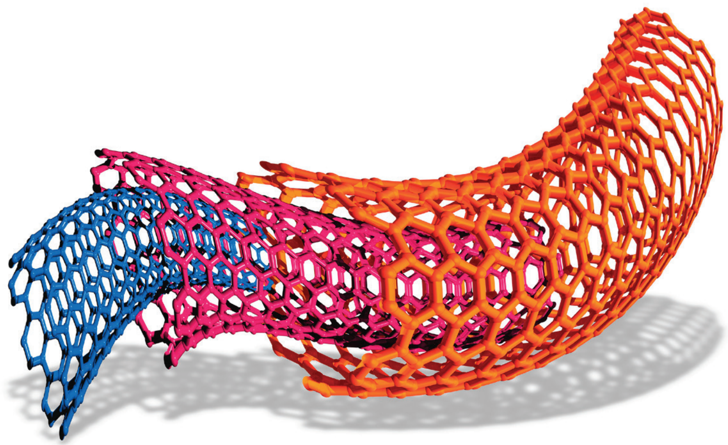
Cambridge Assessment International Education

Scheme of Work

Cambridge IGCSE®
Chemistry 0620

For examination from 2016



Version 2.0

Cambridge Pathway

In order to help us develop the highest quality resources, we are undertaking a continuous programme of review; not only to measure the success of our resources but also to highlight areas for improvement and to identify new development needs.

We invite you to complete our survey by visiting the website below. Your comments on the quality and relevance of our resources are very important to us.

www.surveymonkey.co.uk/r/GL6ZNJB

Would you like to become a Cambridge International consultant and help us develop support materials?

Please follow the link below to register your interest.

www.cambridgeinternational.org/cambridge-for/teachers/teacherconsultants/

Contents

Introduction

This scheme of work has been designed to support you in your teaching and lesson planning. Making full use of this scheme of work will help you to improve both your teaching and your learners' potential. It is important to have a scheme of work in place in order for you to guarantee that the syllabus is covered fully. You can choose what approach to take and you know the nature of your institution and the levels of ability of your learners. What follows is just one possible approach you could take and you should always check the syllabus for the content of your course.

Suggestions for independent study **(I)** and formative assessment **(F)** are also included. Opportunities for differentiation are indicated as **Extension activities**; there is the potential for differentiation by resource, grouping, expected level of outcome, and degree of support by teacher, throughout the scheme of work. Timings for activities and feedback are left to the judgment of the teacher, according to the level of the learners and size of the class. Length of time allocated to a task is another possible area for differentiation.

Guided learning hours

Guided learning hours give an indication of the amount of contact time you need to have with your learners to deliver a course. Our syllabuses are designed around 130 hours for Cambridge IGCSE courses. The number of hours may vary depending on local practice and your learners' previous experience of the subject. The table below gives some guidance about how many hours we recommend you spend on each topic area.

Topic	Suggested teaching time (%)	Suggested teaching order
1: Experimental techniques	5 hours (4% of the course)	1
2: Particles, atomic structure, ionic bonding and the Periodic Table	14 hours (11% of the course)	2
3: Air and water	6 hours (5% of the course)	3
4: Acids, bases and salts	14 hours (11% of the course)	4
5: Reaction rates	10 hours (8% of the course)	5
6: Metals and the Reactivity Series	12 hours (9% of the course)	6
7: Covalent bonding	4 hours (3% of the course)	7
8: Organic 1	14 hours (11% of the course)	8
9: Amount of substance	12 hours (9% of the course)	9

Topic	Suggested teaching time (%)	Suggested teaching order
10: Organic 2	12 hours (9% of the course)	10
11: Redox, electrochemistry and Group VII	14 hours (11% of the course)	11
12: Equilibria	10 hours (8% of the course)	12

Resources

The up-to-date resource list for this syllabus, including textbooks endorsed by Cambridge International, is listed at www.cambridgeinternational.org
Endorsed textbooks have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. As such, all textbooks endorsed by Cambridge International for this syllabus are the ideal resource to be used alongside this scheme of work as they cover each learning objective.

School Support Hub

The School Support Hub www.cambridgeinternational.org/support is a secure online resource bank and community forum for Cambridge teachers, where you can download specimen and past question papers, mark schemes and other resources. We also offer online and face-to-face training; details of forthcoming training opportunities are posted online. This scheme of work is available as PDF and an editable version in Microsoft Word format; both are available on the School Support Hub at www.cambridgeinternational.org/support. If you are unable to use Microsoft Word you can download Open Office free of charge from www.openoffice.org

Resource Plus

Throughout this scheme of work, you will find references to experiments from the *Resource Plus* platform.

Resource Plus

Experiment: The reversible reaction between two cobalt species

This experiment focuses on a reversible reaction demonstrated by a change in colour during the experiment.

Resource Plus provides specific information to help you to either carry out, or engage in virtual experiments with your learners. The materials include videos of experiments and accompanying *Skills Packs. The Skills Packs* have detailed lesson plans, extensive teacher advice and worksheets to guide you. If you don't have access to a lab or equipment, then the videos and materials in the *Skills Packs* can be used to provide a virtual experiment for your learners.

As well as the videos and *Skills Packs, Resource Plus* also offers a wide range of other materials for you to use in your classroom.
To try a demo, find out more, or to subscribe, visit www.cambridgeinternational.org/resourceplus

Websites

This scheme of work includes website links providing direct access to internet resources. Cambridge Assessment International Education is not responsible for the accuracy or content of information contained in these sites. The inclusion of a link to an external website should not be understood to be an endorsement of that website or the site's owners (or their products/services).

The website pages referenced in this scheme of work were selected when the scheme of work was produced. Other aspects of the sites were not checked and only the particular resources are recommended.

How to get the most out of this scheme of work – integrating syllabus content, skills and teaching strategies

We have written this scheme of work for the Cambridge IGCSE Chemistry (0620) syllabus and it provides some ideas and suggestions of how to cover the content of the syllabus. We have designed the following features to help guide you through your course.

Learning objectives help your learners by making it clear the knowledge they are trying to build. Pass these on to your learners by expressing them as 'We are learning to / about…'.

Suggested teaching activities give you lots of ideas about how you can present learners with new information without teacher talk or videos. Try more active methods which get your learners motivated and practising new skills.

Independent study (I) gives your learners the opportunity to develop their own ideas and understanding with direct input from you.

Syllabus ref.	Learning objectives	Suggested teaching activities
7.3	• Understand that some chemical reactions can be reversed by changing the action conditions (Limited the effects of heat and ter on hydrated and hydrous copper(II) sulfate d cobalt(II) chloride.)	Some reactions can be classified as reversible and learners should be introduced to the reversible sign ⇌. Experimental work can involve learners heating hydrated copper(II) sulfate and adding water to anhydrous copper(II) sulfate as an illustration. **(I)** **Extension activity:** learners to determine the amount of water removed on heating and calculate the formula of hydrated copper(II) sulfate (link to Unit 6). Practical procedure for heating hydrated copper(II) sulfate: www.nuffieldfoundation.org/practical-chemistry/reversible-reaction-involving-hydrated-copperii-sulfate-and%C2%A0its-anhydrous-form Practical procedure for determining the amount of water in copper(II) sulfate: www.chalkbored.com/lessons/chemistry-11/hydrate-lab.pdf
14.8.2	• Explain the differences between condensation and addition polymerisation	When monomers react to form condensation polymers a small molecule is eliminated. See 11(b) of this webpage for information: www.docbrown.info/page04/OilProducts11.htm
Past and specimen papers		
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**		

Extension activities provide your abler learners with further challenge beyond the basic content of the course. Innovation and independent learning are the basis of these activities.

Supplement (Extended syllabus) is highlighted throughout the scheme of work for both the learning objectives and the suggested teaching activities.

Past Papers, **Specimen Papers** and **Mark Schemes** are available for you to download at: **www.cambridgeinternational.org/support**

Using these resources with your learners allows you to check their progress and give them confidence and understanding.

Formative assessment (F) is on-going assessment which informs you about the progress of your learners. Don't forget to leave time to review what your learners have learnt, you could try question and answer, tests, quizzes, 'mind maps', or 'concept maps'. These kinds of activities can be found in the scheme of work.

1: Experimental techniques

Syllabus ref.	Learning objectives	Suggested teaching activities
2.1 Measurement	• Name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes and measuring cylinders	A circus of experiments may be used to introduce this by measuring the temperature, mass and volumes of different coloured liquids (water/food dye). **(I)** This will be reinforced when all experimental work is conducted. There are some good videos on YouTube. For example: Using a measuring cylinder: www.youtube.com/watch?v=Q_X8yKlzbkg Using a burette: www.youtube.com/watch?v=mZZqR5KlmTw Using a pipette: www.youtube.com/watch?v=DKRQ95QfWNY
2.2.1 Criteria of purity	• Demonstrate knowledge and understanding of paper chromatography • Interpret simple chromatograms	Experimental work can involve simple inks, sweets, leaves, dyes and food colourings. Non-permanent felt-tip pens work well. Chromatography of sweets: www.practicalchemistry.org/experiments/chromatography-of-sweets%2C194%2CEX.html and www.rsc.org/learn-chemistry/resource/res00000455/smarties-chromatography Chromatography of leaves: www.practicalchemistry.org/experiments/chromatography-of-leaves,199,EX.html Another paper chromatography experiment: www.scienceprojectlab.com/paper-chromatography-experiment.html
	• Interpret simple chromatograms, including the use of *Rf* values	**Extension activity:** with abler learners use *Rf* values to compare the height of the spots on the chromatograms obtained above. **(I)** Clear explanations can be found at: www.chemguide.co.uk/analysis/chromatography/paper.html and www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_21c/further_chemistry/chromatography/revision/4/
	• Outline how chromatography	Experimental work can be extended to include separating a mixture of amino acids (using ninhydrin as a locating agent) and simple sugars. This may be best done as a teacher demonstration.

Syllabus ref.	Learning objectives	Suggested teaching activities
	techniques can be applied to colourless substances by exposing chromatograms to substances called locating agents (Knowledge of specific locating agents is not required.)	Chromatography of amino acids: www.biotopics.co.uk/as/amino_acid_chromatography.html
	• Identify substances and assess their purity from melting point and boiling point information	This can be demonstrated by dissolving sodium chloride or other salts in water or by comparing the melting point of the alloy, solder, with those of lead and tin. The use of salt on roads to melt ice could be mentioned in this context. Practical procedure for comparing melting points of lead, tin and solder: www.nuffieldfoundation.org/practical-chemistry/solid-mixtures-tin-and-lead-solder
	• Understand the importance of purity in substances in everyday life, e.g. foodstuffs and drugs	Chemists need pure substances to study their properties. Pure substances are used in industry to make useful products such as food and drugs. This could be set as a brief research activity. **(I)** This web page contains some information: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_gateway/chemical_economics/batchcontinuousrev4.shtml
2.2.2 Methods of purification	• Describe and explain methods of purification by the use of a suitable solvent, filtration, crystallisation and distillation (including use of fractionating column) (Refer to the fractional distillation of petroleum in section 14.2 and products	Typical solvents to use are water (salt/sand) or ethanol (salt/sugar). Filtration is used in one of the salt preparation methods above to remove the excess solid. Crystallisation is used in most salt preparations to obtain the final product. Experimental work can involve: • purification of an impure solid • demonstration of the extraction of iodine from seaweed • distillation of a carbonated drink or coloured water • demonstration of the (partial) separation of ethanol from water by distillation

Syllabus ref.	Learning objectives	Suggested teaching activities
	of fermentation in section 14.6.)	• demonstration of the separation of 'petroleum fractions' from mixtures of hydrocarbons using 'artificial' crude oil. **Resource Plus** **Experiment:** The distillation of a carbonated drink This experiment focuses on a distillation experiment using a carbonated drink. **Extension activity:** the separation of oxygen and nitrogen from liquid air by fractional distillation. Separating salt and sand: www.nuffieldfoundation.org/practical-chemistry/separating-sand-and-salt Extracting iodine from seaweed: www.nuffieldfoundation.org/practical-chemistry/extracting-iodine-seaweed Fractional distillation of (artificial) crude oil: www.nuffieldfoundation.org/practical-chemistry/fractional-distillation-crude-oil An excellent collection of animations and video clips can be found at: www.nationalstemcentre.org.uk/elibrary/resource/3988/particles-in-motion This was originally published by Royal Society of Chemistry on a CD ROM, 'Particles in Motion', 2006
	• Suggest suitable purification techniques, given information about the substances involved	This may be linked to magnetic properties (less important) and varying solubilities (more important).

Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

2: Particles, atomic structure, ionic bonding and the Periodic Table

Syllabus ref.	Learning objectives	Suggested teaching activities
1 The particulate nature of matter	• State the distinguishing properties of solids, liquids and gases	This could be a quick question and answer session at the beginning of a lesson with examples of solids, liquids and gases to emphasise their properties. The use of the suggested link below would reinforce this. The animation could also be used individually. **(I)** There is a very good, interactive animation linking properties of solids, liquids and gases to the particle model: www.bbc.co.uk/bitesize/ks3/science/chemical_material_behaviour/particle_model/activity/
	• Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion	Use 'particles in boxes' diagrams to represent the three states of matter. This could be a research activity using textbooks or the internet. An excellent collection of animations and video clips can be found at: www.nationalstemcentre.org.uk/elibrary/resource/3988/particles-in-motion This was originally published by Royal Society of Chemistry on a CD, 'Particles in Motion', 2006
	• Describe changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation	The heating of solid octadecanoic acid (stearic acid) until it is liquid, and then allowing it to freeze again, measuring the temperature at regular intervals and plotting the results is a good class practical. Another possibility is investigating the rate of evaporation of propanone, either as a class practical or as a demonstration. Sublimation can be demonstrated by heating ammonium chloride in an evaporating dish and collecting the solid on the sides of an inverted filter funnel above the dish. Melting and freezing of stearic acid: www.nuffieldfoundation.org/practical-chemistry/melting-and-freezing-stearic-acid Rate of evaporation of propanone: www.nuffieldfoundation.org/practical-chemistry/rate-evaporation Sublimation of ammonium chloride: www.tes.co.uk/teaching-resource/Sublimation-of-Ammonium-Chloride-Experiment-6132591/
	• Explain changes of	Relate the conversions to the motion and arrangement of particles. This may be done as a research activity using textbooks or the internet. **(I)**

Syllabus ref.	Learning objectives	Suggested teaching activities
	state in terms of the kinetic theory	Emphasise the change in the arrangement and movement of the particles when a substance changes state. Relate the conversions to the motion and arrangement of particles. Relate this to the energy input/output. Learners can be asked to use the theory to explain properties such as behaviour of gases under pressure and liquid flow (opportunity for a 'circus of experiments' here). **(I)** Also the excellent collection of animations and video clips at: www.nationalstemcentre.org.uk/elibrary/resource/3988/particles-in-motion
	• Describe qualitatively the pressure and temperature of a gas in terms of the motion of its particles	This could be a research activity. **(I)** Pressure is due to particles in a gas hitting the walls of a container. The faster the speed of the particles the higher the pressure. The higher the temperature of a gas the faster the particles are moving.
	• Show an understanding of the random motion of particles in a suspension (sometimes known as Brownian motion) as evidence for the kinetic particle (atoms, molecules or ions) model of matter	One effective way to view Brownian motion is to view a slide of colloidal graphite through a microscope. There are a number of good videos on the internet which show examples of Brownian motion. Carbon particles in water: www.nuffieldfoundation.org/practical-physics/brownian-motion-carbon-particles-water Videos of Brownian motion can be found on YouTube. One example of smoke particles being bombarded by air particles is: www.youtube.com/watch?v=4tt7M2fpI6U Marble simulation is shown as part of a larger set of experiments in this link: www.nuffieldfoundation.org/practical-physics/modelling-brownian-motion
	• Describe and explain Brownian motion in terms of random molecular bombardment • State evidence for Brownian motion	A good simulation explaining Brownian motion can be achieved by gently shaking a tray of small marbles with two or three larger marbles. See above.

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Describe and explain diffusion.	Simple examples of diffusion include: • air freshener, perfume, ether, camphor smells in the lab • movement of nitrogen dioxide gas or bromine vapour in air • coloured inks/$CuSO_4$/$KMnO_4$ in water and $Pb(NO_3)_2$ in KI. **Extension activity:** what would influence diffusion rate, for example temperature using tea bags held by a glass rod in beakers of hot and cold water. Learners should be able to link their observations to the particle model. Details of how to perform a diffusion in liquids experiment: www.nuffieldfoundation.org/practical-chemistry/diffusion-liquids
	• Describe and explain dependence of rate of diffusion on molecular mass	Demonstration: Two cotton wool pads, one soaked with conc. hydrochloric acid and the other with conc. ammonia can be placed at opposite ends of a long glass tube sealed with bungs. A white 'smoke' of the precipitated ammonium chloride is seen where the two gases meet. Diffusion of ammonia and hydrogen chloride: www.nuffieldfoundation.org/practical-chemistry/diffusion-gases-ammonia-and-hydrogen-chloride
3.1 Atomic structure and the Periodic Table	• State the relative charges and approximate relative masses of protons, neutrons and electrons	Opportunity for group work, learners can research and present their ideas on the development of the structure of the atom from the Greeks onwards. They can also discuss the limitations of each model using ICT/textbooks. A summary of atomic structure can be found in all good textbooks. A summary can also be found at: www.gcsescience.com/a1-atom-electron-neutron-proton.htm Good lesson approach to the history of the atomic structure at: www.learnnc.org/lp/pages/2892
	• Define *proton number* (atomic number) as the number of protons in the nucleus of an atom • Define *nucleon number* (mass number) as the total number of protons and neutrons in the	Once learners are aware of the definitions and the relative charges and masses of the sub-atomic particles they can use the information to solve problems, such as the number of protons, neutrons and electrons in the atom of a particular element given the proton number and nucleon number. Introducing the symbols of elements showing nucleon number and proton number is best done here. **(I)** Most good textbooks have questions about this and there are also examples in the Unit 2: Past and Specimen Paper questions attached to this scheme of work. There is a good animation at:

Syllabus ref.	Learning objectives	Suggested teaching activities
	nucleus of an atom	www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atomic_structure/chemcalcact.shtml There is also an interactive quiz at: www.bbc.co.uk/bitesize/quiz/q76774007
	• Use proton number and the simple structure of atoms to explain the basis of the Periodic Table (see section 9), with special reference to the elements of proton numbers 1 to 20	This could be set as a brief research exercise. The first page of this link explains this: www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/periodictable/atomsrev1.shtml
	• Define *isotopes* as atoms of the same element which have the same proton number but a different nucleon number	A good way to illustrate isotopes is by comparing ice cubes in water – D_2O (sinks) and H_2O (floats). The atomic structure of isotopes of hydrogen: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/radiation/atomsisotopesrev2.shtml A good, short video of ice and D_2O in water: www.youtube.com/watch?v=VLiirA5ooS0
	• Understand that isotopes have the same properties because they have the same number of electrons in their outer shell	Although this may be covered here, it should also be reinforced after ‘electronic structures of atoms’ have been covered. This is covered well in most good textbooks.
	• State the two types of isotopes as being radioactive and non-radioactive	If an isotope is radioactive the nucleus is unstable and it will break down over a period of time.
	• State one medical and one industrial use of radioactive isotopes	Possible examples include the location of blockages and leakages in underground pipes and the use of radioactive iodine in tracing thyroid activity. Modern uses of radioactive isotopes: www.chem.duke.edu/~jds/cruise_chem/nuclear/uses.html

Syllabus ref.	Learning objectives	Suggested teaching activities
6.2 Energy transfer	• Describe radioactive isotopes, such as ^{235}U, as a source of energy	Possible issues for discussion include: • the long term nature of nuclear energy (sustainable long after coal and oil run out) • environmental considerations such as the disposal of radioactive waste. This is a good source of information: www.world-nuclear.org/education/uran.htm
3.1 Atomic structure and the Periodic Table	• Describe the build-up of electrons in 'shells' and understand the significance of the noble gas electronic structures and of the outer shell electrons (The ideas of the distribution of electrons in s and p orbitals and in d block elements are not required.) Note: a copy of the Periodic Table will be available in Papers 1, 2, 3 and 4.	Use circles to show the shells up to atomic number 20. Learners can use mini-whiteboards to draw electron diagrams as a class activity. **(I)** **Extension activity:** to use spectroscopes to illustrate different energy shells. A good video that has some interactivity is found at: www.bbc.co.uk/schools/gcsebitesize/science/aqa/fundamentals/atomsact.shtml
	• Understand that isotopes have the same properties because they have the same number of electrons in their outer shell	This could be stated here and related to the Periodic Table in 9.2(S), covered later in this unit.
3.2.1 Bonding: the structure of matter	• Describe the differences between elements, mixtures and compounds, and between metals and non-metals	The reaction between iron sulfur to produce iron(II) sulfide can be carried out by learners to illustrate the varying properties of the elements, the mixture and the compound. (Link to Unit 5.) A good guide to carrying out the experiment suggested: www.nuffieldfoundation.org/practical-chemistry/iron-and-sulfur-reaction

Syllabus ref.	Learning objectives	Suggested teaching activities
		An excellent video animation of Fe, S and FeS is to be found at: www.bbc.co.uk/schools/ks3bitesize/science/chemical_material_behaviour/compounds_mixtures/activity.shtml This video also has a very good section linking back to Unit 1 of this scheme, i.e. chromatography and distillation.
7.1 Physical and chemical changes	• Identify physical and chemical changes, and understand the differences between them	This is a good place to introduce this as learners have already encountered physical changes in changes of state and a chemical change in the formation of iron(II) sulfide. Information at: www.bbc.co.uk/bitesize/ks3/science/chemical_material_behaviour/compounds_mixtures/revision/1/ and http://chemwiki.ucdavis.edu/Analytical_Chemistry/Qualitative_Analysis/Chemical_Change_vs._Physical_Change A sheet that could be used as homework: www.tes.co.uk/ResourceDetail.aspx?storyCode=6212211 (Download the 'full worksheet' document.)
3.2.1 Bonding: the structure of matter	• Describe an alloy, such as brass, as a mixture of a metal with other elements	Awareness of the importance of alloys to meet industrial specifications for metals. Link to Section 2.2.1 Unit 1 and Section 10.3 Unit 6. www.practicalchemistry.org/experiments/intermediate/metals/making-an-alloy-solder,131,EX.html
10.1 Properties of metals	• Identify representations of alloys from diagrams of structure	Construct models of an alloy using modelling clay. The suggested experiment is found at: www.nuffieldfoundation.org/practical-chemistry/modelling-alloys-plasticine
3.2.2 Ions and ionic bonds	• Describe the formation of ions by electron loss or gain	Emphasise formation of a full shell/noble gas configuration. Learners should be shown dot-and-cross diagrams for simple ionic substances, e.g. $NaCl$, KF, MgO; then challenged to draw diagrams for more complicated examples like $CaCl_2$, $MgBr_2$, AlF_3. Learners can use mini-whiteboards to draw electron diagrams as a class activity. This can also be done using cut out electrons and shells so learners can move electrons into place. Link this to Unit 11. There is a good section called 'A simple view of ionic bonding': www.chemguide.co.uk/atoms/bonding/ionic.html

Syllabus ref.	Learning objectives	Suggested teaching activities
		www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/bonding/ionic_bondingrev1.shtml Although the commentary of this animation is a little colloquial, it is certainly worth considering: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/bonding/ionic_bondingrev1.shtml
	• Describe the formation of ionic bonds between elements from Groups I and VII	Concentrate on the attraction of + and – charges and the full outer shells obtained by electron transfer. Use above examples. Consider the above resources and remember that this is usually covered well in the endorsed and other good textbooks.
	• Describe the formation of ionic bonds between metallic and non-metallic elements	Learners can explore the properties of ionic compounds experimentally and link them to the model of ionic bonding – solubility in water, conductivity when solid, in solution and molten (do as a demonstration with $PbBr_2$ (or preferably $ZnCl_2$) and melting point. **Extension activity:** learners could be introduced to writing ionic formulae (Unit 9) and electrolysis (Unit 11). **(I)** A safer alternative to electrolysing lead bromide is to use zinc chloride: www.nuffieldfoundation.org/practical-chemistry/electrolysis-zinc-chloride
	• Describe the lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions	Ball and spoke models will be useful here. Good websites to illustrate this: www.chm.bris.ac.uk/pt/harvey/gcse/ionic.html www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/bonding/structure_propertiesrev4.shtml
6.1 Energetics of reactions	• Describe the meaning of *exothermic* and *endothermic* reactions	This can be seen as a rise or fall in temperature in many chemical reactions used in the syllabus. This concept can be taught across the syllabus rather than as a discrete lesson. Suggested experiments: • neutralisation reactions of acids and alkalis (see Unit 4) • metal displacement reactions (see Unit 6) • dissolving salts, including ammonium salts (see Unit 4) • if data loggers are available, temperature probes could be used.

Syllabus ref.	Learning objectives	Suggested teaching activities
		Link to Section 6.1 in Unit 5
9.1 The Periodic Table	• Describe the Periodic Table as a method of classifying elements and its use to predict properties of elements	Elements to be classified as metals and non-metals. Their states should be mentioned. Properties limited to qualitative idea of melting/boiling point. Three suggested activities: • Learners make observations from a photocopied version of the Periodic Table. • A database of properties and states for elements of periods 1, 2 and 3 could be set up. • Learners, in groups, could be asked to design a flowchart to find the metals, non-metals, solids and liquids and enter the results on a blank copy of the Periodic Table. Good suite of video clips on various elements of the Periodic Table: www.periodicvideos.com/ Interactive Periodic Tables: www.webelements.com/ www.rsc.org/chemsoc/visualelements/index.htm www.ptable.com/ www.chemicool.com/
9.2 Periodic trends	• Describe the change from metallic to non-metallic character across a period	Emphasise the metal/non-metal boundary.
	• Describe and explain the relationship between Group number, number of outer shell electrons and metallic/non-metallic character	Emphasise number of outer shell electrons = group number.
4.1 Stoichiometry	• Use the symbols of the elements and write the formulae of simple compounds	Learners can calculate the formula by using the 'combining powers' or 'valencies' of the elements. Learners can use mini-whiteboards to write formulae or bingo activity for working out the total number of atoms in a formula.

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Deduce the formula of a simple compound from the relative numbers of atoms present	As above. This should be linked with organic molecules and with inorganic substances such as P_4O_{10}.
9.3 Group properties	• Describe lithium, sodium and potassium in Group I as a collection of relatively soft metals showing a trend in melting point, density and reaction with water	Group I metals are called the alkali metals. Demonstration with very small amounts of the metals behind a safety screen or video only of reactions with water due to highly exothermic nature. Focus on the observations here and link to theory and relative reactivity: • metal floats, so less dense than water • fizzing indicates that a gas is given off • molten ball (not Li) indicates highly exothermic reaction • lilac flame (K) indicates very exothermic reaction because the hydrogen gas given off ignites. A very good experimental procedure for demonstrating the properties of the alkali metals: www.practicalchemistry.org/experiments/alkali-metals,155,EX.html Excellent video of the reaction of all the alkali metals with water: www.open2.net/sciencetechnologynature/worldaroundus/akalimetals.html
	• Predict the properties of other elements in Group I, given data, where appropriate	Include reactions of Rb and Cs and physical properties such as melting and boiling points. Trends can be obtained from suitable databases. Sometimes you refer to elements by their symbols. You could tell learners that if you had a sample of caesium, enclosed in a sealed glass tube, it would quickly melt from the warmth of your hand. The video above shows this really well. Useful background data on Rb, Cs and Fr: www.chemtopics.com/elements/alkali/alkali.htm

Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

3: Air and water

Syllabus ref.	Learning objectives	Suggested teaching activities
11.1 Water	• Describe chemical tests for water using cobalt(II) chloride and copper(II) sulfate	Use anhydrous cobalt(II) chloride (blue cobalt chloride paper) and anhydrous copper(II) sulfate (solid). **(I)** Learners could be introduced to 'reversible reactions' (link to Unit 12). **Extension activity:** practical/demonstration of burning a fuel (candle) and illustrating that water is one of the combustion products (link to Unit 8). See 11.4 later in this unit. Preparing cobalt chloride paper: www.nuffieldfoundation.org/practical-chemistry/preparing-and-using-cobalt-chloride-indicator-papers A reversible reaction involving copper sulfate: www.nuffieldfoundation.org/practical-chemistry/reversible-reaction-involving-hydrated-copperii-sulfate-and%C2%A0its-anhydrous-form
	• Describe, in outline, the treatment of the water supply in terms of filtration and chlorination	Emphasis on filtration (link to Unit 1) and chlorination stages. Opportunity to introduce the properties of chlorine/Group VII elements as poisonous, safe only in very dilute solution. Can discuss role of chlorine in eradicating waterborne diseases in many countries. Possible school visit to a water treatment plant. Notes on water purification: www.docbrown.info/page01/AqueousChem/AqueousChem.htm and pages 1–2 of: www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/chemical/waterrev1.shtml
	• Name some of the uses of water in industry and in the home	Water is used as a solvent and a coolant in industry, as well as used for drinking and washing in the home. Possible activities include writing a 24-hour 'water use' diary and presenting data as bar or pie charts, perhaps using a spread sheet. **(I)**
	• Discuss the implications of an inadequate supply	Discussion in groups and presentation of outcomes.

Syllabus ref.	Learning objectives	Suggested teaching activities
	of water, limited to safe water for drinking and water for irrigating crops	Good information at: www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/chemical/waterrev1.shtml
11.2 Air	• State the composition of clean, dry air as being approximately 78% nitrogen, 21% oxygen and the remainder as being a mixture of noble gases and carbon dioxide	Demonstration experiment to derive the % oxygen in the air using the oxidation of heated copper metal. An alternative is iron wool with air. There are several examples of this experiment, e.g.: www.mikecurtis.org.uk/air.htm There is also a video of this experiment: www.youtube.com/watch?v=hiawJDsy8Z4 Video clip on gases from the air. This link takes you to an index. To locate the video click on 'Gases from Air': www.rsc.org/Education/Teachers/Resources/Alchemy/index2.htm Class practical using iron wool: www.nuffieldfoundation.org/practical-chemistry/how-much-air-used-during-rusting
	• Describe the separation of oxygen and nitrogen from liquid air by fractional distillation	Link to Unit 1. Link this to boiling points and the fractional distillation of petroleum and ethanol (Unit 8 and 10). The video clips mentioned in the previous row contain a good sequence on this. Good summary of the process: www.bbc.co.uk/schools/gcsebitesize/science/edexcel_pre_2011/oneearth/usefulproductsrev2.shtml
9.5 Noble gases	• Describe the noble gases, in Group VIII or 0, as being unreactive, monoatomic gases and explain this in terms of electronic structure	Opportunity to reinforce ideas of full outer shells leading to lack of reactivity (link to Unit 2). Good video clip about the noble gases: www.open2.net/sciencetechnologynature/worldaroundus/noblegases.html
	• State the uses of the noble gases in providing an *inert* atmosphere, i.e. argon in lamps, helium	Learners can produce posters, or in groups do a short-presentation/poster illustrating the uses of the different noble gases. **(I)** Information on uses: www.drbateman.net/gcse2003/gcsesums/chemsums/noblegases/noblegases.htm

Syllabus ref.	Learning objectives	Suggested teaching activities
	for filling balloons	
6.2 Energy transfer	• Describe the release of heat energy by burning fuels	Emphasise that combustion is an exothermic process. Relevant examples should include Bunsen burner, fuels for heating the home and fossil fuel burning power stations. Learners can research/do an investigation into what makes a good fuel. **(I)** Opportunities for experiments to compare energy evolved on heating fuels using spirit burner and metal can. Awareness of the importance of energy output of hydrocarbon fossil fuels to transport and manufacturing industry. There is information at: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway/carbon_chemistry/carbon_fuelsrev1.shtml www.nuffieldfoundation.org/practical-chemistry/heat-energy-alcohols
11.4 Carbon dioxide and methane	• State the formation of carbon dioxide: ○ as a product of complete combustion of carbon-containing substances ○ as a product of respiration ○ as a product of the reaction between an acid and a carbonate ○ from the thermal decomposition of a carbonate.	Opportunity for demonstration or learners to perform a variety of experiments to prepare carbon dioxide. The products of combustion can also be identified in a demonstration. This gives the opportunity to revisit the test for water. Learners can be introduced to the limestone cycle (link to Unit 4) and this can be extended to make temporary hard water (calcium hydrogencarbonate solution). Comparison of oxygen and carbon dioxide content in air before and after respiration and combustion. Possible issues to raise include the role of carbon dioxide from combustion of fossil fuels contributing to global warming. (Note that the present concentration of CO_2 in the atmosphere is 0.04%.) Identifying the products of combustion of a solid hydrocarbon: www.nuffieldfoundation.org/practical-chemistry/identifying-products-combustion Experimental set-up to test for carbon dioxide in breath: www.biotopics.co.uk/humans/inhaledexhaled.html Thermal decomposition of a carbonate. This is a good experimental procedure and we suggest you only

Syllabus ref.	Learning objectives	Suggested teaching activities
		decompose one or two of the suggested carbonates, omitting sodium carbonate and potassium carbonate: www.nuffieldfoundation.org/practical-chemistry/thermal-decomposition-metal-carbonates
	• Describe the carbon cycle, in simple terms, to include the processes of combustion, respiration and photosynthesis	This could be a research activity which culminates in the production of posters or class presentations. Information: www.gcsescience.com/w2-carbon-cycle.htm www.bbc.co.uk/schools/gcsebitesize/science/edexcel/problems_in_environment/recyclingrev2.shtml
	• State that carbon dioxide and methane are greenhouse gases and may contribute to climate change • State the sources of methane, including decomposition of vegetation and waste gases from digestion in animals	Emphasise that a greenhouse gas absorbs heat energy and stops heat escaping into space and warms the atmosphere, which causes an increase in global warming. Methane is formed as a result of digestion in cows and from rice paddy fields. A good section on climate change and carbon dioxide in this video: www.bbc.co.uk/bitesize/ks3/science/environment_earth_universe/changes_in_environment/activity/ A good written section at: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway/energy_resources/global_warmingrev1.shtml Simulation experiment: www.nuffieldfoundation.org/practical-chemistry/greenhouse-effect
11.2 Air	• Name the common pollutants in the air as being carbon monoxide, sulfur dioxide, oxides of nitrogen and lead compounds	Emphasise that CO is a poisonous gas and both sulfur dioxide and oxides of nitrogen can lead to breathing difficulties and the formation of acid rain. **Extension activity:** learners can produce a flowchart to show how acid rain is formed. Opportunity for group work – data analysis of tables of air quality data. Overview on air pollution and update readings for nitrogen oxides in London: www.londonair.org.uk/london/asp/information.asp Information on common air pollutants: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/rocks_metals/6_clean_air3.shtml Fact sheet on SO_2 pollution in Australia: www.environment.gov.au/resource/sulfur-dioxide-so2

Syllabus ref.	Learning objectives	Suggested teaching activities
	• State the source of each of these pollutants: ○ carbon monoxide from the incomplete combustion of carbon-containing substances ○ sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds (leading to 'acid rain') ○ oxides of nitrogen from car engines ○ lead compounds from leaded petrol.	Emphasise the source of gas: • CO from incomplete combustion of a carbon-based fuel • SO_2 from the combustion of fossil fuels containing sulfur • nitrogen oxides from the reaction of nitrogen and oxygen inside a car engine at high temperature or by their reaction during a lightning strike. Possible issues for discussion or research include: • reliance on fossil fuels (petrol, power stations) as a major contributory factor to air pollution • why lead compounds in petrol are banned in many countries. The Earth's atmosphere: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/rocks_metals/6_clean_air3.shtml A good article appears in this World Health Organisation Bulletin of 2002: www.who.int/bulletin/archives/80(10)768.pdf
	• Describe and explain the presence of oxides of nitrogen in car exhausts and their catalytic removal	This could be a research activity with presentation of findings/posters. Emphasise the purpose of a catalytic converter to change the poisonous gases, carbon monoxide and oxides of nitrogen, into non-toxic nitrogen and carbon dioxide. Links to other units include the opportunity for treatment of converter reactions in terms of redox (section 7.4, Unit 11). Reinforcement of catalytic chemistry (section 7.2, Unit 5) and transition metal use (section 9.4, Unit 6). Atmospheric pollution: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/rocks_metals/6_clean_air3.shtml
	• State the adverse effect of these common pollutants on buildings and on health and discuss why these pollutants are of global concern	Emphasis on limestone decay, rusting of iron and tarnishing of copper. This provides an opportunity for learners to carry out group research, perhaps presenting their findings to the rest of the class using overhead projection foils or posters. Each group can research the effects of a different pollutant gas in terms of how it is produced, its adverse effects and methods for solving the problem. Issues include: • effects of acid rain on vegetation, aquatic life, limestone buildings

Syllabus ref.	Learning objectives	Suggested teaching activities
		• oxides of nitrogen and sulfur dioxide as respiratory irritants • dangers of CO poisoning from cars and poorly maintained domestic heaters • reasons for high concentration of pollutants in cities and subsequent effects on health. The role of chemistry in a 'search for solutions' can also be discussed, for example: • attempts to control the effects of sulfur emissions (scrubbers) • liming of lakes and soil to neutralise some of the effects of acid rain • development of alternative fuels, catalysts to lower energy use in industry and catalytic converters for cars.
	• State the conditions required for the rusting of iron	Class experiments can be set up and linked to the rust prevention investigations below. Experiments to investigate the causes of rusting: www.nuffieldfoundation.org/practical-chemistry/causes-rusting
	• Describe and explain methods of rust prevention, specifically paint and other coatings to exclude oxygen	Experiment involving the investigation of rusting of iron nails using these methods. A simple investigation or experiment to demonstrate methods of prevention can be: • apply coating to a nail – colourless nail varnish, correction fluid, cling film, grease or oil, oil-based paint • sacrificial protection – wrap a small piece of Mg ribbon around a nail. Rust prevention class practical investigation or demonstration: www.practicalchemistry.org/experiments/preventing-rusting%2C251%2CEX.html
	• Describe and explain sacrificial protection in terms of the reactivity series of metals and galvanising as a method of rust prevention	Opportunity to introduce reactivity series (Section 10.2) and link this with 10.4 – supplement. Both are found in Unit 6. This could be emphasised in the above experiment, where two or three metals of different reactivity could be investigated – Mg, Sn, Cu. **Extension activity:** mechanism of sacrificial protection: www.dynamicscience.com.au/tester/solutions/chemistry/corrosion/rustpreventionsacanode.htm

Past and specimen papers
Past/specimen papers and mark schemes are available to download at **www.cambridgeinternational.org/support (F)**

4: Acids, bases and salts

Syllabus ref.	Learning objectives	Suggested teaching activities
4.1 Stoichiometry	• Construct word equations and simple balanced chemical equations	This can be linked with law of conservation of mass. Various test-tube reactions can be done – $FeCl_3$ + NaOH and $CuSO_4$ + NaOH. Stress that equations are balanced by inserting a number in front of particular formulae of reactants or products. Learners can then work in groups with simple formulae cards to construct balanced equations from word equations. Law of conservation of mass: www.docbrown.info/page04/4_73calcs03com.htm Word and balanced equations: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway/chemical_concepts/fundamentalrev5.shtml
8.1 The characteristic properties of acids and bases	• Describe neutrality and relative acidity and alkalinity in terms of pH measured using Universal Indicator paper (whole numbers only)	An interesting demonstration called Universal Indicator 'Rainbow' could start or conclude this session. Learners can arrange solutions of varying pH values in terms of increasing acidity/basicity, e.g. milk, vinegar, ammonia solution, 'bench' and 'household' chemicals. **(I)** The pH scale runs from 0–14 and it is used to show the acidity or alkalinity of a solution. Universal Indicator can be used to find the pH of a solution. Universal Indicator 'Rainbow': www.nuffieldfoundation.org/practical-chemistry/universal-indicator-rainbow
	• Describe the characteristic properties of acids as reactions with metals, bases, carbonates and effect on litmus and methyl orange	Opportunity for experiments to show exothermic nature of neutralisation. Learners could prepare hydrogen and carbon dioxide gas and perform the distinctive tests (see later in this unit). Test-tube experiments linked to Unit 6.
	• Describe the characteristic properties	Illustrate by reference to examples of neutralisation, e.g. indigestion tablets, treatment of bee and wasp stings, addition of sodium hydroxide to (acidic detergent in) shower gel/washing-up liquid/bubble bath (could look at labels

Syllabus ref.	Learning objectives	Suggested teaching activities
	of bases as reactions with acids and with ammonium salts and effect on litmus and methyl orange	of ingredients). Test-tube experiments linked to above and heating ammonium salts with hydroxides. **Extension activity:** learners could look at safety issues associated with mixing acid cleaner to alkaline bleach. There is a useful, interactive video at: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/acids/acidsbasesact.shtml
11.3 Nitrogen and fertilisers	• Describe the displacement of ammonia from its salts	Experiments involving heating ammonium salts with or without added hydroxide (test for ammonia, see later in this unit). Illustrate by reference to how the liming of soils by farmers to neutralise acidity can lead to ammonia loss from ammonium salts added as fertilisers: $Ca(OH)_2 + 2NH_4Cl \rightarrow 2NH_3 + CaCl_2 + H_2O$ Making and testing ammonia lesson plan and activity: www.nuffieldfoundation.org/practical-chemistry/making-and-testing-ammonia
8.1 The characteristic properties of acids and bases	• Define acids and bases in terms of proton transfer, limited to aqueous solutions	Can introduce the concept of pH meters (conductivity) to measure pH for advanced learners. **Extension activity:** a low pH indicates a high concentration of H^+ ions and high pH a high concentration of OH^- ions. There is more information linked to the IGCSE syllabus at: www.docbrown.info/page03/AcidsBasesSalts10.htm
	• Describe the meaning of weak and strong acids and bases	Emphasise acids are proton donors, e.g. dilute mineral acids, ethanoic acid (vinegar), and bases are proton acceptors, e.g. alkali metal hydroxides and aqueous ammonia. **Extension activity:** the terms concentrated and dilute solutions can be introduced and clearly distinguished from weak and strong acids.
8.2 Types of oxides	• Classify oxides as either acidic or basic, related to metallic and non-metallic character	Demonstration of the reaction of the elements with oxygen. Linked to Unit 2 and Unit 3, oxides of sodium, magnesium, carbon, sulfur and phosphorus are all good examples to use.

Syllabus ref.	Learning objectives	Suggested teaching activities
		The suggested link is a very good class practical. It suggests labelling solutions as particular oxides and water. For example, nitric acid solution as nitrogen oxide and water, and sulfuric acid as sulfur dioxide and water. Examples of acid oxides are P_2O_5, SO_2, SO_3 and NO_2. Examples of basic oxides are Na_2O, CaO and BaO. **Resource Plus** **Experiment:** Types of oxides: reactions with acids and bases This experiment focuses on soluble oxides that dissolve in water to form acidic, basic or amphoteric solutions. A very good approach for a class practical to show the pH of oxides: www.nuffieldfoundation.org/practical-chemistry/ph-oxides
	• Further classify other oxides as neutral or amphoteric	Examples of amphoteric oxides are Al_2O_3 and ZnO. Examples of neutral oxides are nitrogen(I) oxide (N_2O), nitrogen(II) oxide (NO) and carbon monoxide (CO).
13 Carbonates	• Describe the manufacture of lime (calcium oxide) from calcium carbonate (limestone) in terms of thermal decomposition	Learners can investigate the limestone cycle by heating a limestone chip very strongly for 20 minutes and cooling to form calcium oxide on the surface. Observe reaction of calcium oxide when drops of water are added to make slaked lime (example of exothermic reaction – steam and solid crumbling). Then add excess water to form limewater and test the pH. A good method of heating a limestone chip: www.nuffieldfoundation.org/practical-chemistry/thermal-decomposition-calcium-carbonate Notes on limestone cycle: www.docbrown.info/page01/ExIndChem/ExIndChem.htm
8.1 The characteristic properties of acids and bases	• Describe and explain the importance of controlling acidity in soil	Teach with Section 13 below.

Syllabus ref.	Learning objectives	Suggested teaching activities
13 Carbonates	• Name the uses of calcium carbonate in the manufacture of iron and cement	Discuss the importance of limestone in the extraction of iron (link to Unit 6), the building industry and the manufacture of cement. This could be a research activity.
	• Name some uses of lime and slaked lime such as in treating acidic soil and neutralising acidic industrial waste products, e.g. flue gas desulfurisation	Possible issues to discuss include: • the importance of using lime or slaked lime for treating excess acidity in soils, thus making unfertile land fertile. Also in neutralising acidic waste products from industry • the use of calcium carbonate to remove sulfur dioxide from power station emissions by flue-gas emissions • the environmental effects of large scale limestone quarrying to meet the huge demand. A good source of information about using lime on soil, although lime is not really a fertilizer: www.allotment-garden.org/compost-fertiliser/garden-lime.php A good piece on flue gas desulfurisation: www.en.wikipedia.org/wiki/Flue-gas_desulfurization
8.3 Preparation of salts	• Demonstrate knowledge and understanding of preparation, separation and purification of salts as examples of some of the techniques specified in Section 2.2.2 and the reactions specified in Section 8.1	Experiments should include the preparation of salts such as copper(II) sulfate, magnesium sulfate (filtration method) and sodium or potassium salts (titration method). (Link to Unit 1) Methods of preparation are covered in theory at: www.docbrown.info/page03/AcidsBasesSalts06.htm Practical details of preparing salts: www.nuffieldfoundation.org/practical-chemistry/salts
	• Demonstrating knowledge and understanding of the preparation of insoluble salts by precipitation	Extend the salt preparation to include lead(II) chloride, lead(II) iodide and barium sulfate. (Warning: Pb and Ba compounds are poisonous) Preparation details: www.practicalchemistry.org/experiments/preparing-an-insoluble-salt,174,EX.html
	• Suggest a method of making a given salt from suitable starting material, given appropriate information	Introduce solubility rules and ask learners to suggest a suitable method of preparing a particular salt. **(I)** Learners can then put their theory into practice. Useful information can be found on these pages beginning at: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/acids/acidsbasesrev3.shtml

<table>
<tr><th>Syllabus ref.</th><th>Learning objectives</th><th>Suggested teaching activities</th></tr>
<tr><td>8.4 Identification of ions and gases</td><td>
Describe the following tests to identify:

aqueous cations:
aluminium, ammonium, calcium, chromium(III), copper(II), iron(II), iron(III) and zinc (using aqueous sodium hydroxide and aqueous ammonia as appropriate) (Formulae of complex ions are not required)
cations:
use of the flame test to identify lithium, sodium, potassium and copper(II)
anions:
carbonate (by reaction with dilute acid and then limewater), chloride, bromide and iodide (by reaction under acidic conditions with aqueous silver nitrate), nitrate (by reduction with aluminium), sulfate (by reaction under

</td><td>
This allows a great range of simple test-tube reactions to be conducted. (I)

First, known samples can be used in experiments so that the learners may find out the answers for themselves. (I)

Then the experiments can be made more challenging by using unknown samples of an ionic compound (or even a mixture) to enable learners to develop analytical skills. (I)

Experimental work on flame tests of these ions.

There is also a spectacular demonstration that could conclude a session on flame tests.

Resource Plus
Experiments: The identification of unknown compounds C and D
The identification of unknown compounds L and M
The identification of unknown compounds X and Y
These experiments focus on qualitative analysis (the identification of ions and gases).

Very good experimental advice on testing and smelling gases: www.nuffieldfoundation.org/practical-chemistry/testing-and-smelling-gases

Summary sheet for most of these reactions: www.creative-chemistry.org.uk/gcse/documents/Module22/N-m22-02.pdf

Notes on the tests for anions and cations:
www.docbrown.info/page13/ChemicalTests/ChemicalTestsc.htm#KEYWORDS

Flame colours demonstration: www.nuffieldfoundation.org/practical-chemistry/flame-colours-%E2%80%93-demonstration
</td></tr>
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Syllabus ref.	Learning objectives	Suggested teaching activities
	acidic conditions with aqueous barium ions) and sulfite (by reaction with dilute acids and then aqueous potassium manganate(VII))	
	○ *gases*: ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using lighted splint), oxygen (using a glowing splint) and sulfur dioxide (using aqueous potassium manganate(VII)	Demonstration or experimental work to prepare some of these gases. Very good experimental advice on testing and smelling gases: www.nuffieldfoundation.org/practical-chemistry/testing-and-smelling-gases

Past and specimen papers
Past/specimen papers and mark schemes are available to download at **www.cambridgeinternational.org/support (F)**

5: Reaction rates

Syllabus ref.	Learning objectives	Suggested teaching activities
7.2 Rate (speed) of reaction	• Describe and explain the effect of concentration, particle size, catalysts (including enzymes) and temperature on the rate of reactions	Simple test-tube experiments using different-sized marble chippings and hydrochloric acid of different concentrations give a quick visual impression of the factors affecting rate of reaction. **(I)** The explanation of the observations may be made in terms of increasing the number of particles that can collide and react for concentration (in a given volume) and particle size. Increasing the energy makes the particles move faster so they collide more frequently. Using a catalyst allows more particles to collide and react. Video clip introduction to rates: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_gateway/chemical_economics/reactionratesact.shtml A good idea for a test-tube reaction to illustrate catalysis: www.nuffieldfoundation.org/practical-chemistry/catalysis-reaction-between-zinc-and-sulfuric-acid There are good explanations in the endorsed textbooks and other suggested textbooks. This is also explained well at: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/reaction/ratesrev3.shtml
	• Demonstrate knowledge and understanding of a practical method for investigating the rate of a reaction involving gas evolution Note: candidates should be encouraged to use the term *rate* rather than *speed*.	Reactions can involve metals and dilute acids or carbonates and dilute acids. Gas syringes (or measurement of displacement of water by gas in an upturned measuring cylinder) can be used to measure the volume of gas produced. Rules for drawing graphs and the terms independent and dependent variables should be introduced. Measurement of mass decrease in reaction involving evolution of gas could also be demonstrated. **Extension activity:** following the progress of a precipitation reaction. Various practical experiments to illustrate reaction rates: www.nuffieldfoundation.org/practical-chemistry/rates-reaction

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Devise and evaluate a suitable method for investigating the effect of a given variable on the rate of a reaction	Particle size, concentration and temperature can easily be changed for both the above types of reaction (metals and dilute acids or carbonates and dilute acids). (I) **Extension activity:** use of data loggers to record experimental results.
	• Interpret data obtained from experiments concerned with rate of reaction	This allows the use of spreadsheets and graphing to plot volume vs. time data to determine the speed of a reaction. A good explanation: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/chemical_synthesis/ratereactionrev2.shtml
	• Describe and explain the effects of temperature and concentration in terms of collisions between reacting particles. (An increase in temperature causes an increase in collision rate and more of the colliding molecules have sufficient energy (activation energy) to react whereas an increase in concentration only causes an increase in collision rate.)	Emphasise that a collision of sufficient energy is required for a chemical reaction. Not all collisions lead to chemical reactions. Relate to everyday life. A very good video clip that uses animations of atoms to explain collision theory: www.bbc.co.uk/learningzone/clips/collision-theory-and-rates-of-reaction/10668.html A good explanation: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/chemical_synthesis/ratereactionrev3.shtml and www.docbrown.info/page03/3_31rates.htm
	• Describe the application of the above factors to the danger of explosive combustion with fine powders, (e.g. flour mills) and gases (e.g. methane in mines)	Custard powder or cornflour explosion experiment in tin with tight fitting lid may be demonstrated. Information on the cornflour experiment: www.nuffieldfoundation.org/practical-chemistry/cornflour-%E2%80%98bomb%E2%80%99

Syllabus ref.	Learning objectives	Suggested teaching activities
6.1 Energetics of a reaction	• Interpret energy level diagrams showing exothermic and endothermic reactions	Exothermic and endothermic can be demonstrated here using a class practical. These diagrams represent what happens to the energy of reactants and products and explain why reactions are exothermic or endothermic. Revision of exothermic and endothermic reactions: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_21c/chemical_synthesis/whychemicalsrev8.shtml Practical to revise this: www.nuffieldfoundation.org/practical-chemistry/energy-or-out-classifying-reactions Energy level diagrams: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_21c/chemical_synthesis/whychemicalsrev9.shtml
	• Draw and label energy level diagrams for exothermic and endothermic reactions using data provided	Learners will need to practice this. **(I)** The data will tell learners whether a reaction is endothermic or exothermic so that the energy levels can be drawn in an appropriate position. The arrow between the energy levels should point to the product energy level and be labelled with the energy value (usually in kJ/mol).
	• Describe bond breaking as an endothermic process and bond forming as an exothermic process	Emphasise that a collision between two particles with sufficient energy is necessary for a reaction to occur (a successful collision). Not all collisions between particles are successful. Relate to the dodgem fairground ride. You can use a mnemonic or memorable phrase such as 'MexoBendo': • Mexo is 'making is exothermic' • Bendo is 'breaking is endothermic'. This can then be related to energy level diagrams to explain the two different stages in chemical reactions. This can be linked to the concept of activation energy. There is a useful PowerPoint which downloads by pasting in this address: www.ibchem.com/ppt/shelves/ene/energylevels.pps
	• Calculate the energy of a reaction using bond energies	A number of examples should be set so that learners can get used to doing this type of calculation. **(I)** Example calculations: www.docbrown.info/page03/3_51energy.htm#1

Syllabus ref.	Learning objectives	Suggested teaching activities
7.2 Rate (speed) of reaction	• Describe and explain the role of light in photochemical reactions and the effect of light on the rate of these reactions (This should be linked to section 14.4.)	Emphasise need of light for photosynthesis. This can be linked to Cambridge IGCSE Biology (0610).

Past and specimen papers

Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

6: Metals and the Reactivity Series

Syllabus ref.	Learning objectives	Suggested teaching activities
10.1 Properties of metals	• List the general physical properties of metals	Physical properties could include appearance, melting/boiling point, conduction of heat and electricity, malleability and ductility. This could be a research activity. **(I)** Physical properties linked to uses: www.s-cool.co.uk/gcse/chemistry/metals-the-reactivity-series/revise-it/properties-of-metals-and-non-metals Also there are good sections in the endorsed textbooks and most good textbooks.
3.2.5 Metallic bonding	• Describe metallic bonding as a lattice of positive ions in a 'sea of electrons' and use this to describe the electrical conductivity and malleability of metals	This explains the physical properties of metals, such as why they have high melting and boiling points, why metals conduct electricity and why they are malleable and ductile. Emphasise that the 'free' electrons can move (delocalised electrons) in the metallic structure. Model a metallic structure using a shallow dish of water with detergent. Notes on metallic bonding: www.docbrown.info/page04/4_72bond5.htm
10.1 Properties of metals	• Describe the general chemical properties of metals, e.g. reaction with dilute acids and reaction with oxygen	Chemical properties: could include reactions with water, steam and dilute mineral acids (link with Unit 4). A good way to link into the concept of the reactivity series is a practical that links metal-acid reactions of different metals to their exothermicity. This is shown in the links below – could be demonstrated, or used as a class practical. Exothermic metal-acid reactions: www.practicalchemistry.org/experiments/exothermic-metal-acid-reactions%2C101%2Cex.html Chemical properties, with some animations at: www.s-cool.co.uk/gcse/chemistry/metals-the-reactivity-series/revise-it/reactions-of-metals
	• Explain in terms of their properties why alloys are used instead of pure metals	Relate to improvement in corrosion resistance and mechanical properties such as strength. This can be illustrated using a simple particle diagram (particles cannot slide over each other as easily – different sized particles). (Link to Unit 2) Learners, in groups, can research different alloys and their uses and compare the alloy properties to those of pure

Syllabus ref.	Learning objectives	Suggested teaching activities
		metals. Their results could be presented in class or on a poster. Link to production of steel and brass. Background information on some common alloys: www.bbc.co.uk/schools/gcsebitesize/design/resistantmaterials/materialsmaterialsrev2.shtml and www.bbc.co.uk/schools/gcsebitesize/science/edexcel/metals/obtaining_using_metalsrev5.shtml
10.2 Reactivity series	• Place in order of reactivity: potassium, sodium, calcium, magnesium, zinc, iron, (hydrogen) and copper, by reference to the reactions, if any, of the metals with: ○ water or steam ○ dilute hydrochloric acid and the reduction of their oxides with carbon.	Possible experiments include: • potassium, sodium with water (as demonstration only) (link to Unit 2) • calcium, magnesium with water • magnesium, zinc with steam • magnesium, zinc, iron with dilute hydrochloric acid • heating carbon with metal oxides. Establishing the position of carbon in the reactivity series with a class practical and a demonstration: www.nuffieldfoundation.org/practical-chemistry/where-does-carbon-come-reactivity-series This experiment establishes the position of iron in the reactivity series relative to magnesium and copper, using its reaction with oxides: www.practicalchemistry.org/experiments/the-position-of-iron-in-the-reactivity-series%2C173%2CEX.html
	• Describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction, if any, with: ○ the aqueous ions ○ the oxides of the other listed metals.	Experiments could include: Reaction of the metals magnesium, zinc, iron and copper with aqueous solutions of their ions. This could be extended to introduce redox reactions (link to Unit 11). Aluminium and iron(III) oxide (Thermite reaction) as a demonstration of the reactions of metals and oxides. Good worksheet: www.creative-chemistry.org.uk/gcse/documents/Module5/N-m05-03.pdf Good advice about conducting this experiment: www.nuffieldfoundation.org/practical-chemistry/displacement-reactions-between-metals-and-their-salts A good animation of these experiments: http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/redox/home.html

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Account for the apparent unreactivity of aluminium in terms of the oxide layer which adheres to the metal	This could be a research activity. Do not confuse with rusting of iron. A demonstration showing the real reactivity of aluminium can be demonstrated using the procedure in the link below. Go to the bottom of this web page for information about the oxide layer: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway/chemical_resources/making_carsrev1.shtml The real reactivity of aluminium: www.nuffieldfoundation.org/practical-chemistry/real-reactivity-aluminium
10.4 Uses of metals	• Name the uses of aluminium: ○ in the manufacture of aircraft because of its strength and low density ○ in food containers because of its resistance to corrosion.	Relate to the uses of aluminium, e.g. aluminium is toxic, but oxide layer enables its use for drinks cans. This could form part of a research activity.
10.2 Reactivity series	• Deduce an order of reactivity from a given set of experimental results	Reactions of metals with water, steam and dilute hydrochloric or sulfuric acid (for advanced candidates also with other aqueous metal ions). Learners, in groups, can be given three/four elements on cards and asked to put in order of reactivity and present their reasoning to the class. This web page gives suggestions of video clips and animations that may be used: www.chemguide.co.uk/igcse/chapters/chapter8.html
10.3 Extraction of metals	• Describe the ease in obtaining metals from their ores by relating the elements to the reactivity series	Electrolysis, carbon + metal oxide (reduction using carbon) and mining of native metal as the different methods. Although we mention electrolysis here the extraction of aluminium from bauxite is covered in Unit 11. Demonstration of the reduction of lead(IV) oxide and charcoal blocks with a blowpipe. A test-tube class experiment using charcoal powder, lead(IV) oxide and copper(II) oxide.

<table>
<tr><th>Syllabus ref.</th><th>Learning objectives</th><th>Suggested teaching activities</th></tr>
<tr><td></td><td></td><td>Emphasise that metals above carbon in the reactivity series are extracted by electrolysis. Metals below carbon are usually extracted by heating their corresponding metal oxide with carbon.

Relate these three methods to the position of the metal in the reactivity series.

Possible issues to discuss include:
• the economic and environmental cost of the high energy required in metal extraction processes
• the large input of non-renewable fossil fuel resources into electrolysis and carbon reduction
• the importance of recycling metals.

Class experiment, extracting metals with carbon (charcoal): www.nuffieldfoundation.org/practical-chemistry/extracting-metals-charcoal

Resource Plus
Experiment: The extraction of iron on a match head
This experiment focuses on metal extraction.

Video clips on the various methods of extraction: www.rsc.org/Education/Teachers/Resources/Alchemy/

Notes on extraction of metals:
www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/rocks/metalsrev1.shtml

www.chemguide.co.uk/inorganic/extractionmenu.html</td></tr>
<tr><td></td><td>• Describe and state the essential reactions in the extraction of iron from hematite</td><td>Emphasise the use of a blast furnace and the raw materials: hematite (iron ore), coke and hot air.

Stress limestone is added to remove acidic impurities like SiO_2 in the ore and forms a useful by-product called calcium silicate (slag).

Iron from the blast furnace is 95% pure, very brittle and is called cast iron.

Possible issues to discuss include:
• local environmental effect of large-scale mining of hematite
• the economic and environmental cost of the high energy demand of blast furnace
• the large input of non-renewable fossil fuel resources into carbon reduction
• the need to collect waste - toxic carbon monoxide, which can be used as a fuel to reduce energy cost of</td></tr>
</table>

Syllabus ref.	Learning objectives	Suggested teaching activities
		plant • the need to recycle iron. Iron and steel manufacture: www.chemguide.co.uk/inorganic/extraction/iron.html www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/rocks/metalsrev2.shtml Use the iron and steel video clip from: www.rsc.org/Education/Teachers/Resources/Alchemy/
	• Describe the conversion of iron into steel using basic oxides and oxygen	The impurities in cast iron are removed to form pure iron. Pure iron is very soft and rusts easily. So it is converted into various types of steel by adding calculated amounts of carbon/other metals. Link to 10.3 – supplement below. Use of Basic Oxygen Process (O^2 lance) limited to the removal of carbon (good example of redox chemistry to illustrate syllabus section 7.4). (Link to Unit 11). This is a good video that could be used. It also summarises several of the other learning objectives covered in this unit: www.bbc.co.uk/schools/gcsebitesize/science/edexcel/metals/obtaining_using_metalsact.shtml
10.4 Uses of metals	• Describe the idea of changing the properties of iron by the controlled use of additives to form steel alloys	Use of other elements (often transition elements) and changing carbon content to alter properties such as strength and hardness. Illustrate the above structure changes using a particle model, emphasising that the different sized atoms stop the layers sliding over one another easily. (Link to Unit 2.) Opportunity for data analysis activities to link steel specifications to use. **(I)** The video described in the previous row is excellent for this: www.bbc.co.uk/schools/gcsebitesize/science/edexcel/metals/obtaining_using_metalsact.shtml
	• Name the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery)	Relate to greater resistance to chemical attack of stainless steel. This could be research activity.
10.3 Extraction of	• Describe in outline, the extraction of zinc from	Raw materials zinc blende, coke and air: • roast the zinc sulfide in air to form ZnO and SO_2

Syllabus ref.	Learning objectives	Suggested teaching activities
metals	zinc blende	• then it is a similar process to iron manufacture – the zinc oxide is heated with coke (carbon) reduced to form Zn and carbon monoxide (except there is no limestone and zinc vaporises and condenses in pans high in the furnace). Learners, in groups, could produce a flowchart or a poster of the process. Possible issues to discuss: • high energy demand of process and input of non-renewable fossil fuel • polluting effects of waste sulfur dioxide • the need to recycle zinc. Information about extraction: www.zinc.org/basics/zinc_production www.newton.dep.anl.gov/askasci/chem03/chem03435.htm
10.4 Uses of metals	• Explain the uses of zinc for galvanising and for making brass	This could be a research activity. It can be expanded to include coinage and musical instruments. This links with galvanising and sacrificial protection in Unit 3 and it is a good idea to reinforce 11.2 – supplement from this unit here. This is usually covered well in textbooks. Information about galvanising can be found at: www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/chemistry_out_there/redox_reactions/revision/2/
	• Name the uses of copper related to its properties (electrical wiring and in cooking utensils)	Properties such as electrical conductivity, melting point and general low chemical reactivity. This could be a research activity. Uses can be expanded to include coinage. Link to Unit 11 regarding the purification of copper. There are many websites with good information.

Syllabus ref.	Learning objectives	Suggested teaching activities
10.3 Extraction of metals	• Discuss the advantages and disadvantages of recycling metals, limited to iron/steel and aluminium	This could be a research activity with presentations or poster displays. You may prefer to concentrate on iron and steel here and link this to Unit 11 when aluminium extraction is covered. There are many websites with good information. Good section at bottom of this web page: www.chemguide.co.uk/inorganic/extraction/iron.html Although aimed at the UK this information is useful for the advantages of recycling iron/steel: www.tatasteeleurope.com/en/responsibility/cspr/recycling_steel_packaging/why_recycle_steel/ www.recyclemetals.org/tim_cans_story
9.4 Transition elements	• Describe the transition elements as a collection of metals having high densities, high melting points and forming coloured compounds, and which, as elements and compounds, often act as catalysts	Relevant elements for colours include iron (valency of 2 and 3), manganese (in potassium manganate(VII)), and copper(II). Learners can be introduced to different coloured ions and asked to predict the colours of some compounds. Catalysts to include nickel for hydrogenation of alkenes/fats, platinum/rhodium/palladium in car catalytic converters and iron in the Haber process (also vanadium(V) oxide in the Contact process). This could be set as a research task. Possible issues to discuss include the importance of catalysts in lowering the energy demand of industrial processes and hence conserving fossil fuel and increasing profitability. This is a good place to introduce the naming of the ions and to point out that oxidation states are used to name compounds. (Links to Section 7.4 of the syllabus and to Unit 11 of this scheme of work.) Encourage learners to make comparisons with the Group I metals covered in Unit 2. Transition metal properties: www.bbc.co.uk/schools/gcsebitesize/science/edexcel/patterns/transitionmetalsrev1.shtml
	• Know that transition elements have variable oxidation states	You could consider introducing this at this point. This links to Unit 11.

Syllabus ref.	Learning objectives	Suggested teaching activities
10.2 Reactivity series	• Describe and explain the action of heat on the hydroxides, carbonates and nitrates of the listed metals Note: the listed metals are: potassium, sodium, calcium, magnesium, zinc, iron, (hydrogen) and copper	Emphasise that this type of reaction is called thermal decomposition. Describe the action of heat on the hydroxides, carbonates and nitrates of potassium, sodium calcium, magnesium, zinc, iron(II), iron(III), copper(II). Note: Action of heat on nitrates should be demonstrated. The more reactive the metal, the more stable its nitrate, hydroxide or carbonate. Most metal hydroxides decompose to the corresponding metal oxide and water when heated. Potassium and sodium carbonate will not decompose, even after prolonged heating. The other metal carbonates will give the metal oxide and carbon dioxide. Potassium and sodium nitrate decompose to nitrites and oxygen. The others on the list decompose to oxides, nitrogen dioxide and oxygen when heated. A demonstration of 'writing with fire': www.nuffieldfoundation.org/practical-chemistry/thermal-decomposition-nitrates-writing-fire An experimental procedure for heating carbonates: www.nuffieldfoundation.org/practical-chemistry/thermal-decomposition-metal-carbonates

Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

7: Covalent bonding

Syllabus ref.	Learning objectives	Suggested teaching activities
3.2.3 Molecules and covalent bonds	• Describe the formation of single covalent bonds in H_2, Cl_2, H_2O, CH_4, NH_3 and HCl as the sharing of pairs of electrons leading to the noble gas configuration	Use overlapping circles to show where the bonding electrons are. Learners should distinguish the origin of the electrons by dots and crosses. Learners can use mini-whiteboards to draw electron diagrams as a class activity. **(I)** Notes on covalent bonding in some of these molecules: www.docbrown.info/page04/4_72bond3.htm www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/periodictable/covalentbondingrev1.shtml
	• Describe the electron arrangement in more complex covalent molecules such as N_2, C_2H_4, CH_3OH and CO_2	As above examples. Extension activity: some complicated examples like $AsCl_3$, SO_3, PCl_5 and BF_3. Notes on covalent bonding in these complex molecules: www.docbrown.info/page04/4_72bond3.htm
	• Describe the differences in volatility, solubility and electrical conductivity between ionic and covalent compounds	Learners can be given samples of salt, powdered wax and silver sand as three examples of white solids. They can carry out experiments to identify the bonding in each. For advanced learners, sugar can be given as an additional example to show that some simple covalent compounds are soluble in water. A database could be set up for a range of compounds of all bonding types with fields for each property. More advanced learners could be asked to design questions based on the properties, which would produce lists of compounds with a particular bonding type. PowerPoint presentation on simple covalent compound properties at: http://noadswood.hants.sch.uk/science/noadswood_science_website/GCSE_Additional_Science_-_Chemistry_I.html
	• Explain the differences in melting	Although covalent bonds are strong, the attractive forces between simple covalent molecules are weak so they have low melting and boiling points.

Syllabus ref.	Learning objectives	Suggested teaching activities
	point and boiling point of ionic and covalent compounds in terms of attractive forces	Ionic compounds have strong electrostatic forces between the ions, giving high melting and boiling points. This presentation is useful and so are some of the slides towards the end of the Ionic Bonding compounds presentation at the same site: http://noadswood.hants.sch.uk/science/noadswood_science_website/GCSE_Additional_Science_-_Chemistry_I.html Pages 1–2 of this website offer useful information and an animation: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/atomic/differentsubrev1.shtml
3.2.4 Macromolecules	• Describe the giant covalent structures of graphite and diamond	Ball and spoke models will be useful here. Emphasise key features in their structures: • Graphite: ○ each carbon attached to three other carbon atoms ○ hexagonal ring layered lattice structure ○ delocalised electrons within each layer ○ weak intermolecular forces between the layers. • Diamond: ○ each carbon forms four covalent bonds with other carbon atoms ○ each carbon has a tetrahedral arrangement ○ all electrons are localised in covalent bonds. This could be a research activity. Good interactive site on giant covalent bonding: www.avogadro.co.uk/structure/chemstruc/network/g-molecular.htm
	• Relate their structures to their uses, e.g. graphite as a lubricant and a conductor, and diamond in cutting tools	Relate the above key features to the properties of graphite and diamond – high melting/boiling point, conductivity, hardness. Discuss the importance of the one-directional strength of graphite to its use to reinforce fishing rods, sports rackets and modern polymer-based materials such as those used to build aircraft.
	• Describe the macromolecular	Ball and spoke models will be useful here.

Syllabus ref.	Learning objectives	Suggested teaching activities
	structure of silicon(IV) oxide (silicon dioxide)	Note the similarities and differences between SiO_2 and diamond. Worksheet activity to compare the differences between SiO_2 and CO_2: www.schools.longman.co.uk/gcsechemistry/worksheets/index.html
	• Describe the similarity in properties between diamond and silicon(IV) oxide, related to their structures	Emphasise the key features in SiO_2: • tetrahedral arrangement of silicon atoms • an oxygen atom between each pair of silicon atoms • each silicon forms four covalent bonds to other oxygen atoms • each oxygen forms two covalent bonds to other silicon atoms. This could be a research activity. **(I)** Good information about giant covalent structures at: www.chemguide.co.uk/atoms/structures/giantcov.html and www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/atomic/differentsubrev3.shtml

Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

8: Organic 1

Syllabus ref.	Learning objectives	Suggested teaching activities
14.1 Names of compounds	• Name and draw the structures of methane, ethane, ethene, ethanol, ethanoic acid and the products of the reactions stated in syllabus references 14.4–14.6	Learners need to be able to draw full structural formulae (showing all atoms and all bonds). Stress the importance of correct bond attachments. Establish rules of number of bonds formed for carbon, hydrogen and oxygen (links to valency, Group number and electronic configuration are possible, but not essential, if Unit 7 has been covered). Learners, in pairs or groups, could be given molecules to build using model kits or name/draw using mini-whiteboards. Excellent model kits can be purchased: www.molymod.com Drawing packages and other software are listed at: www.acdlabs.com/resources/freeware/
	• Name and draw the structures of the unbranched alkanes, alkenes (not *cis-trans*), alcohols and acids containing up to four carbon atoms per molecule	Extend the practical above by increasing the number of carbon, hydrogen and oxygen atoms available for modelling. Learners could use mini-whiteboards for drawing structures. **(I)** Learners could be introduced to the term 'functional group' to aid the identification of these organic compounds, for example alkene C=C, alcohol –OH, carboxylic acids –COOH. You may wish to introduce the ester functional group here. (Link to Unit 10) Good website for teaching notes, or for possible use by learners: www.chemistryrules.me.uk/junior/organic.htm#JunOrgAlkeneName
	• State the type of compound present, given a chemical name ending in *-ane*, *-ene*, *-ol*, or *-oic acid*, or a molecular structure	Cards with names or structures could be used as an activity.

Syllabus ref.	Learning objectives	Suggested teaching activities
14.3 Homologous series	• Describe the concept of homologous series as a 'family' of similar compounds with similar properties due to the presence of the same functional group	Learners could make models from 14.1 to determine the structural formula of successive members. The molecular, empirical formula and general formula can be worked out. Emphasise the difference of CH_2 between successive members of the homologous series. Stress that the functional group determines chemical reactions, but M_r and length of molecule affects physical properties, e.g. state, boiling point. **Opportunity for ICT:** learners could develop (or be provided with) a spreadsheet showing number of carbon atoms. They could devise formulae for calculating number of hydrogen atoms for alkanes/alkenes/alcohols and/or carboxylic acids. Formulae could also be derived to calculate molecular masses. If boiling point and/or enthalpy change of combustion data are included, there are opportunities for learners to produce line graphs to show trends of mass, boiling points and enthalpies of combustion against number of carbon atoms down the series. Database of chemical compound data: http://webbook.nist.gov/chemistry/
	• Describe the general characteristics of a homologous series	Discuss the effect of increased molecular mass down the series on boiling point (see suggested ICT activity, above). Link to fractional distillation (section 14.2). Homologous series: www.bbc.co.uk/schools/gcsebitesize/science/triple_edexcel/organic_chemistry/organic_chemistry/revision/5/
	• Recall that the compounds in a homologous series have the same general formula	Homologous series: www.bbc.co.uk/schools/gcsebitesize/science/triple_edexcel/organic_chemistry/organic_chemistry/revision/5/
	• Describe and identify structural isomerism	Emphasise drawing of structural formulae to represent isomers. Use butane as the initial example and extend to other examples. Learners could use mini-whiteboards or design posters showing all the isomers of a particular alkane with names.
6.2 Energy transfer	• State the use of hydrogen as a fuel	Possible demonstrations include burning hydrogen balloons and fuel cells (link to Unit 11). Possible group work for learners to present the pros and cons of using hydrogen as a fuel source.

Syllabus ref.	Learning objectives	Suggested teaching activities
		Possible issues to discuss: • the high cost of hydrogen due to the energy demand of electrolysis of water/brine • that obtaining hydrogen involves input of fossil fuel energy for electrolysis • that hydrogen is difficult to store for fuel use, particularly for cars, due to explosion risk and need for heavy pressurised cylinders • that hydrogen is non-polluting when burnt, the only product being water. Exploding balloons: www.nuffieldfoundation.org/practical-chemistry/exploding-balloons An alternative with a plastic bottle: www.nuffieldfoundation.org/practical-chemistry/controlled-explosion-hydrogen-air-mixture A good source of information: www.alternative-energy-news.info/technology/hydrogen-fuel/ http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/fuel-cell.htm
14.2 Fuels	• Name the fuels coal, natural gas and petroleum	Awareness of the finite nature of fossil fuel supply and the role of chemistry in the 'search for solutions' for alternative fuels and alternative industrial feedstock. Awareness of the competing demand for hydrocarbons as fuels and as raw materials for the petrochemical industry. This could be a research activity.
	• Name methane as the main constituent of natural gas	Relate to use in the home and in Bunsen burners.
	• Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation	Define a hydrocarbon as a molecule containing carbon and hydrogen atoms only. Awareness that the use of the fractions as fuels is rapidly depleting crude oil, the essential raw material for plastics and other petrochemicals. Discuss the supply and demand problem for some fractions – link to cracking in this unit. Also why the composition of crude oil differs between locations.

Syllabus ref.	Learning objectives	Suggested teaching activities
		This links to Unit 2 and there is an opportunity to demonstrate fractional distillation of synthetic crude oil as suggested. Video clip and useful information on fractional distillation: www.rsc.org/Education/Teachers/Resources/Alchemy/. http://science.howstuffworks.com/environmental/energy/oil-refining1.htm
	• Describe the properties of molecules within a fraction	This could be linked to the above and tackled as a research activity. See the above resources.
	• Name the uses of the fractions as: ○ refinery gas for bottled gas for heating and cooking ○ gasoline fraction for fuel (petrol) in cars ○ naphtha fraction for making chemicals ○ kerosene/paraffin fraction for jet fuel ○ diesel oil/gas oil for fuel in diesel engines ○ fuel oil fraction for fuel for ships and home heating systems ○ lubricating fraction for lubricants, waxes and polishes ○ bitumen for making roads	Opportunity for display work. Learners can find magazine pictures and advertisements to illustrate the uses of the fractions. The pictures can be mounted on a large outline of the fractionating column, showing where fractions emerge, with boiling points and chemical detail, such as number of carbon atom range in each fraction.
14.4 Alkanes	• Describe the properties of alkanes (exemplified	Lack of reactivity is partly due to the presence of strong C–C and C–H bonds only (link to Unit 5).

Syllabus ref.	Learning objectives	Suggested teaching activities
	by methane) as being generally unreactive, except in terms of burning	
	• Describe substitution reactions of alkanes with chlorine	Demonstration of the reactions of bromine with liquid alkanes/cyclo-alkanes in strong sunlight shows the general substitution reaction for alkanes. www.chemguide.co.uk/organicprops/alkanes/halogenation.html
	• Describe the bonding in alkanes	Single covalent bonds only (links to Unit 7). Information at: www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/rocks/fuelsrev1.shtml
14.5 Alkenes	• Describe the manufacture of alkenes and of hydrogen by cracking	Paraffin on mineral wool can be cracked using hot broken pot or granules of aluminium oxide as a catalyst. The resultant gas can be collected over water. Awareness of the importance of cracking to the petrochemical industry to meet demand for smaller molecules, e.g. petrol components, from larger molecules in crude oil for which there is less demand. Hydrogen is also a by-product. Link to the Haber process in Unit 12. Information on experiments: www.nuffieldfoundation.org/practical-chemistry/cracking-hydrocarbons A useful animation and information: www.bbc.co.uk/schools/gcsebitesize/science/edexcel/fuels/hydrocarbonsrev2.shtml
	• Describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam	The addition of bromine water to the product of the above reaction demonstrates this addition reaction. Emphasise the difference between an addition and a substitution reaction. Examples of hydrogen addition include the hydrogenation of polyunsaturated vegetable oils to make solid margarines.
	• Distinguish between saturated and unsaturated hydrocarbons	Relate this to the modelling at the start of the unit and the reactions of alkanes and alkenes mentioned above. Emphasise that a saturated molecule contains only single covalent bonds and an unsaturated molecule contains one or more C=C double bonds.

Syllabus ref.	Learning objectives	Suggested teaching activities
	○ from molecular structures ○ by reaction with aqueous bromine	
	• Describe the formation of poly(ethene) as an example of addition polymerisation of monomer units	Demonstration of the polymerisation of styrene or acrylates shows the general addition polymerisation reaction. Video clip on polyethene: www.rsc.org/Education/Teachers/Resources/Alchemy/
14.6 Alcohols	• Describe the manufacture of ethanol by fermentation and by the catalytic addition of steam to ethene	Demonstration of fermentation of sugar is possible here. (Link with Unit 10).
	• Outline the advantages and disadvantages of these two methods of manufacturing ethanol	Learners can tabulate the pros and cons of each process. A very useful comparison of the two methods: www.bbc.co.uk/schools/gcsebitesize/science/triple_edexcel/organic_chemistry/organic_chemistry/revision/4/
	• Describe the properties of ethanol in terms of burning	Discuss the importance of ethanol as a renewable fuel, already used in many countries where sugar cane grows easily, e.g. Brazil, Italy. Ethanol may become a ‘fuel for the future’ as fossil fuel supplies run out. You could also discuss with learners the implications of using land for growing fuel crops, which could be used to grow crops for food.
	• Name the uses of ethanol as a solvent and as a fuel	This could be a research activity with a presentation or poster display. A video looking at properties, uses and manufacture of ethanol: www.my-gcsescience.com/videos/ethanol-and-its-uses/

Past and specimen papers

Past/specimen papers and mark schemes are available to download at **www.cambridgeinternational.org/support (F)**

9: Amount of substance

Syllabus ref.	Learning objectives	Suggested teaching activities
4.1 Stoichiometry	• Determine the formula of an ionic compound from the charges on the ions present	Learners can be given a list of ions encountered in IGCSE and rules for writing chemical formulae. They can construct correct chemical formulae from ions (link to Unit 2). **(I)** The charges on ions should be linked with the Group number of the element in the Periodic Table. They can be introduced to the idea of using brackets when more than one of a complex ion is present. Basic information on chemical formulae: www.bbc.co.uk/schools/ks3bitesize/science/chemical_material_behaviour/compounds_mixtures/revise4.shtml Ion charges and ionic formulae: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/bonding/ionic_bondingrev7.shtml and www.occc.edu/kmbailey/chem1115tutorials/formulas_ionic.htm
	• Deduce the formula of a simple compound from a model or a diagrammatic representation	This can be linked with organic molecules but also include examples from suitable pictures of giant ionic structures. This could be a group activity with learners being given several examples. Learners need to be able to use both molecular and full structural formulae. (Link to Unit 8).
	• Construct equations with state symbols, including ionic equations	Introduce the four state symbols (s), (l), (g) and (aq). This should be linked to all theoretical and experimental work during the course. Ionic equations (link with Unit 11). This could be linked with the formation of precipitates in Unit 4. Learners can use flash cards (formulae of ions and simple molecules) as an activity to construct ionic equations. This also links to Unit 9. Experimental work on the formation of precipitates could be done here, if not covered in Unit 9. Spectator ions can be introduced here. The construction of ionic half-equations: www.chemguide.co.uk/inorganic/redox/equations.html

Syllabus ref.	Learning objectives	Suggested teaching activities
		Ionic equations and precipitates: www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/how_much/ionic_equations/revision/1/
	• Deduce the balanced equation for a chemical reaction, given relevant information	The information could be masses or amounts of material that react together. See below.
	• Define *relative atomic mass, Ar*, as the average mass of naturally occurring atoms of an element on a scale where the ^{12}C atom has a mass of exactly 12 units	You could introduce this by looking at the actual masses of some atoms and how very tiny these masses are. This leads in to the concept of relative masses where all atoms are compared to the standard atom, carbon-12. Information on relative atomic mass and a test: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atomic_structure/atomic_structurerev4.shtml
	• Define *relative molecular mass*, M_r, as the sum of the relative atomic masses (*Relative formula mass* or M_r will be used for ionic compounds (Calculations involving reacting masses in simple proportions may be set. Calculations will not involve the mole concept.)	Learners can use *Ars* to calculate the relative molecular mass from the molecular formula. Use of mini-whiteboards, bingo and crossword activities could be used. Also information at: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atomic_structure/atomic_structurerev3.shtml
4.2 The mole concept	• Define the mole and the Avogadro constant	Emphasise the idea of a mole being a particular amount of substance with the Avogadro number (Avogadro constant) of specified particles. Learners should be introduced to the terms ‘stoichiometry’, ‘limiting reactant’ and ‘in excess’ which may be used in calculations.

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Use the molar gas volume, taken as 24 dm^3 at room temperature and pressure	Learners will need plenty of practice. An experiment reacting magnesium with dilute sulfuric acid can be used to find/use the molar gas volume. Demonstrate how to calculate the Ar of Lithium ($Li + H_2O$) or Calcium ($Ca + H_2O$). (Link to % purity later in this unit).
	• Calculate stoichiometric reacting masses, volumes of gases and solutions, and concentrations of solutions expressed in g/dm^3 and mol/dm^3 (Calculations involving the idea of limiting of reactants may be set. Questions on the gas laws and the conversion of gaseous volumes to different temperatures and pressures will not be set.)	Learners will need plenty of practice. An experiment to find the formula of copper oxide could be demonstrated, or if equipment is available this could be a class practical. This can be linked back to the preparation of salts by titration, e.g. preparation of sodium chloride. Learners should also be competent at handling reactant mass data given in tonnes for industrial scale reactions, e.g. preparation of salts for use as fertilisers. (Link to Unit 12.) Finding the formula of copper oxide: www.nuffieldfoundation.org/practical-chemistry/finding-formula-copper-oxide Titrating NaOH with HC*l*: www.practicalchemistry.org/experiments/titrating-sodium-hydroxide-with-hydrochloric-acid,129,EX.html
	• Calculate empirical formulae and molecular formulae	Learners will need plenty of practice. Suggested experiment – heating a coil of magnesium ribbon to complete oxidation in a crucible. This gives appropriate data if an accurate digital balance is available. Finding the formula of magnesium oxide: www.practicalchemistry.org/experiments/the-change-in-mass-when-magnesium-burns,207,EX.html **Resource Plus** **Experiment:** Finding the empirical formula by displacement This experiment focuses on calculating the empirical formula of a compound (copper chloride) using a chemical displacement reaction. The other experiment that illustrates this is 'Finding the formula of copper oxide' above.

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Calculate percentage yield and percentage purity	Percentage yield can be calculated by analysing the results for simple displacement reactions. Percentage purity can be calculated by working out how much copper is in a known mass of malachite or by using titration techniques to estimate, for example, the amount of iodine in a known mass of potassium iodate or the percentage purity of iron wire. Extension activity: learners can be introduced to the concept of atom economy and the benefits of designing processes with high atom economy. This could involve group work and presentations based on their findings. Finding the percentage purity of iron wire: http://schools.longman.co.uk/gcsechemistry/worksheets/pdfs/worksheet4.pdf

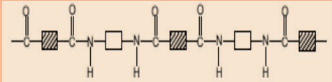
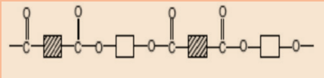
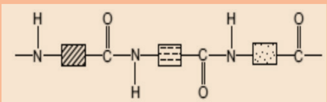
Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

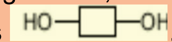
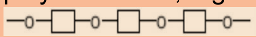
10: Organic 2

Syllabus ref.	Learning objectives	Suggested teaching activities
14.7 Carboxylic acids	• Describe the formation of ethanoic acid by the oxidation of ethanol by fermentation and with acidified potassium manganate(VII)	Awareness of implications for storage of ethanol to prevent spoilage. Extension to the purification by distillation (link to Unit 1) and the term 'reflux'. Information about carboxylic acids: www.bbc.co.uk/schools/gcsebitesize/science/triple_aqa/alcohols_carboxylic_acids_esters/carboxylic_acids/revision/1/
	• Describe the properties of aqueous ethanoic acid	Link to Unit 4. This is a good opportunity to revise properties of acids using simple test-tube reactions.
	• Describe ethanoic acid as a typical weak acid	Learners can illustrate this by: • testing its pH with Universal Indicator • comparing the rate of reaction with magnesium with that of hydrochloric acid, a strong acid.
	• Describe the reaction of a carboxylic acid with an alcohol in the presence of a catalyst to give an ester	This can be shown by a simple test-tube experiment with careful assessment of risks. Learners can be given samples of esters to smell. Risk assessment. Awareness of importance of sweet-swelling esters as food and cosmetics additives. Information on esters: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/carbon_chem/3_smells1.shtml A link about the smells of common esters: www.chm.bris.ac.uk/motm/ethylacetate/smells.htm
14.1 Naming of compounds	• Name and draw the structural formulae of the esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms	This could be a problem-solving activity to deduce the structural formulae and may be combined with the experimental preparations detailed in the link below. The link mentioned above is useful here: www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/carbon_chem/3_smells1.shtml Experiments to produce some of these esters: www.nuffieldfoundation.org/practical-chemistry/making-esters-alcohols-and-acids

Syllabus ref.	Learning objectives	Suggested teaching activities
14.8.1 Polymers	• Define polymers as large molecules built up from small units (monomers)	Demonstrations of the preparation of poly(phenyltethene), commonly known as poly(styrene), or poly(acrylates) are possible here. Importance of crude oil as a raw material for polymers and its finite supply. Experimental procedure for poly(phenylethene): www.nuffieldfoundation.org/practical-chemistry/addition-polymerisation Notes on addition polymers: www.docbrown.info/page04/OilProducts07.htm
	• Understand that different polymers have different units and/or different linkages	This could be a research activity to look at different polymers, their structural formulae and their properties, with presentations or poster displays.
14.8.2 Synthetic polymers	• Name some typical uses of plastics and of man-made fibres such as nylon and *Terylene*	Relate this to everyday items such as drinks containers, detergent bottles and other household items as well as clothes. Look at the underneath of bottles to determine the polymer and on clothing labels to find the fibres used. Opportunity for display work about clothes, packaging (real packaging can be stuck to display) or building to show where polymers are used, their names, classification as synthetic or natural and diagrammatical representation of polymerisation. **Extension activity:** to investigate smart polymers (hydrogels – super absorbent polymers) in disposable nappies/diapers. Issues of disposal can be included. **Resource Plus** **Experiment:** Making nylon This experiment focuses on a demonstration for making nylon using a diacyl chloride and a diamine using condensation polymerisation. Video clip on uses of polymers: www.bbc.co.uk/learningzone/clips/uses-of-polymers/1467.html Experiments with hydrogels: www.nuffieldfoundation.org/practical-chemistry/experiments-hydrogels-hair-gel-and-

Syllabus ref.	Learning objectives	Suggested teaching activities
		disposable-nappies
	• Describe the pollution problems caused by non-biodegradable plastics	Learners can look for polymers around the home using recycling information. **(I)** Learners can discuss the benefits and disadvantages of polymer production and research the steps taken by chemists to reduce the environmental impact. Learners could prepare a presentation on impacts of polymers and benefits and constraints of recycling. Issues to discuss include: • economic barriers to the collection, sorting and processing of waste for recycling • environmental effects of burning and landfill • centuries scale longevity of examples such as disposable nappies and packaging • learners can carry out a survey to collect, classify and weigh a day's discarded plastic waste. Green Teacher (Education for Planet Earth: www.greenteacher.com/
	• Deduce the structure of the polymer product from a given alkene and *vice versa*	Opportunity to reinforce the importance of writing clear structural formulae here. Use models to illustrate addition polymerisation and images to allow identification of repeat units and monomers. Use kinaesthetic activity to illustrate the mechanism of polymerisation. Video about making poly(ethene): www.bbc.co.uk/learningzone/clips/making-polythene-cracking-and-polymerisation/4427.html
	• Explain the differences between condensation and addition polymerisation	When monomers react to form condensation polymers a small molecule is eliminated. See 11(b) of this webpage for information: www.docbrown.info/page04/OilProducts11.htm
	• Describe the formation of nylon (a polyamide) and *Terylene* (a polyester) by condensation polymerisation, the	The formation of nylon can be demonstrated by the reaction of a diacid chloride with a diamine (nylon rope trick). This is a condensation reaction (addition/elimination reaction). Learners can gently melt nylon granules on a tin lid and draw out a 'fishing line' using a glass rod.

Syllabus ref.	Learning objectives	Suggested teaching activities
	structure of nylon being represented as:  and the structure of *Terylene* as:  (Details of manufacture and mechanisms of these polymerisations are not required.)	Emphasise the structure of both polymers (opposite). Learners should be instructed to show the amide/ester bond clearly and draw two repeat units for each polymer in examinations. Opportunity to make models of each polymer. Nylon rope trick demonstration, experimental procedure: www.rsc.org/learn-chemistry/resource/res00000755/making-nylon-the-nylon-rope-trick Video showing the nylon rope trick: www.chemistry-videos.org.uk/chem%20clips/Nylon/nylon.html Video clip on nylon: www.rsc.org/Education/Teachers/Resources/Alchemy/
14.8.3 Natural polymers	• Name proteins and carbohydrates as constituents of food	Food packaging labels and 'healthy eating' claims on labels can be used as a source of discussion. Extensive information about sugar: www.sucrose.com/
	• Describe proteins as possessing the same (amide) linkages as nylon but with different units	Stress the amide (peptide) CONH group present linking the monomers together. Opportunity to make models of a section of a protein.
	• Describe the structure of proteins as: 	

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Describe the hydrolysis of proteins to amino acids (Structures and names are not required.)	Opportunity to link to experimental use of locating agents in chromatography. (See Unit 1) Awareness of the use of this process as a diagnostic tool to identify when patients lack a particular amino acid. Stress the COO group present linking the monomers together. Demonstration procedure and information: www.biotopics.co.uk/as/amino_acid_chromatography.html
	• Describe complex carbohydrates in terms of a large number of sugar units, considered as , joined together by condensation polymerisation, e.g. 	Link this with Cambridge IGCSE Biology. Awareness of the importance of photosynthesis as a means of producing a renewable energy resource. Opportunity to make models of a section of a carbohydrate either from the same sugar or different sugar units.
	• Describe the hydrolysis of complex carbohydrates (e.g. starch) by acids or enzymes to give simple sugars	Awareness of the importance of this reaction to the ability of animals to absorb food for energy as soluble sugar from ingested insoluble complex carbohydrate. Information on hydrolysis of starch at: www.bbc.co.uk/bitesize/standard/chemistry/plasticsandothermaterials/carbohydrates/revision/5/ **Resource Plus** **Experiment:** Hydrolysis of starch by acid and enzyme This experiment focuses on the hydrolysis of starch using both an enzyme (amylase) and acid (hydrochloric acid).
	• Describe the fermentation of simple sugars to produce ethanol (and carbon dioxide)	Experiment/demonstration of fermentation possibly combined with distillation to produce alcohol (link to Unit 8 and Cambridge IGCSE Biology 0610). Awareness of limitations on industrial conditions to increase the rate of this reaction due to living organism involved (yeast). Emphasise reaction stops when either the glucose is used up or the yeast is killed by the higher concentration of ethanol.

Syllabus ref.	Learning objectives	Suggested teaching activities
	(Candidates will not be expected to give the molecular formulae of sugars.)	Emphasise that enzymes are not killed – they are denatured in the yeast. Compare the pros and cons of the different methods to produce ethanol (fermentation of sugar solution and hydration of ethane - link to Unit 8). Link to important potential of ethanol as a renewable fuel.
	• Describe, in outline, the usefulness of chromatography in separating and identifying the products of hydrolysis of carbohydrates and proteins	Experiments possible include the separation of a mixture of amino acids using ninhydrin as a locating agent (link to Unit 1).

Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

11: Redox, electrochemistry and Group VII

Syllabus ref.	Learning objectives	Suggested teaching activities
7.4 Redox	• Define *oxidation* and *reduction* in terms of oxygen loss/gain (Oxidation state limited to its use to name ions, e.g. iron(II), iron(III), copper(II), manganate(VII))	Stress that oxidation and reduction reactions always occur together in a redox reaction. Redox changes can often be observed as significant colour changes, e.g. rusting/corrosion of iron or iron + copper(II) sulfate ==> iron(II) sulfate + copper. Link to ideas of the role of redox reactions in the production of energy from fuels and the extraction of metals. The reactions in car catalytic converters can also be studied here (link to Section 11.2, Unit 3). Experiments possible include the reaction of metals/non-metals with oxygen and the reaction of metal oxides with carbon. Some of these could be class experiments while others should be demonstrations. Definitions of oxidation and reduction: www.chemguide.co.uk/inorganic/redox/definitions.html
	• Define redox in terms of electron transfer	Use the mnemonic 'OILRIG' (oxidation is loss of electrons; reduction is gain of electrons). Practice ionic equations and identify the substance oxidised and reduced in a given reaction. **(I)** Link this to the reactivity series and reactions of metals and metal salt solutions in Unit 6, the halogens and electrolysis later in this unit. Definitions of oxidation and reduction: www.chemguide.co.uk/inorganic/redox/definitions.html www.gcsescience.com/r7-oxidation-reduction-redox.htm Displacement reactions and redox: www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/chemistry_out_there/redox_reactions/revision/4/
	• Identify redox reactions by changes in oxidation state and by the colour changes involved when using acidified potassium manganate(VII), and	Demonstrations can include: • reaction of ethanol and acidified $KMnO_4$ to yield ethanoic acid (link to Unit 8) • preparation of chlorine by reaction of conc. HC*l* and $KMnO_4$ solid and the reaction of potassium iodide solution with either chlorine or bromine (link to Group VII later in this unit). Other reactions which could be demonstrated include zinc + copper(II) sulfate and iodide ions + hydrogen peroxide.

Syllabus ref.	Learning objectives	Suggested teaching activities
	potassium iodide (Recall of equations involving $KMnO_4$ is not required.)	This links to Unit 6, syllabus Section 9.4 – supplement, knowing that 'transition elements have variable oxidation states'. Iodine clock reaction: www.nuffieldfoundation.org/practical-chemistry/iodine-clock-reaction
	• Define oxidising agent as a substance which oxidises another substance during a redox reaction. • Define reducing agent as a substance which reduces another substance during a redox reaction.	Having just defined oxidation and reduction, this concept can be confusing for learners. There is good advice about this lower down the web page in the link below. Advice about oxidising agent and reducing agent definitions: www.chemguide.co.uk/inorganic/redox/definitions.html
	• Identify oxidising agents and reducing agents from simple equations	This could be set as a problem-solving activity. Advice about oxidising agent and reducing agent definitions: www.chemguide.co.uk/inorganic/redox/definitions.html
7.2 Rate (speed) of reaction	• Describe the use of silver salts in photography as a process of reduction of silver ions to silver; and photosynthesis as the reaction between carbon dioxide and water in the presence of chlorophyll and sunlight (energy) to produce glucose and oxygen	Experiments on how light affects photosynthesis and darkening of slow photographic film in various light intensities. A simple experiment can be to make silver chloride, bromide and iodide by precipitation (link to Unit 4 and watch them change colour under strong light). Photosynthesis is an endothermic process. Information about silver salts in photography: www.kodak.com/US/en/corp/researchDevelopment/whatWeDo/technology/chemistry/silver.shtml
5 Electricity and chemistry	• Define electrolysis as the breakdown of an	This definition should be linked to the practical activities below.

Syllabus ref.	Learning objectives	Suggested teaching activities
	ionic compound, molten or in aqueous solution, by the passage of electricity	
	• Describe the electrode products and the observations made during the electrolysis of: ○ molten lead(II) bromide ○ concentrated hydrochloric acid ○ concentrated aqueous sodium chloride ○ dilute sulfuric acid and between inert electrodes (platinum or carbon).	These are demonstrations only and link with the production of halogens later in this unit. Learners can safely carry out the electrolysis of small quantities of aqueous sodium chloride. Tests from Unit 4 can be used to identify all three products. Link this to the industrial electrolysis of brine later in this unit. Learners can practise writing electron half-equations and link this to ideas of redox from earlier in this unit. Excellent video of electrolysis of lead bromide: www.youtube.com/watch?v=4x2ZCSr23Z8 Practical details of electrolysis of lead bromide: www.nuffieldfoundation.org/practical-chemistry/electrolysing-molten-leadii-bromide Notes on electrochemistry: www.docbrown.info/page01/ExIndChem/ExtraElectrochem.htm
	• State the general principle that metals or hydrogen are formed at the negative electrode (cathode), and that non-metals (other than hydrogen) are formed at the positive electrode (anode)	The demonstration of the electrolysis of molten lead bromide and the other experiments above can be used to illustrate this principle. Learners can electrolyse a range of aqueous solutions of salts and collect and test electrode products to confirm this. The procedure for a class practical: www.nuffieldfoundation.org/practical-chemistry/identifying-products-electrolysis
	• Predict the products of the electrolysis of a specified binary compound in the molten state	This should involve metal halides or metal oxides only. Emphasise that the product at the cathode is the corresponding metal and at the anode, a non-metal molecule (O_2 or Group VII molecule).

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Construct ionic half-equations for reactions at the cathode	Plenty of practice during the rest of this unit will help learners to become familiar with this. (Link to Syllabus section 4.1 – supplement in Unit 9.) Information at: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/ions/electrolysisrev5.shtml
	• Describe the transfer of charge during electrolysis to include: ○ the movement of electrons in the metallic conductor ○ the removal or addition of electrons from the external circuit at the electrodes ○ the movement of ions in the electrolyte	The video of the electrolysis of lead bromide from YouTube, suggested below, has an excellent animation. Posters to show the flow of ions and electrons. Video of electrolysis of lead bromide: www.youtube.com/watch?v=4x2ZCSr23Z8
10.3 Extraction of metals	• Know that aluminium is extracted from the ore bauxite by electrolysis	Video clips on aluminium extraction: www.rsc.org/Education/Teachers/Resources/Alchemy/ Information: www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/periodictable/electrolysisrev1.shtml
	• Describe in outline, the extraction of aluminium from bauxite including the role of cryolite and the reactions at the electrodes	Information about cryolite: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/electrolysis/electrolysisrev3.shtml
5 Electricity and chemistry	• Describe, in outline, the manufacture of aluminium from pure aluminium oxide in molten cryolite (refer to section 10.3)	Link the production of aluminium back to the production of other metals from their ores (Unit 6). Link to methods of extraction linked to metal reactivity Unit 6. Awareness of the economic and environmental implications of the very high energy demand for electrolysis (link to need for recycling of aluminium and hydroelectric power).

Syllabus ref.	Learning objectives	Suggested teaching activities
	(Starting materials and essential conditions should be given but not technical details or diagrams.)	Video clips on aluminium extraction: www.rsc.org/Education/Teachers/Resources/Alchemy/ See also the resources above.
	• Describe the reasons for the use of copper and (steel-cored) aluminium in cables, and why plastics and ceramics are used as insulators	The steel core provides additional strength. Aluminium is lightweight and a good conductor. Ceramics are found on pylons carrying high tension (voltage) cables.
	• Describe electrolysis in terms of the ions present and reactions at the electrodes in the examples given	This links with writing ionic equations (Unit 9). www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/ions/electrolysisrev3.shtml
	• Predict the products of electrolysis of a specified halide in dilute or concentrated aqueous solution	Demonstrations of the electrolysis of dilute and concentrated brine can show this. The electrolysis of dilute solutions could also be a class practical. Potential for group work as learners can produce a model to illustrate each process. Emphasise the difference in products at the anode, oxygen (dilute solution) and the corresponding halogen (concentrated solution). In addition, stress that the concentration of the halide in solution increases in the electrolysis of the dilute solution, but in a concentrated halide solution it decreases. Links to information and activities: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/ions/electrolysisrev4.shtml The procedure for a class practical given here could be adapted to fit the requirements of the syllabus: www.nuffieldfoundation.org/practical-chemistry/identifying-products-electrolysis A video about electrolysis and the section towards the end covers this:

Syllabus ref.	Learning objectives	Suggested teaching activities
		www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/electrolysis/electrolysisact.shtml
	• Describe, in outline, the manufacture of chlorine, hydrogen and sodium hydroxide from concentrated aqueous sodium chloride (Starting materials and essential conditions should be given but not technical details or diagrams.)	Awareness of the importance of the products of the processes in terms of their uses, e.g. hydrogen for making ammonia, chlorine for water treatment, NaOH for making soap. Video clips on the electrolysis of NaC*l*: www.rsc.org/Education/Teachers/Resources/Alchemy/ A video about electrolysis - the section at the end covers this: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/electrolysis/electrolysisact.shtml
9.3 Group properties	• Describe the halogens, chlorine, bromine and iodine in Group VII, as a collection of diatomic non-metals showing a trend in colour and density and state their reaction with other halide ions	Demonstration of preparation of chlorine (from concentrated hydrochloric acid and potassium manganate(VII)) and physical state and colour of bromine/iodine carried out in fume cupboard. (Link to Unit 2.) Learners can predict the trend in reactivity and oxidising nature (giving reasons) and, as a result, predict the effect of adding an aqueous halogen to a halide salt. They could then carry out test-tube scale displacement reactions to see if their predictions are true. Opportunity to practise writing half-equations. **(I)** Possible extension activity could be to demonstrate the reaction of iron with the halogens. Information and animation about the halogens: www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/periodictable/group7rev1.shtml Experimental procedures: www.nuffieldfoundation.org/practical-chemistry/reactions-aqueous-solutions-halogens Information about chlorine: www.americanchemistry.com/chlorine/ Reaction of iron with halogens: www.practicalchemistry.org/experiments/halogen-reactions-with-iron%2C44%2CEX.html

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Predict the properties of other elements in Group VII, given data where appropriate	This extends the list of halogens to include fluorine and astatine in theory only. In groups, learners could predict the reactivity, colour/physical state, melting/boiling point of fluorine and astatine. Information: www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_gateway/periodic_table/group7rev5.shtml
	• Identify trends in Groups, given information about the elements concerned	Information could include melting and boiling points, density and chemical reactivity. Learners could do a group activity and present their findings to other members of the class. Include examples from any group in the Periodic Table.
5 Electricity and chemistry	• Describe the electroplating of metals	Learners can electroplate zinc strips with copper. An initial can be painted onto the strip with clear nail varnish, to give a silver initial on a copper background. Electroplating: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/electrolysis/electrolysisrev2.shtml
	• Outline the uses of electroplating	To protect metals from corrosion and improve the appearance of metals, e.g. plating cutlery with silver and jewellery with gold or silver.
	• Relate the products of electrolysis to the electrolyte and electrodes used, exemplified by the specific examples in the Core together with aqueous copper(II) sulfate using carbon electrodes and using copper electrodes (as used in the refining of copper)	Awareness of the need for very pure copper for electrical wiring (pupils can cut open samples of wire to find copper) due to the interruption of current flow by impurities, as compared to copper needed for water pipes (link to Unit 6). Electrolysis activity – a useful interactive video: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/electrolysis/electrolysisact.shtml Video clip on copper refining: www.rsc.org/Education/Teachers/Resources/Alchemy/

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Describe the production of electrical energy from simple cells, i.e. two electrodes in an electrolyte (This should be linked with the reactivity series in section 10.2 and redox in section 7.4.)	Learners can make simple cells using a potato or any citrus fruit with metal electrodes. Opportunity for group work – learners could investigate the best substance for making a simple cell. Potato cell: www.miniscience.com/projects/PotatoElectricity/
6.2 Energy transfer	• Describe the use of hydrogen as a fuel reacting with oxygen to generate electricity in a fuel cell (Details of the construction and operation of a fuel cell are not required.)	Possible issues to discuss include: • toxicity of heavy metals used in batteries and subsequent hazards of their disposal • usefulness of re-chargeable batteries including their use for storage of energy from alternative energy sources such as domestic solar panels and wind-powered generators (and in cars). Background information: www.greenspec.co.uk/building-design/fuel-cells/

Past and specimen papers
Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support **(F)**

12: Equilibria

Syllabus ref.	Learning objectives	Suggested teaching activities
7.3 Reversible reactions	• Understand that some chemical reactions can be reversed by changing the reaction conditions (limited to the effects of heat and water on hydrated and anhydrous copper(II) sulfate and cobalt(II) chloride.) (Concept of equilibrium is not required.)	Some reactions can be classified as reversible and learners should be introduced to the reversible sign ⇌. Experimental work can involve learners heating hydrated copper(II) sulfate and adding water to anhydrous copper(II) sulfate as an illustration. **Extension activity:** learners to determine the amount of water removed on heating and calculate the formula of hydrated copper(II) sulfate (link to Unit 6). Practical procedure for heating hydrated copper(II) sulfate: www.nuffieldfoundation.org/practical-chemistry/reversible-reaction-involving-hydrated-copperii-sulfate-and%C2%A0its-anhydrous-form Practical procedure for determining the amount of water in copper(II) sulfate: www.chalkbored.com/lessons/chemistry-11/hydrate-lab.pdf **Resource Plus** **Experiment:** The reversible reaction between two cobalt species This experiment focuses on a reversible reaction demonstrated by a change in colour during the experiment.
	• Demonstrate knowledge and understanding of the concept of equilibrium	This could be introduced using the escalator analogy and by demonstrating the effect of acid and alkali on: • methyl orange indicator • sodium chromate/dichromate equilibrium • iodide/iodine equilibrium. A class practical to show an equilibrium with copper(II) ions may be carried out. The escalator analogy and an interactive tool to introduce equilibrium: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/chemreac/reversiblereacrev1.shtml Practical procedure for sodium chromate/dichromate equilibrium: www.nuffieldfoundation.org/practical-chemistry/equilibrium-involving-chromatevi-and-dichromatevi-ions

Syllabus ref.	Learning objectives	Suggested teaching activities
		Equilibrium with copper(II) ions: www.nuffieldfoundation.org/practical-chemistry/equilibrium-involving-copperii-ions
	• Predict the effect of changing the conditions (concentration, temperature and pressure) on other reversible reactions	Learners, in groups, can analyse yield data comparing rate and yield with varying conditions and extend this to predicting reaction conditions used for equilibrium reactions to produce the most efficient reaction. The effect of concentration can be demonstrated using the chlorine/iodine monochloride equilibrium. Care and use of a fume cupboard are essential. Illustrate how changing the temperature and pressure and the introduction of a catalyst affects the yield and rate (link with Unit 4) in the Haber and Contact processes (below). Important issues to consider include: • Raising the temperature increases the rate and the energy demand and hence economic cost. This lowers the yield for exothermic but increases the yield for endothermic reactions. • Increasing the pressure increases the rate and the energy demand and hence economic/equipment costs. The yield changes depend on the number of moles of gas reactants to products. • Introduction of a catalyst leads to a lower energy demand (lower temperature for an equivalent rate) and hence economic cost and saving fossil fuel resources. • Considerations of increased yield against increased cost are balanced to give ‘optimum conditions’. It is important to distinguish the effect of changing a condition on the reaction rate and equilibrium. Summarise in a table to avoid confusion. A practical procedure for the iodine monochloride iodine trichloride equilibrium: www.nuffieldfoundation.org/practical-chemistry/le-chatelier%E2%80%99s-principle-effect-concentration-and-temperature-equilibrium Effect of temperature on an equilibrium: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/chemreac/reversiblereacrev2.shtml An interactive animation of the effect of temperature in the Haber process: www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/chemreac/reversiblereacrev3.shtml This is followed on the next two pages by the effect of pressure on the Haber process.
11.3 Nitrogen and fertilisers	• Describe and explain the essential conditions for the manufacture of	Nitrogen from the air (link with Unit 1). Hydrogen from natural gas (link with Unit 4). Opportunity for group work where learners can produce a series of flash cards to make a flowchart of this process

Syllabus ref.	Learning objectives	Suggested teaching activities
	ammonia by the Haber process including the sources of the hydrogen and nitrogen, i.e. hydrocarbons or steam and air	or question loop activity to sequence the process. The importance of recycling unreacted nitrogen and hydrogen needs to be mentioned. The effect of the variation of values of temperature and pressure can be studied by advanced learners. Awareness of the economic and environmental advantages of placement of a manufacturing site can be investigated by learners. Opportunities for reacting masses and volume calculations (link with Unit 6 – Amount of Substance). www.chemguide.co.uk/physical/equilibria/haber.html Video clip of the process: www.bbc.co.uk/learningzone/clips/formation-of-ammonia-in-the-haber-process/4432.html Video clip on ammonia: www.rsc.org/Education/Teachers/Resources/Alchemy/
	• Describe the need for nitrogen-, phosphorus- and potassium-containing fertilisers	This could be a research activity. Links to biology and practical involving plant growth under controlled conditions.
12 Sulfur	• Name some sources of sulfur	This could be set as a research activity with the next syllabus references below. Sulfur is found uncombined or combined with metals as zinc blende (ZnS) or galena (PbS).
	• Name the use of sulfur in the manufacture of sulfuric acid	90% of the extracted sulfur is converted to sulfuric acid.
	• State the uses of sulfur dioxide as a bleach in the manufacture of wood pulp for paper and as a food preservative (by killing bacteria)	Emphasise the uses of sulfur dioxide as a bleaching agent (paper manufacture) and in killing bacteria (to preserve food). Look at food labels to see if sulfites (which release sulfur dioxide in acidic conditions) are present. **(I)**

Syllabus ref.	Learning objectives	Suggested teaching activities
	• Describe the manufacture of sulfuric acid by the Contact process, including essential conditions and reactions	Mention specific temperature, pressure and catalyst information. Learners can practise using flow diagrams to represent the process. **(I)** Economic issues relating to temperature and catalyst use could be discussed here, as with the Haber Process. Opportunity for group work as in the Haber process above. As with the Haber process, more advanced learners could study the effect of variation of temperature and pressure on the yield of sulfuric acid. Stress that the industrial process does not use high pressure even though it would be theoretically beneficial – it is not cost effective for the mediocre increase in yield. Opportunities for reacting masses and volume calculations (link with Unit 6). **(I)** www.chemguide.co.uk/physical/equilibria/contact.html Video clip on the Contact process: www.rsc.org/Education/Teachers/Resources/Alchemy/ There are also other teaching resources and information at this site. Manufacture of sulfuric acid: www.greener-industry.org.uk/pages/sulphuric_acid/9SulphuricAcidManu.htm www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/how_much/equilibria/revision/4/
	• Describe the properties and uses of dilute and concentrated sulfuric acid	The properties of dilute sulfuric acid are those of a typical acid and this links to acids, bases and salts (Unit 3). Learners could prepare ammonium sulfate. Demonstrate concentrated sulfuric acid as a dehydrating agent with hydrated copper(II) sulfate and sucrose provided. The uses of both dilute and concentrated sulfuric acid would make a good research activity. Sulfuric acid as a dehydrating agent: www.nuffieldfoundation.org/practical-chemistry/sulfuric-acid-dehydrating-agent Uses of sulfuric acid: www.docbrown.info/page01/ExIndChem/ExIndChemb.htm

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