain single bonds only) Understand the term 'structural isomerism' and be able to draw the structural isomers of organic molecules, given their molecular formula Be able to draw the structural isomers of alkanes and cycloalkanes with up to six carbon atoms	Introduce the terminology listed for Organic Chemistry – this can be done in an introductory lesson or as they encountered in other statements later in this Topic and in Topic 5. Introduce rules for recognising and naming different alkanes and cycloalkanes. You could give students a model and ask them to draw and name it or give them a name and ask them to draw or model it. Use molecular, structural, displayed and skeletal formulae. Test understanding using online quizzes e.g. http://www.knockhardy.org.uk/sci_htm_files/mcane.HTM or RSC AfL activity e.g. http://www.rsc.org/learn-chemistry/resource/res00000110/afl-naming-hydrocarbons Ask students to make a model of butane then ask them to rearrange the atoms to form a different molecule (2-methylpropane), hence introduce the idea of structural isomerism. Organise a competition between groups to find, draw model and name as many possible isomers of hexane. This could be repeated with cyclic isomers of C_6H_{12}.	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
12	**Alkane fuels and pollution** Know that alkanes are used as fuels and obtained from the fractional distillation, cracking and reforming of crude oil Know that pollutants, including carbon monoxide, oxides of nitrogen and sulfur, carbon particulates and unburned hydrocarbons, are emitted during the combustion of alkane fuels Understand the problems that arise from the toxicity of carbon monoxide and the acidity of the oxides of nitrogen and sulfur Be able to discuss the reasons for developing alternative fuels in terms of sustainability and reducing emissions, including the emission of CO_2 and its relationship to climate change Be able to apply the concept of carbon neutrality to different fuels, such as petrol, bioethanol and hydrogen	Students work in groups to research the uses of alkanes as fuels, the possible environmental effects and the role of chemist's in reducing the environmental impact. They present their research to the rest of the class. The class can ask questions to assess how much the students know about this topic then judge the quality of the presentation by telling the students what they did well and what they can work on to improve in the future. Possible resources: http://www.rsc.org/learn-chemistry/resource/res00000754/the-fractional-distillation-of-crude-oil http://www.rsc.org/learn-chemistry/resource/res00000112/afl-what-are-the-origins-and-environmental-implications-of-pollutants-in-car-exhaust-gases http://www.rsc.org/learn-chemistry/resource/res00000378/faces-of-chemistry-catalysts#!cmpid=CMP00000447	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
13	**Reactions of alkanes** Understand the reactions of alkanes with: i oxygen in the air (combustion) ii halogens Understand the mechanism of the free radical substitution reaction between an alkane and a halogen: i using free radicals, which are species with an unpaired electron, represented by a single dot ii showing the initiation step of the mechanism, with curly half-arrows for free radical formation iii showing the propagation and termination steps of the mechanism iv with limited use in synthesis because of further substitution reactions Understand the difference between hazard and risk Understand the hazards associated with organic compounds and why it is necessary to carry out risk assessments when dealing with potentially hazardous materials Be able to suggest ways by which risks can be reduced and reactions can be carried out safely, for example: i working on a smaller scale ii taking precautions specific to the hazard iii using an alternative method that involves less hazardous substances	Demonstrate the burning of an alkane and testing the carbon dioxide and water produced e.g. http://www.rsc.org/learn-chemistry/resource/res00000707/identifying-the-products-of-combustion Ask students to prepare for the lesson by watching a video on the free radical substitution reaction between methane and chlorine e.g. https://www.youtube.com/watch?v=MI74WOW8jac Discuss the mechanism, then ask students to work out the mechanism for the reaction of chloromethane with chlorine, so introducing the idea of further substitution and the limited use of this reaction in synthesis Students work in groups to carry out an experiment to crack an alkane by thermal decomposition (e.g. decane in liquid paraffin with aluminium oxide catalyst) e.g. http://www.rsc.org/learn-chemistry/resource/res00000681/cracking-hydrocarbons Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
14	**Alkenes** Know the general formula of alkenes and understand that alkenes and cycloalkenes are hydrocarbons which are unsaturated (have a carbon-carbon double bond which consists of a σ and a π bond) Be able to explain geometric isomerism in terms of restricted rotation around a C=C double bond and the nature of the substituents on the carbon atoms Understand the *E-Z* naming system for geometric isomers and why it is necessary to use this when the *cis*- and *trans*- naming system breaks down	Students make models of alkenes, name them and write structural, displayed and skeletal formulae for the molecules. Students make up as many different (non-cyclic) models of C_4H_8 as they can but-1-ene, but-2-ene, 2-methylpropene) and recognise these as structural isomers. Look at the structures of but-2-ene that they have made to see if they are all the same or if any are different and hence introduce the idea of geometric isomerism. Introduce the idea of *cis*- and *trans*- isomers then *E-Z* isomers. Students work in groups to extract limonene from orange or lemon peel by steam distillation e.g. http://www.rsc.org/learn-chemistry/resource/res00000692/extracting-limonene-from-oranges Students work in groups to prepare cyclohexene from cyclohexanol e.g. Chemistry in Context Laboratory Manual and Study Guide: Hill and Holman ISBN 0-17-448191-8	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
15	**Reactions of alkenes** Be able to describe the reactions of alkenes, limited to: i the addition of hydrogen, using a nickel catalyst, to form an alkane ii the addition of halogens to produce a di-substituted halogenoalkane iii the addition of hydrogen halides to produce mono-substituted halogenoalkanes iv the addition of steam, in the presence of an acid catalyst, to produce alcohols v oxidation of the double bond by acidified potassium manganate(VII) to produce a diol Know the qualitative test for a C=C double bond using bromine or bromine water Be able to describe the mechanism (including diagrams), giving evidence where possible of: i the electrophilic addition of bromine and hydrogen bromide to ethane ii the electrophilic addition of hydrogen bromide to propene Be able to describe the addition polymerisation of alkenes and draw the repeat unit given the monomer, and vice versa Understand how chemists limit the problems caused by polymer disposal by: i developing biodegradable polymers ii removing toxic waste gases produced by the incineration of polymers	Students work in groups to carry out test tube reactions to investigate the difference in reactivity of alkanes and alkenes e.g. combustion, reaction with bromine water, reaction with acidified potassium manganate(VII). Students make models to show the addition reactions of ethene. They should understand that only the π bond breaks and the σ bond remains intact. This resource from RSC has useful information on Organic Chemistry reaction mechanisms : http://www.rsc.org/learn-chemistry/resource/res00001107/reaction-mechanisms Students should use curly arrows in mechanisms and these must start from either a bond or a lone pair of electrons. They should know the relative stability of primary, secondary and tertiary carbocation intermediates. Demonstration or video of the preparation of Perspex from methyl 2-methylpropenoate or polystyrene from phenylethene e.g. http://www.rsc.org/learn-chemistry/resource/res00000479/addition-polymerisation Students use models to see the formation of long chain molecules	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
16	**Enthalpy changes** Know that the enthalpy change, ΔH, is the heat energy change measured at constant pressure and that standard conditions are 100 kPa and a specified temperature, usually 298 K Know that, by convention, exothermic reactions have a negative enthalpy change and endothermic reactions have a positive enthalpy change Be able to construct and interpret enthalpy level diagrams showing exothermic and endothermic enthalpy changes Know the definition of standard enthalpy change of: i reaction, $\Delta_r H$ ii formation, $\Delta_f H$ iii combustion, $\Delta_t H$ iv neutralisation, $\Delta_{neut} H$ v atomisation, $\Delta_{at} H$ Be able to use experimental data to calculate: i energy transferred in a reaction using the expression: energy transferred (J) = mass (g) × specific heat capacity (J g^{-1} $°C^{-1}$)× temperature change (°C) ii enthalpy change of the reaction in kJ mol^{-1} *This will be limited to experiments where substances are mixed in an insulated container, and combustion experiments using a suitable calorimeter*	Check definitions using RSC starter activity. http://tinyurl.com/enthalpystarter Students work in groups to carry out practicasl to determine the enthalpy change of: i combustion of an alcohol ii reaction between zinc and copper(II) sulfate solution iii hydration of anhydrous copper(II) sulfate e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
17	**Hess's Law** Know Hess's Law and be able to apply it to: i constructing enthalpy cycles ii calculating enthalpy changes of reaction using data provided, or data selected from a table or obtained from experiments Be able to evaluate the results obtained from experiments and comment on sources of error and uncertainty and any assumptions made in the experiments. *Students will need to consider experiments where substances are mixed in an insulated container, and combustion experiments using e.g. a spirit burner* **CORE PRACTICAL 2** Determination of the enthalpy change of a reaction using Hess's Law	Worksheets on Hess's Law calculations. Students work in groups to carry out a practical to determine the enthalpy change for the decomposition of calcium carbonate using the enthalpy changes of reaction of calcium carbonate and calcium oxide with hydrochloric acid.	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
18	**Bond enthalpies** Understand the terms 'bond enthalpy' and 'mean bond enthalpy', and be able to use bond enthalpies to calculate enthalpy changes, understanding the limitations of this method Be able to calculate mean bond enthalpies from enthalpy changes of reaction Understand that bond enthalpy data gives some indication about which bond will break first in a reaction, how easy or difficult it is and therefore how rapidly a reaction will take place at room temperature	Students research bond enthalpy data and use it to produce spreadsheet that will calculate the enthalpy changes for reactions	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
19	**Intermolecular forces** Understand the nature of the following intermolecular forces: i London forces (instantaneous dipole-induced dipole) ii permanent dipole-permanent dipole interactions iii hydrogen bonds Understand the interactions in molecules, such as H_2O, liquid NH_3 and liquid HF, which give rise to hydrogen bonding Understand the following anomalous properties of water resulting from hydrogen bonding: i its high melting and boiling temperature when compared with molecules of a similar molar mass ii the density of ice compared to that of water Be able to predict the presence of hydrogen bonding in molecules analogous to those mentioned above	Card sort task to order elements in terms of electronegativity and /or bonds in terms of polarity. Test predictions by experiment – effect of electrostatic field on a stream of liquid – this can be done as a demonstration. e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Compare boiling temperatures of unbranched hydrocarbons to introduce concept of London Forces. Consider hydrogen bonding in a range of molecules and assess understanding using observations and deductions from practical work (e.g. 'What are Hydrogen Bonds and where are they found?' – RSC). (http://tinyurl.com/whatraehydrogenbonds) Whiteboard / PRU Quiz.	

19 **Cont..**	Understand, in terms of intermolecular forces, physical properties shown by substances, including: i the trends in boiling temperatures of alkanes with increasing chain length ii the effect of branching in the carbon chain on the boiling temperatures of alkanes iii the relatively low volatility (higher boiling temperatures) of alcohols compared to alkanes with a similar number of electrons iv the trends in boiling temperatures of the hydrogen halides HF to HI Understand factors that influence the choice of solvents, including: i water, to dissolve some ionic compounds, in terms of the hydration of the ions ii water, to dissolve simple alcohols, in terms of hydrogen bonding iii water, as a poor solvent for compounds (to include polar molecules such as halogenoalkane), in terms of inability to form hydrogen bonds iv non-aqueous solvents, for compounds that have similar intermolecular forces to those in the solvent	Plot data and annotate graph to explain trends in boiling temperature of hydrogen halides Students work in groups to carry out these practicals: i investigating the solubility of simple molecules in different solvents ii measuring the enthalpy change of vaporisation of water iii measuring temperature changes when substances dissolve	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
20	**Redox reactions** Know what is meant by the term 'oxidation number' and understand the rules for assigning oxidation numbers Be able to calculate the oxidation number of elements in compounds and ions, including in peroxides and metal hydrides Be able to indicate the oxidation number of an element in a compound or an ion, using a Roman numeral Be able to write formulae given oxidation numbers Understand oxidation and reduction in terms of electron transfer and changes in oxidation number, and the application of these ideas to reactions of s-block and p-block elements Know that oxidising agents gain electrons and reducing agents lose electrons Understand that a disproportionation reaction involves an element in a single species being simultaneously oxidised and reduced Know that oxidation number is a useful concept in terms of the classification of reactions as redox and as disproportionation Understand that metals, in general, form positive ions by loss of electrons with an increase in oxidation number whereas non-metals, in general, form negative ions by gain of electrons with a decrease in oxidation number Be able to write ionic half-equations and use them to construct full ionic equations	Carry out a series of displacement reactions. Introduce concept of oxidation numbers and use them to reassign each change as a redox reaction, writing both full and ionic equations. Thermite reaction can be used as a 'fascinator'. Give students a range of cards each showing the equation for a disproportionation reaction. Each group has 2 minutes to describe the link between each reaction. Groups then come up with a definition to describe their findings and feedback to rest of group. http://www.rsc.org/learn-chemistry/resource/res00000511/redox-reactions	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
21	**Chemistry of Groups 1 and 2** Understand reasons for the trend in ionisation energy down Groups 1 and 2 Understand reasons for the trend in reactivity of the elements down Group 1 (Li to K) and Group 2 (Mg to Ba) Know the reactions of the elements of Group 1 (Li to K) and Group 2 (Mg to Ba) with oxygen, chlorine and water Know the reactions of: i oxides of Group 1 and 2 elements with water and dilute acid ii hydroxides of Group 1 and 2 elements with dilute acid Know the trends in solubility of the hydroxides and sulfates of Group 2 elements Understand the reasons for the trends in thermal stability of the nitrates and the carbonates of the elements in Groups 1 and 2 in terms of the size and charge of the cations involved Understand the formation of characteristic flame colours by Group 1 and 2 compounds in terms of electron transitions Know experimental procedures to show: i patterns in the thermal decomposition of Group 1 and 2 nitrates and carbonates ii flame colours in compounds of Group 1 and 2 elements	Students work in groups to carry out these practicals: i experiments to study the thermal decomposition of Group 1 and 2 nitrates and carbonates *Students will be expected to know tests for carbon dioxide and oxygen; and to recognise nitrogen dioxide by its colour and acidic pH* ii flame tests on compounds of Group 1 and 2 *Students will be expected to know the flame colours for Group 1 and 2 compounds* e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
22	**Analysis** Know reactions, including ionic equations where appropriate, for identifying: i carbonate ions, CO_3^{2-}, and hydrogencarbonate ions, HCO_3^-, using an aqueous acid to form carbon dioxide (and testing the gas with lime water) ii sulfate ions, SO_4^{2-}, using acidified barium chloride solution iii ammonium ions, NH_4^+, using sodium hydroxide solution and warming to form ammonia (and testing with litmus and HCl fumes) Be able to calculate solution concentrations, in mol dm^{-3} and g dm^{-3}, including simple acid-base titrations using the indicators methyl orange and phenolphthalein **CORE PRACTICAL 3** Finding the concentration of a solution of hydrochloric acid Understand how to minimise the sources of measurement uncertainty in volumetric analysis and estimate the overall uncertainty in the calculated result. **CORE PRACTICAL 4** Preparation of a standard solution from a solid acid and use it to find the concentration of a solution of sodium hydroxide	Students work in groups to carry out these practicals: i test tube reactions to identify the ions listed in the specification ii simple acid-base titrations using the indicators methyl orange and phenolphthalein to calculate solution concentrations in g dm^{-3} and mol dm^{-3} iii the solubility of calcium hydroxide by titration iv determination of moles of water of crystallisation by titration	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
23	**Chemistry of Group 7** Understand reasons for the trends for Group 7 elements in: i melting and boiling temperatures and physical state at room temperature ii electronegativity iii reactivity down the group Understand the trend in reactivity of Group 7 elements in terms of the redox reactions of Cl_2, Br_2 and I_2 with halide ions in aqueous solution Understand the following reactions: precipitation reactions of the aqueous anions Cl^-, Br^- and I^- with aqueous silver nitrate solution, and the solubility of the precipitates in aqueous ammonia solutions Be able to make predictions about fluorine and astatine and their compounds, in terms of knowledge of trends in halogen chemistry	Students are expected to know the colours of the elements in aqueous solution and in a non-polar organic solvent Carry out research task based on physical properties and uses of halogens Students work in groups to carry out these test tube reactions: i precipitation reaction for halides ii use tests for all the ions in Topic 8 to identify some unknown compounds in preparation for Core Practical 8 in Topic 10D e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 http://www.rsc.org/learn-chemistry/resource/res00000464/testing-salts-for-anions-and-cations	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
24	**Explaining redox reactions of Group 7** Understand, in terms of changes in oxidation number, the following reactions of the halogens: i oxidation reactions with Group 1 and 2 metals ii the disproportionation reaction of chlorine with water and the use of chlorine in water treatment iii the disproportionation reaction of chlorine with cold, dilute aqueous sodium hydroxide to form bleach iv the disproportionation reaction of chlorine with hot alkali v reactions analogous to those specified above Understand the following reactions: i solid Group 1 halides with concentrated sulfuric acid, to illustrate the trend in reducing ability of the hydrogen halides iii hydrogen halides with ammonia gas (to produce ammonium halides) and with water (to produce acids)	Students can use knowledge of oxidation numbers and disproportionation to predict the products from the reactions outlined on the specification. Predictions can be tested by demonstrations and/or videos. Students work in groups or see a demonstration of the reaction of solid potassium halides with concentrated sulfuric acid e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
25	**Kinetics** Understand, in terms of the collision theory, the effect of changes in concentration, temperature, pressure and surface area on the rate of a chemical reaction Understand that reactions only take place when collisions have sufficient energy, known as the activation energy Be able to calculate the rate of a reaction from: i the time taken for a reaction, using rate = 1/time ii the gradient of suitable graph, by drawing a tangent, either for initial rate, or at a time, t Understand qualitatively in terms of, the Maxwell-Boltzmann distribution of molecular energies how changes in temperature affect the rate of a reaction Understand the role of catalysts in providing alternative reaction routes of lower activation energy Be able to draw the reaction profiles for uncatalysed and catalysed reactions including the energy level of the intermediate formed with the catalyst Understand the use of catalysts in industry to make processes more sustainable by using less energy and/or higher atom economy Be able to interpret the action of a catalyst in terms of a qualitative understanding of the Maxwell-Boltzmann distribution of molecular energies	Students work in groups to carry out experiments to demonstrate the factors that influence the rate of chemical reactions, e.g. the decomposition of hydrogen peroxide, reaction of marble chips with acid, reaction of thiosulfate ions with acid Produce suitable graphs which can then be annotated to describe trends and explain them using collision theory. Give students a selection of reaction profiles with errors. Ask students to find and explain the errors.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
26	**Equilibria** Know that many reactions are readily reversible and that they can reach a state of dynamic equilibrium in which: i the rate of the forward reaction is equal to the rate of the backward reaction ii the concentrations of the reactants and the products remain constant Be able to predict and justify the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium in a homogeneous system Evaluate data to explain the necessity, for many industrial processes, to reach a compromise between the yield and the rate of reaction	Demonstrate the effect of a change of temperature, pressure and concentration on a system at equilibrium: i chlorine reacting with iodine to form iodine(I) chloride which then reacts with chlorine to form iodine(III) chloride ii the equilibrium system between nitrogen dioxide (NO_2) and dinitrogen tetroxide (N_2O_4)	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
27	**Introduction to halogenoalkanes** Be able to classify reactions (including those in Unit 1) as addition, elimination, substitution, oxidation, reduction, hydrolysis or polymerisation Understand the concept of a reaction mechanism Understand that heterolytic bond breaking results in species that are electrophiles or nucleophiles Know the definition of the term 'nucleophile' Understand the link between bond polarity and the type of reaction mechanism a compound will undergo Understand the nomenclature of halogenoalkanes and be able to draw their structural, displayed and skeletal formulae Understand the distinction between primary, secondary and tertiary halogenoalkanes Understand the reactions of halogenoalkanes with: i aqueous alkali, e.g. KOH(aq) to produce alcohols (where the hydroxide ion acts as a nucleophile) ii ethanolic potassium hydroxide to produce alkenes by an elimination reaction (where the hydroxide ion acts as a base) iii aqueous silver nitrate in ethanol (where water acts as a nucleophile) iv alcoholic ammonia under pressure to produce amines (where the ammonia acts as a nucleophile) v alcoholic potassium cyanide to produce nitriles (where the cyanide ion acts as a nucleophile Understand the mechanisms of the nucleophilic substitution reactions between primary halogenoalkanes and: i aqueous potassium hydroxide ii ammonia	Knowledge of the concepts introduced in Unit 1, Topics 5 and 6 will be assumed and extended in this topic. The first five points can be used as general revision from Unit 1 or taught as they arise in other specification points Students work in groups to carry out the following practicals: i the use of silver nitrate solution to identify the halogen present in halogenoalkanes as preparation for Core Practical 5 ii preparation of 1-bromobutane from butan-1-ol, potassium bromide and sulfuric acid as preparation for Core Practicals 6 and 7 Students should know the reaction with alcoholic potassium cyanide as an example of increasing the length of the carbon chain Note S_N1 and S_N2 substitution mechanisms will be tested in Unit 4	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
28	**Trends in Reactivity of Nucleophilic Substitution Reactions** Understand that experimental observations and data can be used to compare the relative rates of hydrolysis of: i primary, secondary and tertiary structural isomers of a halogenoalkane ii primary chloro-, bromo- and iodoalkanes using aqueous silver nitrate in ethanol **CORE PRACTICAL 5** Investigation of the rates of hydrolysis of some halogenoalkanes Know the trend in reactivity of primary, secondary and tertiary halogenoalkanes Understand, in terms of bond enthalpy, the trend in reactivity of chloro-, bromo- and iodoalkanes **CORE PRACTICAL 6** Chlorination of 2-methylpropan-2-ol with concentrated hydrochloric acid	Interpret data from Core Practical 5 Research data for C-Cl, C-Br and C-I bonds and use this to help explain trend in data from Core Practical 5	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
29	**Alcohols** Understand the nomenclature of alcohols and be able to draw their structural, displayed and skeletal formulae Understand the reactions of alcohols with: i oxygen in air (combustion) ii halogenating agents: PCl_5 to produce chloroalkanes (including its use as a qualitative test for the presence of the –OH group) 50% concentrated sulfuric acid and potassium bromide to produce bromoalkanes red phosphorus and iodine to produce iodoalkanes iii concentrated phosphoric acid to form alkenes by elimination	Students work in groups to investigate reactions of primary and secondary alcohols e.g. propan-1-ol and propan-2-ol Descriptions of the mechanisms of these reactions are not required	

29 **Cont…**	Understand that potassium dichromate(VI) in dilute sulfuric acid can oxidise: i primary alcohols to produce aldehydes (which give a positive result with Benedict's or Fehling's solution) if the product is distilled as it forms ii primary alcohols to produce carboxylic acids (which give a positive result with sodium carbonate or sodium hydrogencarbonate) if the reagents are heated under reflux iii secondary alcohols to produce ketones Understand, the following techniques in the preparation and purification of a liquid organic compound: i heating under reflux ii extraction with a solvent using a separating funnel iii distillation iv drying with an anhydrous salt v boiling temperature determination **CORE PRACTICAL 7** The oxidation of propan-1-ol to produce propanal and propanoic acid	In equations, the oxidising agent can be represented by [O]	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
30	**Mass spectra and IR** Be able to interpret data from mass spectra to suggest possible structures of simple organic compounds using the m / z of the molecular ion and fragmentation patterns Be able to use infrared spectra, or data from infrared spectra, to deduce functional groups present in organic compounds, and predict infrared absorptions, due to familiar functional groups including given wavenumber data: i C–H stretching absorptions in alkanes, alkenes and aldehydes ii C=C stretching absorption in alkenes iii O–H stretching absorptions in alcohols and carboxylic acids iv C=O stretching absorptions in aldehydes, ketones and carboxylic acids v C–X stretching absorption in halogenoalkanes vi N-H stretching absorption in amines **CORE PRACTICAL 8** Analysis of some inorganic and organic unknowns	Students can research IR and mass spectra of simple organic compounds using Spectra School and can annotate spectra using data from data booklet. Molecular models can be made then broken up by students to try to identify peaks in mass spectra due to fragmentation. http://spectraschool.rsc.org/	

IA2

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
1	**The Rate Law** Understand the terms: i rate of reaction ii rate equation, rate=k[A]^m[B]^n where m and n are 0, 1 or 2 iii order with respect to a substance in a rate equation iv overall order of a reaction v rate constant vi half-life vii rate-determining step viii activation energy ix heterogeneous and homogeneous catalyst Be able to calculate the half-life of a reaction using data from a suitable graph and identify a reaction with a constant half-life as being first order Be able to select and justify a suitable experimental technique to obtain rate data for a given reaction, including: i titration ii colorimetry iii mass change iv volume of gas evolved v other suitable technique(s) for a given reaction Understand experiments that can be used to investigate reaction rates by an initial-rate method, carrying out separate experiments where different initial concentrations of one reagent are used **CORE PRACTICAL 13b**: Rates of reaction Following the rate of a reaction using a 'clock reaction' (Harcourt-Esson, iodine clock)	Knowledge of the concepts introduced in Unit 2, Topic 9A: Kinetics will be assumed and extended in this topic. Students can research these key terms as part of a 'Flipped Learning' session. Many videos can be found on YouTube. During contact time students can check their understanding using a series of worksheets, scaffolded in difficulty. Students can be provided with the details of a number of novel reactions and asked to produce suitable techniques to obtain rate data. Students work in pairs or groups to carry out the reaction between marble chips and hydrochloric acid (change of mass or change in volume of gas) or sodium thiosulfate and hydrochloric acid as preparation for Core Practical 13 A 'clock reaction' is an acceptable approximation of the initial-rate method	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
2	**Studying the Kinetics of Reactions** Understand experiments that can be used to investigate reaction rates by a continuous monitoring method to generate data to enable concentration-time or volume-time graphs to be plotted Be able to deduce the order (0, 1 or 2) with respect to a substance in a rate equation using data from: i a concentration-time graph ii a rate-concentration graph iii an initial-rate method **CORE PRACTICAL 13a**: Rates of reaction Following the rate of the iodine-propanone reaction by a titrimetric method	Students process data collected (e.g. graphs of concentration against time, calculation of estimate of initial rate) or data provided to determine orders and hence rate constants.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
3	**Using Kinetics to Investigate Mechanisms** Understand how to: i obtain data to calculate the order with respect to the reactants (and the hydrogen ion) in the acid-catalysed iodination of propanone ii use these data to make predictions about species involved in the rate-determining step iii deduce a possible mechanism for the reaction Be able to deduce the rate-determining step from a rate equation and vice versa Be able to deduce a reaction mechanism, using knowledge of the rate equation and the stoichiometric equation for a reaction Understand that knowledge of the rate equations for the hydrolysis of halogenoalkanes can be used to provide evidence for S_N1 and S_N2 mechanisms for tertiary and primary halogenoalkane hydrolysis	Students could also follow the rate of the iodine-propanone reaction by a colorimetric method or watch a demonstration or video of this technique Students can process data from rate experiments featuring the hydrolysis of different classifications of halogenoalkanes. Having determined the order with respect to the reactants they can propose mechanisms for each reaction.	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
4	**Activation energy and catalysts** Be able to use calculations and graphical methods to find the activation energy for a reaction from experimental data **CORE PRACTICAL 10** Finding the activation energy of a reaction Understand the use of a solid (heterogeneous) catalyst for industrial reactions, in the gas phase, in terms of providing a surface for the reaction	The Arrhenius equation will be given if needed Students work in groups to determine the activation energy for the reaction between magnesium and hydrochloric acid as preparation for Core Practical 10 Students work in groups to carry out the catalysis by a cobalt(II) salt of potassium sodium tartrate and hydrogen peroxide and /or the action of the enzyme urease on urea and thiourea	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
5	**Entropy** Understand that, since endothermic reactions can occur spontaneously at room temperature, enthalpy changes alone do not control whether reactions occur Understand entropy as a measure of disorder of a system in terms of the random dispersal of molecules and of energy quanta between molecules Understand that the entropy of a substance increases with temperature, that entropy increases as solid → liquid → gas and that perfect crystals at zero kelvin have zero entropy Be able to interpret the natural direction of change as being in the direction of increasing total entropy (positive entropy change), e.g. gases spread spontaneously through a room Understand why entropy changes occur during: i changes of state ii dissolving of a solid ionic lattice iii reactions in which there is a change in the number of moles from reactants to products Understand that the total entropy change of any reaction is the sum of the entropy change of the system and the entropy change of the surroundings, summarised by the expression: $\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$ Be able to calculate the entropy change of the system for a reaction, ΔS_{system}, given the entropies of the reactants and products Continued on next page	Students work in groups to carry out a series of reactions to estimate changes in disorder due to system and surroundings. Use qualitatively to justify why a reaction occurs under a particular set of conditions: i dissolving a solid, e.g. adding ammonium nitrate crystals to water ii gas evolution, e.g. reacting ethanoic acid with ammonium carbonate iii exothermic reaction producing a solid, e.g. burning magnesium ribbon in air iv endothermic reaction of two solids, e.g. mixing solid barium hydroxide, $Ba(OH)_2.8H_2O$ with solid ammonium chloride Carry out a series of calculations to confirm, using the total entropy change, whether a reaction is feasible under a given set conditions.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
5 cont…	Be able to calculate the entropy change in the surroundings, and hence ΔS_{total}, using the expression $$\Delta S_{surroundings} = \frac{-\Delta H}{T}$$ Understand that the feasibility of a reaction depends on: i the balance between ΔS_{system} and $\Delta S_{surroundings}$, so that even endothermic reactions can occur spontaneously at room temperature ii temperature, as higher temperatures decreases the magnitude of $\Delta S_{surroundings}$ so its contribution to ΔS_{total} is less Understand that reactions can occur as long as ΔS_{total} is positive even if one of the other entropy changes is negative Understand and distinguish between the concepts of thermodynamic stability and kinetic stability	Students should be able to calculate the temperature at which a reaction is feasible Students may also use $\Delta G = \Delta H - T\Delta S_{system}$ in answers, although this approach is not a requirement of the specification	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
6	**Lattice Energy** Be able to define the terms: i standard enthalpy change of atomisation, $\Delta_{at}H$ ii electron affinity iii lattice energy (as the exothermic process for the formation of one mole of an ionic solid from its gaseous ions) Be able to construct Born-Haber cycles and carry out related calculations Understand that a comparison of the experimental lattice energy value (from a Born-Haber cycle) with the theoretical value (obtained from electrostatic theory) in a particular compound indicates the degree of covalent bonding understand that polarisation of anions by cations leads to some covalency in an ionic bond, based on evidence from the Born-Haber cycle Be able to define the terms 'enthalpy change of solution, $\Delta_{sol}H$' and 'enthalpy change of hydration, $\Delta_{hyd}H$ *of* an ion' Be able to use energy cycles and energy level diagrams to calculate the enthalpy change of solution of an ionic compound, using enthalpy change of hydration and lattice energy Understand the effect of ionic charge and ionic radius on the values of enthalpy change of hydration and the lattice energy of an ionic compound Be able to use entropy and enthalpy changes of solution values to predict the solubility of ionic compounds and discuss trends in the solubility of ionic compounds covered in Unit 2	Students are given the definitions and have to decide which term they define, with reasons. After being shown a model example of a Born-Haber calculation, students can carry out calculations on a variety of ionic compounds. The Born-Haber values can be compared to theoretical values and any differences discussed in terms of ionic radii and charge. Students work in groups to calculate the enthalpy change when a variety of ionic solids are dissolved in water Students carry out problem solving task 'Cool Drinking' from RSC. http://tinyurl.com/cool-drinkRSC	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
7	**Chemical Equilibria** Be able to deduce an expression for K_c, for homogeneous and heterogeneous systems, in terms of equilibrium concentrations Be able to deduce an expression for K_p for homogeneous and heterogeneous systems, in terms of equilibrium partial pressures in atm Be able to calculate a value, with units where appropriate, for the equilibrium constants (K_c and K_p) for homogeneous and heterogeneous reactions, from experimental data Understand how, if at all, a change in temperature, pressure or the presence of a catalyst affects the equilibrium composition in a homogeneous or heterogeneous system Understand that the value of the equilibrium constant is not affected by changes in concentration or pressure or by the addition of a catalyst Know the effect of changing the temperature on the equilibrium constant (K_c and K_p) for both exothermic and endothermic reactions Understand that the effect of temperature on the position of equilibrium is explained using a change in the value of the equilibrium constant Understand the effect of a change in temperature on: i the value of ΔS_{total} ii the magnitude of the equilibrium constant, since $\Delta S_{total} = R \ln K$ Be able to apply knowledge of the value of equilibrium constants to predict the extent to which a reaction takes place	Students work in groups to carry out these practicals, or watch demonstrations or videos: i the reaction of ethanol and ethanoic acid (this can be used as an example of the use of ICT to present and analyse data), ii the equilibrium $Fe^{2+}(aq) + Ag^{+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ag(s)$ iii the distribution of ammonia or iodine between two immiscible solvents iv the thermal decomposition of ammonium chloride v the effect of temperature and pressure changes in the system $2NO_2 \rightleftharpoons N_2O_4$ e.g. Advanced Practical Chemistry ISBN:978-0-7195-7507-5 Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 http://tinyurl.com/eqmmicroscale Calculate Kc for a reaction at different temperatures then link back to Le Chatelier to justify change in value. e.g. Advanced Chemistry Calculations ISBN: 0-7195-4189-1 Check understanding using RSC AfL activity. http://tinyurl.com/eqmafl	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
8	**Acid-base equilibria** Understand that a Brønsted–Lowry acid is a proton donor and a base a proton acceptor and that acid-base equilibria involve proton transfer Be able to identify Brønsted–Lowry conjugate acid-base pairs Be able to define the term 'pH' Be able to calculate pH from hydrogen ion concentration Be able to calculate the concentration of hydrogen ions in a solution, in mol dm^{-3}, from its pH, using the expression $[H^+] = 10^{-pH}$ Understand the difference between a strong acid and a weak acid in terms of the degree of dissociation Be able to calculate the pH of a strong acid	Students use acid-base simulation (RSC) to investigate properties of strong and weak acids, producing a summary document of their findings for self-assessment. http://tinyurl.com/acid-baseRSC Carry out experiments to find the pH of a range of solutions of different concentration. Compare experimental value to calculated value. Check understanding using RSC 'Acid Strength' task. http://tinyurl.com/pr3urph	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
9	**Weak acids, water and bases** Be able to deduce the expression for the acid dissociation constant, K_a for a weak acid Be able to calculate the pH of a weak acid from K_a or pK_a values, making relevant assumptions *Students will not be expected to solve quadratic equations* Be able to define the ionic product of water, K_w Be able to calculate the pH of a strong base from its concentration, using K_w or pK_w Be able to define the terms 'pK_a' and 'pK_w' Be able to analyse data from the following experiments: i measuring the pH of a variety of substances, e.g. equimolar solutions of strong and weak acids, strong and weak bases, and salts ii comparing the pH of a strong and weak acid after dilution 10, 100, and 1000 times Be able to calculate K_a for a weak acid from experimental data given the pH of a solution containing a known mass of acid **CORE PRACTICAL 11** Finding the K_a value for a weak acid	Students work in groups to carry out experiments to find the pH of a weak acid at different concentrations. Use this data to find K_w to show this is a more useful way of comparing acidic strength. e.g. Advanced Practical Chemistry ISBN:978-0-7195-7507-5 Introduce key definitions then students work in groups to carry out a problem solving exercise to find number of hydrogen ions in drops of water, acid and base. http://tinyurl.com/H-ionsRSC Students work in groups to carry out the measuring of the pH of solutions mentioned in 14.13.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
10	**Titration curves and buffer solutions** Be able to draw and interpret titration curves using all combinations of strong and weak acids and bases Be able to select a suitable indicator for a titration, using a titration curve and appropriate data Know what is meant by the term 'buffer solution' Understand the action of a buffer solution Be able to calculate the pH of a buffer solution given appropriate data Be able to calculate the concentrations of solutions required to prepare a buffer solution of a given pH Understand how to use a weak acid-strong base or strong acid-weak base titration curves to: i demonstrate buffer action ii determine K_a from the pH at the point where half the acid is neutralised Understand the importance of buffer solutions in biological environments: i buffers in cells and in blood (H_2CO_3/HCO_3^-) ii in foods to prevent deterioration due to pH change (caused by bacterial or fungal activity)	Students work in groups to obtain data to draw titration curves (which gives an opportunity to use data loggers). They plot a series of titration curves using combinations of strong acids, strong bases, weak acids and weak bases. Students can annotate curves to show key features such as equivalence point and buffering as well as to justify choice of suitable indicator(s) and calculate K_a. e.g. Advanced Practical Chemistry ISBN:978-0-7195-7507-5 Students work in groups to analyse a sample of vinegar Carry out calculations to work out quantities needed to make a buffer solution of a specific pH, then make the solution and measure its pH. Research roles of buffer solutions in biological systems, identifying component parts of the buffer. Check understanding with problem solving task 'On the Acid Trail'. http://tinyurl.com/acid-trail	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
11	**Chirality and mechanisms** Know that optical isomerism is a result of chirality in molecules with a single chiral centre Understand that optical isomerism results from chiral centre(s) in a molecule with asymmetric carbon atom(s) and that optical isomers are object and non-superimposable mirror images Know that optical activity is the ability of a single optical isomer to rotate the plane of polarisation of plane-polarised monochromatic light in molecules containing a single chiral centre Know what is meant by the term 'racemic mixture' Be able to use data on optical activity of reactants and products as evidence for S_N1 and S_N2 mechanisms and addition to carbonyl compounds	Revise structural isomerism and geometric isomerism from Unit 1, Topic 4B: Alkanes and Topic 5: Alkenes. Students research key concepts in as a Flipped Learning' task, using support videos. http://tinyurl.com/stereo-iso Give the students models of a pair of enantiomers and ask them to decide if they are different and if so, how. Use a starter to promote discussion of optical activity. Students research thalidomide. Use scaffolded questions to develop understanding of nucleophilic substitution from Unit 2: Topic 10. http://tinyurl.com/stereo-selective-reactions	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
12	**Chemistry of carbonyl compounds** Understand the nomenclature of aldehydes and ketones and be able to draw their structural, displayed and skeletal formulae Understand that aldehydes and ketones: i do not form intermolecular hydrogen bonds and this affects their physical properties ii can form hydrogen bonds with water and this affects their solubility Understand the reactions of carbonyl compounds with: i Fehling's or Benedict's solution, Tollens' reagent and acidified dichromate(VI) ions *In equations, the oxidising agent can be represented as [O]* ii lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in dry ether (ethoxyethane) *In equations, the reducing agent can be represented by [H]* iii HCN, in the presence of KCN, as a nucleophilic addition reaction, using curly arrows, relevant lone pairs, dipoles and evidence of optical activity to show the mechanism iv 2,4-dinitrophenylhydrazine (2,4-DNPH), as a qualitative test for the presence of a carbonyl group and to identify a carbonyl compound given data of the melting temperatures of derivatives *The equation for this reaction is not required* v iodine in the presence of alkali (the iodoform test)	Prepare a 'giant silver mirror' test as a 'hook' to generate initial interest in the lesson(s). http://www.nuffieldfoundation.org/practical-chemistry/giant-silver-mirror Revise preparation of carbonyl compounds from alcohols in Unit 2, Topic 10C: Alcohols Make models of carbonyl compounds and water and use these to illustrate solubility. Students work in groups to carry out test tube reactions of aldehydes and ketones given in 15.8 i, iv and v. Use RSC Mechanism Inspector to introduce nucleophilic addition in a 'Flipped Learning' environment. Test understanding using a series of scaffolded question in class. http://tinyurl.com/mechinspect Use 'Write–Cover–Rewrite' technique to embed knowledge of mechanism. Students work in groups to prepare a dry sample of a 2,4-dinitrophenylhydrazine derivative and identify the carbonyl compound by determining the melting temperature of the derivative. http://tinyurl.com/24DNP-test http://tinyurl.com/24DNP-derivative	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
13	**Chemistry of carboxylic acids and their derivatives** Understand the nomenclature of carboxylic acids and be able to draw their structural, displayed and skeletal formulae Understand that hydrogen bonding affects the physical properties of carboxylic acids, in relation to their boiling temperatures and solubility Understand that carboxylic acids can be prepared by the oxidation of alcohols or aldehydes and the hydrolysis of nitriles Understand the reactions of carboxylic acids with: i lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in dry ether (ethoxyethane) ii bases to produce salts iii phosphorus(V) chloride (phosphorus pentachloride) iv alcohols in the presence of an acid catalyst	Students produce summary mind map of reactions involving carboxylic acids from IGCSE and IA level year 1, including appropriate reagents and conditions. Discussion of structural features of acids can lead to suggestions of further reactions, which can be researched and added to map. Students work in groups to carry out these practicals: i investigate the solubility of a range of carboxylic acids, aldehydes and ketones ii prepare a carboxylic acid by the oxidation of alcohols and aldehydes iii test tube reactions of carboxylic acids given in 15.12 ii,iii and iv iv prepare an ester such as ethyl ethanoate as a solvent or a pineapple flavouring	

13 **cont**	Understand the nomenclature of acyl chlorides and esters and be able to draw their structural, displayed and skeletal formulae Understand the reactions of acyl chlorides with: i water ii alcohols iii concentrated ammonia iv amines Understand the hydrolysis reactions of esters, in acidic and alkaline solution Understand how polyesters are formed by condensation polymerisation reactions	v hydrolyse an ester. e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Demonstrate the reactions of ethanoyl chloride given in 15.14 i, ii and iii Advanced Practical Chemistry ISBN:978-0-7195-7507-5	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
14	**Spectroscopy** Be able to use data from mass spectra to: i suggest possible structures of a simple organic compound given accurate relative molecular masses ii calculate the accurate relative molecular mass of a compound, given accurate relative atomic masses to four decimal places Understand that ^{13}C NMR spectroscopy provides information about the positions of ^{13}C atoms in a molecule Be able to use data from ^{13}C NMR spectroscopy to: i predict the different environments for carbon atoms present in a molecule, given values of chemical shift, δ ii justify the number of peaks present in a ^{13}C NMR spectrum in terms of the number of carbon atoms in different environments Be able to use both low and high resolution proton NMR spectroscopy to: i predict the different types of proton present in a molecule, given values of chemical shift, δ ii relate relative peak areas, or ratio number of protons, to the relative numbers of ^{1}H atoms in different environments iii deduce the splitting patterns of adjacent, non-equivalent protons using the (n+1) rule and hence suggest the possible structures for a molecule iv predict the chemical shifts and splitting patterns of the ^{1}H atoms in a given molecule	Knowledge of the concepts introduced in Unit 2, Topic 10D: Mass Spectra and IR will be assumed and extended in this topic. Students research the key principles of NMR using 'Spectra School' – this could be in a 'flipped learning' environment. Students annotate large print spectra to map peaks against different carbon environments. http://tinyurl.com/Spec-homeRSC	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
15	**Chromatography** Know that chromatography separates components of a mixture using a mobile phase and a stationary phase Be able to calculate R_f values from one-way chromatograms Know that high performance liquid chromatography, HPLC, and gas chromatography, GC, are types of column chromatography which separate substances because of different retention times in the column and may be used in conjunction with mass spectrometry, in applications such as forensics or drug testing in sport	Use paper chromatogram to illustrate key terms. Calculate R_f values of amino acids on paper chromatogram and attempt to match to accepted values for solvent used. View RSC video on Gas Chromatography. http://tinyurl.com/spec-videos Use understanding of chromatography to help solve a synoptic problem (e.g. Patient Prognosis – RSC). http://tinyurl.com/patient-prognosis	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
16	**Redox Equilibria – Electrode Potentials** Understand the terms 'oxidation' and 'reduction' in terms of electron transfer and changes in oxidation number, applied to *s*-, *p*- and *d*-block elements Know what is meant by the term 'standard electrode potential', E^{θ} Know that the standard electrode potential, E^{θ}, to is measured in conditions of: i 298 K temperature ii 100 kPa pressure of gases iii 1.00 mol dm^{-3} concentration of ions Know the features of the standard hydrogen electrode and understand why a reference electrode is necessary Understand that different methods are used to measure standard electrode potentials of: i metals or non-metals in contact with their ions in aqueous solution ii ions of the same element with different oxidation numbers **CORE PRACTICAL 12** Investigating some electrochemical cells	Revisit redox and oxidation numbers as a 'mini whiteboard' or Pupil Response Unit Quiz. Use 'flip learning' technique to introduce concept of standard electrode potential and hydrogen electrode in non-contact time using RSC video. http://tinyurl.com/sepRSC Students can add labels to an unlabelled diagram against the clock. http://tinyurl.com/9l5c9an (Countdown Clock!)	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
17	**Redox Equilibria – Uses of $E^\ominus_{cell}$** Be able to calculate a standard emf, E^θ_{cell} , by combining two standard electrode potentials Be able to write cell diagrams using the conventional representation of half-cells Understand the importance of the conditions when measuring an electrode potential, *E* Be able to use standard electrode potentials to predict the thermodynamic feasibility of a reaction Understand that E^θ_{cell} is directly proportional to the total entropy change and to ln*K* for a reaction	Students take photos of cells set up in practical lesson and annotate prints outs with the calculation for $E^\ominus_{cell}$ and a conventional cell diagram. Students work in groups to carry out experiments to investigate how E_{cell} varies with concentration. e.g. Advanced Practical Chemistry ISBN:978-0-7195-7507-5 Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Use the difference between $E^\ominus$ values to predict feasibility of reactions. Write an equation for each proposed reaction, calculate $E^\ominus_{cell}$, then test whether a reaction is observed. Students produce a summary of the links between $E^\ominus_{cell}$, lnK and ΔStotal.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
18	**Redox Equilibria – More uses of E°_{cell}** Understand the limitations of predictions made using standard electrode potentials, in terms of kinetic stability of systems and departure from standard conditions Know that standard electrode potentials are sometimes referred to as standard reduction potentials and can be listed as an electrochemical series Understand how standard electrode potentials can be used to predict the thermodynamic feasibility of disproportionation reactions Understand that fuel cells use the energy released on the reaction of a fuel with oxygen to generate a voltage *Knowledge that methanol and other hydrogen-rich fuels are used in fuel cells is expected.* Know the electrode reactions that occur in a hydrogen-oxygen fuel cell *Knowledge of hydrogen-oxygen fuel cells with both acidic and alkaline electrolyte is expected*	A demonstration of a uncatalysed reaction and catalysed (e.g. decomposition of hydrogen peroxide) can be used to promote discussion regarding limitations of thermodynamic predictions. Research application of cells (e.g. lead-acid, lithium ion). http://tinyurl.com/lead-acidRSC Build fuel cell using kits. Write equations to show reactions at both electrodes. Use simulations or models to illustrate changes at electrodes. http://tinyurl.com/Hyd-CellSIM	

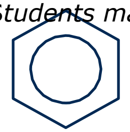
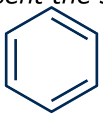
weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
19	**Redox Equilibria – Redox Titrations** Be able to carry out both structured and unstructured titration calculations involving redox reactions, including iron(II) ions and potassium manganate(VII) and sodium thiosulfate and iodine Be able to discuss the uncertainty of measurements and their implications for the validity of the final results **CORE PRACTICAL 13a and b** Be able to carry out redox titrations with both i iron(II) ions and potassium manganate(VII) ii sodium thiosulfate and iodine	Students work in groups to carry out these practicals to prepare for the Core Practicals: i investigate the percentage of copper in brass, using iodine-thiosulfate titration ii investigate the percentage of iron in iron tablets, using potassium manganate(VII) titration iii prepare crystals of potassium iodate(VII) and measure their purity e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 http://tinyurl.com/cleaningRSC	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
20	**Properties of Transition Metals and their Compounds** Know that transition metals are d-block elements that form one or more stable ions with incompletely-filled *d*-orbitals Be able to deduce the electronic configurations of atoms and ions of the d-block elements of period 4 Sc-Zn) given their atomic number and charge (if any) Understand why transition metals show variable oxidation number Know what is meant by the term 'ligand' Understand that dative (coordinate) covalent bonding is involved in the formation of complex ions Know that a complex ion is a central metal ion surrounded by ligands Know that aqueous solutions of transition metal ions are usually coloured Understand that the colour of aqueous ions, and other complex ions, is a consequence of the splitting of the energy levels of the *d*-orbitals by ligands Understand why there is a lack of colour in some aqueous ions and other complex ions Understand the meaning of the term 'coordination number' Understand that colour changes in transition metal ions may arise as a result of changes in: i oxidation number of the ion ii ligand iii coordination number of the complex	Practice a number of electronic configurations of atoms and ions, using copper and chromium as challenge activities. Students could make a colour wheel and use this as the start of a discussion regarding the colour of complex ion solutions. http://www.chemguide.co.uk/inorganic/complexions/colour.html	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
21	**Transition Metal Complexes and Ligands** Understand that H_2O, OH^- and NH_3 act as monodentate ligands Understand why complexes with six-fold coordination have an octahedral shape, such as those formed by metal ions with H_2O, OH^- and NH_3 as ligands Know that transition metal ions may form tetrahedral complexes with relatively large ions such as Cl^- Know that square planar complexes are also formed by transition metal ions and that *cis*-platin is an example of such a complex which is used in cancer treatment where it is supplied as a single isomer and not in a mixture with the *trans* form Understand the terms bidentate and hexadentate in relation to ligands, and be able to identify examples such as $NH_2CH_2CH_2NH_2$ and $EDTA^{4-}$ Know that haemoglobin is an iron(II) complex containing a polydentate ligand and that ligand exchange occurs when an oxygen molecule bound to haemoglobin is replaced by a carbon monoxide molecule *The structure of the haem group will not be assessed*	Students can be shown a range of complex ion solutions with formulae, be asked to draw or model their shapes and deduce coordination number. Research role of cis-platin in cancer treatments. Listen to podcast about cis-platin and produce summary notes. http://tinyurl.com/cis-platin-podcast Listen to podcast about haemoglobin and produce summary notes. http://tinyurl.com/haemo-podcast	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
22	**Reactions of Transition Metal ions in solution** Know the colours of the oxidation states of vanadium (+5, +4, +3 and +2) in its compounds Understand redox reactions for the interconversion of the oxidation states of vanadium (+5, +4, +3 and +2), in terms of the relevant $E^{\ominus}$ values Understand, in terms of the relevant $E^{\ominus}$ values, that the dichromate(VI) ion, $Cr_2O_7^{2-}$: i can be reduced to Cr^{3+} and Cr^{2+} ions using zinc in acidic conditions ii can be produced by the oxidation of Cr^{3+} ions using hydrogen peroxide in alkaline conditions (followed by acidification) Know that the dichromate(VI) ion, $Cr_2O_7^{2-}$ can be converted into chromate(VI) ions as a result of the equilibrium $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$ Be able to record observations and write suitable equations for the reactions of $Cr^{3+}(aq)$, $Mn^{2+}(aq)$, $Fe^{2+}(aq)$, $Fe^{3+}(aq)$, $Co^{2+}(aq)$ $Ni^{2+}(aq)$, $Cu^{2+}(aq)$ and $Zn^{2+}(aq)$ with aqueous sodium hydroxide and aqueous ammonia, including in excess Be able to write ionic equations to show the meaning of amphoteric behaviour, deprotonation and ligand exchange in the reactions in 17.22 Understand that ligand exchange, and an accompanying colour change, occurs in the formation of: i $[Cu(NH_3)_4(H_2O)_2]^{2+}$ from $[Cu(H_2O)_6]^{2+}$ via $Cu(OH)_2(H_2O)_4$ ii $[CuCl_4]^{2-}$ from $[Cu(H_2O)_6]^{2+}$ iii $[CoCl_4]^{2-}$ from $[Co(H_2O)_6]^{2+}$ Understand, in terms of the positive increase in ΔS_{system}, that the substitution of a monodentate ligand by a bidentate or hexadentate ligand leads to a more stable complex ion	Students work in groups to predict suitable reactants to form vanadium in each of its common oxidation states and carry out an experiment to confirm their predictions. e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Students can attempt justify redox reactions involving chromium using E_{cell} They can then construct half-equations and hence a full equation for each reaction. Students work in groups to carry out experiments to investigate reactions of transition metal ions with sodium hydroxide and ammonia, writing ionic equations for each change. Observations/equations can be self-assessed. e.g. http://tinyurl.com/ions-complex Students work in groups to carry out a series of experiments to show ligand exchange reactions of $[Cu(H_2O)_6]^{2+}$, recording colour changes, writing ionic equations and explaining any changes in coordination number. e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
23	**Catalysis** Know that transition metals and their compounds can act as heterogeneous and homogeneous catalysts Know that a heterogeneous catalyst is in a different phase from the reactants and that the reaction occurs at the surface of the catalyst – Understand, in terms of oxidation number, how v_2o_5 acts as a catalyst in the contact process Understand how a catalytic converter decreases carbon monoxide and nitrogen monoxide emissions from internal combustion engines by: i adsorption of co and no molecules onto the surface of the catalyst, resulting in the weakening of bonds and chemical reaction ii desorption of co_2 and n_2 product molecules from the surface of the catalyst Know that a homogeneous catalyst is in the same phase as the reactants and appreciate that the catalysed reaction will proceed via an intermediate species Understand the role of Fe^{2+} ions in catalysing the reaction between i^- and $S_2O_8^{2-}$ ions Know the role of Mn^{2+} ions in autocatalysing the reaction between MnO_4^- and $C_2O_4^{2-}$ ions **Core practical 14** The preparation of a transition metal complex	Students work in groups to build a model of a catalytic converter to illustrate how catalyst reduces harmful emissions from road vehicles, annotating their model to clearly show the processes involved. Students can make predictions regarding mechanism of catalysis in the reaction and investigate a number of possible transition metal ions as catalysts. Students work in groups to investigate the role of Mn^{2+} ions in the oxidation of $C_2O_4^{2-}$ ions by following the progress of the reaction using titrimetric techniques. e.g. Advanced Practical Chemistry ISBN:978-0-7195-7507-5 Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	

Weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
24	**Chemistry of Arenes – Structure of Benzene** Be able to use thermochemical, X-ray diffraction and infrared data as evidence for the structure and stability of the benzene ring *Students may represent the structure of benzene as*  or  *as appropriate in equations and mechanisms* Understand that the delocalised model for the structure of benzene involves overlap of *p*-orbitals to form π-bonds Understand why benzene is resistant to bromination, compared to alkenes, in terms of delocalisation of π-bonds in benzene compared to the localised electron density of the π-bond in alkenes	Knowledge of the common uses of organic compounds mentioned in this topic is expected. Students can make models of benzene and ethene and use them to help compare the bonding in both and explain why benzene does not give a positive result for unsaturation. Draw and annotate energy level diagrams for hydrogenation of benzene and cyclohexene and use these as evidence for the delocalised model. Use starter activities to test understanding (e.g. naming rules). RSC have produced a series of these called 'Starters for 10'. http://tinyurl.com/RSC-Starters	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
25	**Chemistry of Arenes – Electrophilic Substitution Reactions** Know the following reactions of benzene, limited to: i oxygen in air (combustion to form a smoky flame) ii bromine, in the presence of a catalyst iii a mixture of concentrated nitric and sulfuric acids iv fuming sulfuric acid v halogenoalkanes and acyl chlorides with aluminium chloride as catalyst (Friedel Crafts reaction) Understand the mechanism of the electrophilic substitution reactions of benzene in halogenation, nitration and Friedel-Crafts reactions including the generation of the electrophile Understand the reaction of phenol with bromine water and the reasons for the relative ease of this reaction compared to benzene	Students work in groups to carry out the reactions in 18.4, and 18.6 where appropriate (using methylbenzene or methoxybenzene) Students work in groups to carry out preparation of methyl-3-nitrobenzoate. e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Alternatively, this could be done as a longer synoptic project, staring with the synthesis of the ester methyl benzoate. This could link together several strands of organic content, the key practical skills as well as instrumental methods of determining structure (see Week 30). Students can predict likely nature of attacking species and be introduced to mechanism Use 'Write–Cover–Rewrite' technique to embed knowledge of mechanism then test using 'mini-whiteboard' quiz.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
26	**Organic compounds containing nitrogen** Understand the nomenclature of amides, amines and amino acids and be able to draw their structural, displayed and skeletal formulae Understand the reactions of primary aliphatic amines (using butylamine as an example) and aromatic amines (using phenylamine as an example) with: i water to form an alkaline solution ii acids to form salts iii halogenoalkanes iv ethanoyl chloride v complex ion formation with copper(ii) ions Understand that amines are miscible with water as a result of hydrogen bonding, and the reasons for the difference in basicity between ammonia, primary aliphatic amines and primary aromatic amines Understand, in terms of reagents and general reaction conditions the preparation of primary aliphatic amines: i from halogenoalkanes ii by the reduction of nitriles Know the preparation of aromatic amines by the reduction of aromatic nitro-compounds using tin and concentrated hydrochloric acid Be able to describe the reaction of aromatic amines with nitrous acid to form benzenediazonium ions followed by a coupling reaction with phenol to form a dye Understand that amides can be prepared from acyl chlorides	Students work in pairs to carry out some of the reactions of amines from 19.2 i to v Research pK_a of a number of amines and use the data to list amines in order of basic strength. Justify order in terms of structure of amines. Students can revisit the reactions of halogenoalkanes and nitration of aromatic rings. They can then suggest how to prepare amines and research suitable reagents. Revisit esterification reactions and use this to promote discussion on how acyl chlorides could be used to form amides. Test understanding of amines using RSC 'Starter for 10' activities. http://tinyurl.com/RSC-Starters Students work in pairs to prepare an azo dye.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
27	**Condensation polymers and amino acids** Be able to describe: i condensation polymerisation for the formation of polyesters such as terylene and polyamides such as nylon and proteins ii addition polymerisation including poly(propenamide) and poly(ethenol) Be able to draw the structural formulae of the repeat units of the polymers in 19.8 Be able to comment on the physical properties of polyamides and the solubility in water of the addition polymer poly(ethenol) in terms of hydrogen bonding, e.g. soluble laundry bags or liquid detergent capsules (liquitabs) Be able to describe experiments to investigate the characteristic behaviour of amino acids limited to: i acidity and basicity and the formation of zwitterions ii effect of aqueous solutions on plane-polarised monochromatic light iii formation of peptide bonds by condensation polymerisation **CORE PRACTICAL 15** Analysis of some inorganic and organic unknowns	Students work in groups to carry out reactions of amino acids from 19.11 i and iii and chromatography Demonstrate how to prepare nylon-6.6 or 6.10 from 19.8 e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Students draw or model the structures of a range of polymers including proteins.	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
28	**Identifying Organic Structures** Be able to deduce the empirical formulae, molecular formulae and structural formulae from data drawn from combustion analysis, element percentage composition, characteristic reactions of functional groups, infrared spectra, mass spectra and nuclear magnetic resonance spectra (both ^{13}C and proton) Understand methods of increasing the length of the carbon chain in a molecule by the use of magnesium to form Grignard reagents and the reactions of the latter with carbon dioxide and with carbonyl compounds in dry ether	Carry out qualitative tests on a series of unknown organic compounds and use the observations and data from Combustion analysis, IR, Mass Spectrometry, and NMR to identify them. e.g. 'Identification of organic compounds' - Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7 Compound Confusion – RSC - http://tinyurl.com/comp-confuse Students research use of Grignard reagents in synthesis. http://tinyurl.com/grignard-Chemguide	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
29	**Planning how to Synthesise Compounds** Be able to use knowledge of organic chemistry contained in this specifications to solve problems such as: i predicting the properties of unfamiliar compounds containing one or more of the functional groups included in the specification, and explain these predictions ii planning reaction schemes of up to four steps, recalling familiar reactions and using unfamiliar reactions given sufficient information iii selecting suitable practical procedures for carrying out reactions involving compounds with functional groups included in the specification iv identifying appropriate control measures to reduce risk based on data of hazards	Students produce their own large-scale summary of the organic reactions covered in the specification, including appropriate reagents and conditions. Alternatively they could be given cards with names of products, reactants and reagents and they could construct a class-wall size summary together, which can be photographed by all group members. Students carry out synthesis problems / research using the 'Synthesis Explorer' as support. http://www.rsc.org/learn-chemistry/resources/synthesis-explorer/instructions.asp	

weeks	Topic Area Aims and Learning Outcomes	Exemplar classroom activities, teaching points and suggested teaching resources	Integrated Transferable Skills
30	**Carrying out Preparations of Organic Compounds** Understand the following techniques used in the preparation and purification of organic compounds: i refluxing ii purification by washing, e.g. with water and sodium carbonate solution iii solvent extraction iv recrystallisation v drying vi distillation vii steam distillation viii melting temperature determination ix boiling temperature determination **CORE PRACTICAL 16** The preparation of aspirin	Many of these techniques are likely to have been introduced and used in the earlier organic sections of the specification. This is an opportunity for students to plan and carry out a synthesis, considering quantities, equipment, techniques and risks. Students work in groups to carry out the preparation of an organic compound e.g. cholesteryl benzoate (a liquid crystal) or methyl 3-nitrobenzoate or oil of wintergreen as preparation for the Core Practical. e.g. Nuffield Advanced Chemistry: 4th edition ISBN: 0-582-32835-7	