

## Scheme of Work

# Cambridge IGCSE™ / Cambridge IGCSE (9–1) Chemistry 0620 /0971

For examination from 2023



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## 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 judgement 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 (hours / % of the course)
1 States of matter	It is recommended that this should take about 4 hours / 3% of the course.
2 Chemistry of the environment	It is recommended that this should take about 8 hours / 6% of the course.
3 Experimental techniques and chemical analysis	It is recommended that this should take about 10 hours / 8% of the course.
4 Atoms, elements and compounds	It is recommended that this should take about 14 hours / 11% of the course.
5 Metals	It is recommended that this should take about 10 hours / 8% of the course.
6 Chemical energetics	It is recommended that this should take about 6 hours / 5% of the course.
7 Acids, bases and salts	It is recommended that this should take about 12 hours / 9% of the course.
8 The Periodic Table	It is recommended that this should take about 14 hours / 11% of the course.
9 Stoichiometry	It is recommended that this should take about 12 hours / 9% of the course.

Topic	Suggested teaching time (hours / % of the course)
12 Chemical reactions	It is recommended that this should take about 12 hours / 9% of the course.
11 Electrochemistry	It is recommended that this should take about 12 hours / 9% of the course.
12 Organic chemistry	It is recommended that this should take about 16 hours / 12% of the course.

## Resources

You can find the up-to-date resource list, including endorsed resources to support Cambridge IGCSE Chemistry on the Published resources tab of the syllabus page on our public website [here](#).

Endorsed textbooks have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. 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. In addition to reading the syllabus, you should refer to the updated specimen assessment materials.

## School Support Hub

The School Support Hub [www.cambridgeinternational.org/support](http://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 <http://www.cambridgeinternational.org/support>. If you are unable to use Microsoft Word you can download Open Office free of charge from [www.openoffice.org](http://www.openoffice.org)

## 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 mentioned 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 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 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.

Syllabus ref.	Learning objectives	Suggested teaching activities
6.2.4 Rate of reaction	Describe and evaluate practical methods for investigating the rate of a reaction, including change in mass of a reactant or a product and gas evolution	<p><b>Effect of changing a) the concentration of solutions. b) pressure of gases</b>  <b>Experiment:</b> Reacting magnesium ribbon with different concentrations of hydrochloric acid solution  <a href="https://edu.rsc.org/resources/the-rate-of-reaction-of-magnesium-with-hydrochloric-acid/1916.article">https://edu.rsc.org/resources/the-rate-of-reaction-of-magnesium-with-hydrochloric-acid/1916.article</a> [collection over water method]</p> <p><b>Experiment:</b> Reacting marble chips (calcium carbonate) with hydrochloric acid of varying concentration  <a href="http://www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/6">www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/6</a> [gas syringe method]</p>
6.2.5 Rate of reaction	Interpret data, including graphs, from rate of reaction experiments	<p><b>Resource Plus</b>            Carry out <i>The effect of changing the concentration of hydrochloric acid on the rate of reaction</i> with experiment referring to the Teaching Pack for lesson plans and resources.</p> <p><b>Experiment:</b> The effect of concentration on the rate of reaction between sodium thiosulfate and hydrochloric acid  <a href="https://edu.rsc.org/resources/the-effect-of-concentration-on-reaction-rate/743.article">https://edu.rsc.org/resources/the-effect-of-concentration-on-reaction-rate/743.article</a> [disappearing cross]  <a href="http://www.york.ac.uk/orq/seq/salters/ChemistryArchive/ResourceSheets/thiosulphate_acid.PDF">www.york.ac.uk/orq/seq/salters/ChemistryArchive/ResourceSheets/thiosulphate_acid.PDF</a> [algebra]</p> <p><b>Experiment:</b> The loss in mass method for measuring rate of reaction  <a href="http://www.youtube.com/watch?v=Uj_74hXRuqI">www.youtube.com/watch?v=Uj_74hXRuqI</a></p> <p>It is not necessary to perform all of these experiments and for whichever one or more you choose to perform, make sure that they consider why the rate of reaction increases with increasing concentration of the reactants (a) and (b) in this learning objective.</p> <p><b>Extension: Stretch and prepare for A level</b>            This is a more in-depth explanation of how concentration affects the rate of chemical reactions:  <a href="https://www.chemguide.co.uk/physical/basicrates/concentration.html">https://www.chemguide.co.uk/physical/basicrates/concentration.html</a></p> <p>If you have no access to chemicals and equipment use resources that teach practical and ideas science through simulations:  <a href="https://teachchemistry.org/classroom-resources/reaction-rates-simulation">https://teachchemistry.org/classroom-resources/reaction-rates-simulation</a>  <a href="https://phet.colorado.edu/en/simulation/reactions-and-rates">https://phet.colorado.edu/en/simulation/reactions-and-rates</a> [ensure you have Java installed on your computer]</p> <p><b>Extension: Stretch and prepare for A level</b>            These simulations might interest learners who wish to learn more:  <a href="https://chemdemos.uoregon.edu/Topics/Rates-of-Reaction">https://chemdemos.uoregon.edu/Topics/Rates-of-Reaction</a></p>
		c) <b>Effect of changing surface area</b>

**Resource Plus** provides Teaching Packs and experiment videos to develop your learners' practical science skills. available for you to view and download at: [www.cambridgeinternational.org/support](http://www.cambridgeinternational.org/support).

**Extension activities** provide your more able learners with further challenge beyond the basic content of the course and help prepare them for A Level study and beyond.

**Past papers, specimen papers** and **mark schemes** are available for you to download at: [www.cambridgeinternational.org/support](http://www.cambridgeinternational.org/support)

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

### Past and specimen papers

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

**Experiment** activities are included to help you integrate practical science into your teaching programme, so that learners are prepared for the practical papers. Many include links to example videos and other resources you can use to run experiments in the lab with your learners.

## 1 States of matter

Syllabus ref.	Learning objectives	Suggested teaching activities
1.1.1 Solids, liquids and gases	State the distinguishing properties of solids, liquids and gases	<p>Learners will have met this topic earlier. At this level however, the precise use of scientific vocabulary is very important.</p> <p>Show learners a solid substance (such as a piece of metal) and a liquid (such as water), and wave your hand through the air to indicate the gases around us.</p> <p>In pairs, learners discuss and note down what they think these defining <b>properties</b> are. Emphasise that you want them to initially think of their general macroscopic properties and not worry about particles at this stage. If they need prompting, you could ask the following questions: Does it <b>flow</b>? Does it <b>change shape</b> to fill the container it is in? Can it be <b>compressed</b>? Does it always occupy the same <b>volume</b> in space (at a certain temperature)?</p>
1.1.2 Solids, liquids and gases	Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and motion	<p>Explain that scientists often use the particle model of matter to explain the observable macroscopic properties in 1.1.1. Present learners with three empty boxes in which they have to draw how they think the particle arrangement is structured.</p> <p>Learners could also go out onto the playground and pretend to be solids then gases then liquids. This is a nice team-building activity at the start of the course. Encourage them to use the key vocabulary accurately to describe the separation between particles, their arrangement and their movement.</p> <p>This page summarises both the macroscopic and microscopic properties of matter: <a href="http://www.bbc.co.uk/bitesize/guides/zthyj6f/revision/1">www.bbc.co.uk/bitesize/guides/zthyj6f/revision/1</a></p> <p>Once learners have grasped the main ideas and are using the correct terms, give them a blank table to complete, to consolidate the above ideas.</p>
1.1.3 Solids, liquids and gases	Describe changes of state in terms of melting, boiling, evaporating, freezing and condensing	<p>First discuss how water exists in different physical states at different temperatures. Ask learners at what temperatures melting and freezing and boiling and condensing occur. Emphasise that other substances, not just water, have unique change of state data associated with them. Give a few examples.</p> <p>Show learners a range of substances (physically and using images and/or videos) to show that different substances exist as solids, liquids or gases at room temperature. Example substances to discuss and show: iodine, sulfur, glucose, ethanol, propanone, bromine, nitrogen dioxide, chlorine, nitrogen.</p> <p>Ask learners questions such as, How would sulfur become liquid? [heating it gently].</p> <p>Ask related questions such as, What would happen if you had some nitrogen gas and cooled it? [It would liquefy] Do you think solid nitrogen exists? and if yes, Where might solid nitrogen exist?</p>
1.1.4 Solids, liquids and	Describe the effects of temperature and pressure	<p>Demonstrate some state changes: for example, melting some sugar gently, sublimation of iodine, evaporation of a drop</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
gases	on the volume of a gas	of acetone on the bench.
1.1.5 Solids, liquids and gases	Explain changes of state in terms of kinetic particle theory, including the interpretation of heating and cooling curves	<p>Images/videos for inspiration (I):</p> <p><a href="https://planetaria.ca/2018/06/09/dunes-on-pluto-yes-but-made-of-methane-ice/">https://planetaria.ca/2018/06/09/dunes-on-pluto-yes-but-made-of-methane-ice/</a> (methane or possibly solid nitrogen on Pluto)</p> <p><a href="http://www.bbc.com/news/magazine-29376436">www.bbc.com/news/magazine-29376436</a> (shows liquid and bromine vapour)</p> <p><a href="http://www.sciencesource.com/archive/Iodine-Sublimation-and-Condensation-SS21318336.html">www.sciencesource.com/archive/Iodine-Sublimation-and-Condensation-SS21318336.html</a> (sublimation of iodine)</p> <p><a href="http://www.wikiwand.com/simple/Condensation">www.wikiwand.com/simple/Condensation</a> (condensing of water)</p> <p><a href="http://www.youtube.com/watch?v=bxapF7HRjZo">www.youtube.com/watch?v=bxapF7HRjZo</a> (iodine sublimation (and deposition))</p> <p><a href="http://cosmobiologist.blogspot.com/2016/02/sulfur-in-yellows-reds-and-blues-oh-my.html">http://cosmobiologist.blogspot.com/2016/02/sulfur-in-yellows-reds-and-blues-oh-my.html</a> (molten and solid sulfur)</p> <p>Learners should be able to explain each change of state in terms of the kinetic theory as in this link: <a href="http://www.chemguide.co.uk/physical/kt/basic.html">www.chemguide.co.uk/physical/kt/basic.html</a></p>
1.1.6 Solids, liquids and gases	Explain, in terms of kinetic particle theory, the effects of temperature and pressure on the volume of a gas	<p>Learners can explore and explain changes of state using this simulation: <a href="https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html">https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html</a></p> <p>They should choose 'states' from the bottom tab and explore the changes of state for neon, argon and oxygen first. Afterwards, they can check it for water and if they are able, they should attempt the following activity.</p> <p><b>Extension activity: Stretch and prepare for A Level</b></p> <p>Learners research why water has the unusual arrangement it does as a solid, and they compare this to the more compact structure of liquid water. Challenge learners to explain what implications these water structures have for life on our planet and what kind of bonding exists between water molecules. Key terms to research and understand are: density, arrangement, hydrogen bonding.</p> <p><b>Experiment:</b> The heating and/or cooling curve of stearic acid</p> <p>Learners plot a graph of temperature against time and identify the melting and freezing point of stearic acid from it. In terms of particles, they also explain what process is happening in each region of the graph. The data in this experiment may be collected using data loggers or traditionally, using a thermometer. <a href="https://edu.rsc.org/resources/melting-and-freezing-stearic-acid/1747.article">https://edu.rsc.org/resources/melting-and-freezing-stearic-acid/1747.article</a></p> <p><b>Extension activity: Stretch and prepare for A Level</b></p> <p>Learners investigate why Oobleck does not obey the usual rules when considering states of matter.</p> <p>Common misconceptions in this topic:</p> <ul style="list-style-type: none"> <li>• Solids, liquids and gases expand when heated. The particles which make up the materials do not expand. They merely move more therefore occupy a larger volume.</li> <li>• Some learners think that particles are something <u>inside</u> matter, instead of particles being the matter itself.</li> </ul>



Syllabus ref.	Learning objectives	Suggested teaching activities
		<ul style="list-style-type: none"> <li>• Sometimes learners think that matter is continuous rather than being formed of discrete particles.</li> <li>• Space between particles is filled with air.</li> <li>• Forces are responsible for particle movement instead of the fact that the particles themselves are moving.</li> <li>• Particles themselves change state rather than the substance changing state due to the change in energy and position of the particles relative to each other.</li> </ul> <p>A number of these misconceptions are explained in more detail in the following article:  <a href="https://edu.rsc.org/cpd/states-of-matter-and-particle-theory/3010239.article">https://edu.rsc.org/cpd/states-of-matter-and-particle-theory/3010239.article</a></p>
1.2.1 Diffusion	Describe and explain diffusion in terms of kinetic particle theory	<p>Make sure learners are aware, if they also study biology, that there are contextual differences when defining diffusion. Present learners with the definition used in chemistry (which they have probably already seen): 'Diffusion is the movement of particles from a higher to a lower concentration'. Ask them, in pairs, to explain what it means, quoting examples of substances they have seen diffuse.</p> <p>Learners then research examples of diffusion in everyday life. A long list of examples is at:  <a href="https://examples.yourdictionary.com/examples-of-diffusion.html">https://examples.yourdictionary.com/examples-of-diffusion.html</a></p> <p><b>Experiment: Diffusion in gases</b></p> <ul style="list-style-type: none"> <li>• Use a deodorant spray. Spray it into the air at the front of the classroom. Learners put their hands up as soon as they can smell it.</li> <li>• Diffusion of nitrogen dioxide gas. It is a toxic and corrosive gas, but safer than using bromine. Preparation and demonstration are at:  <a href="https://edu.rsc.org/resources/diffusion-of-gases-a-safer-alternative-to-bromine/684.article">https://edu.rsc.org/resources/diffusion-of-gases-a-safer-alternative-to-bromine/684.article</a></li> <li>• Demonstrate this classic experiment to learners:  <a href="https://edu.rsc.org/resources/diffusion-of-gases-ammonia-and-hydrogen-chloride/682.article">https://edu.rsc.org/resources/diffusion-of-gases-ammonia-and-hydrogen-chloride/682.article</a>  Learners can see that ammonia travels faster than hydrogen chloride. Discuss and explain the result of this experiment in terms of the relative molecular masses of ammonia and hydrogen chloride. A common misconception made in this experiment is that the <u>liquids</u> diffuse. Carefully explain that the liquids placed onto the cotton wool balls give off <u>gases</u> which then diffuse through the tube. Also stress that hydrochloric acid produces hydrogen chloride <u>gas</u>.</li> </ul> <p><b>Experiment: Diffusion in liquids</b></p> <ul style="list-style-type: none"> <li>• Learners place a crystal of lead nitrate at one side of a petri dish and a crystal of potassium iodide at the other. Diffusion occurs and a new colourful yellow product is formed.  <a href="https://edu.rsc.org/resources/diffusion-in-liquids/685.article">https://edu.rsc.org/resources/diffusion-in-liquids/685.article</a></li> <li>• Learners can also perform the classic experiment in which a crystal of potassium permanganate or a coloured dye, is introduced carefully into the bottom of a beaker of water using a straw. After removing the straw, the</li> </ul>
1.2.2 Diffusion	Describe and explain the effect of relative molecular mass on the rate of diffusion of gases	

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>intense colour of the potassium permanganate or dye, diffuses throughout the water until it is of uniform colour throughout.</p> <p>Diffusion simulation: <a href="https://phet.colorado.edu/sims/html/diffusion/latest/diffusion_en.html">https://phet.colorado.edu/sims/html/diffusion/latest/diffusion_en.html</a></p>
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		

## 2 Chemistry of the environment

Syllabus ref.	Learning objectives	Suggested teaching activities
10.1.4 Water	<p>State that water from natural sources contains a variety of substances, including:</p> <ul style="list-style-type: none"> <li>(a) dissolved oxygen</li> <li>(b) metal compounds</li> <li>(c) plastics</li> <li>(d) sewage</li> <li>(e) harmful microbes</li> <li>(f) nitrates from fertilisers</li> <li>(g) phosphates from fertilisers and detergents</li> </ul>	<p>Discuss the meaning of <b>pure</b> water in the chemistry sense as the chemical substance <math>\text{H}_2\text{O}</math> containing 100% water molecules and nothing else and that truly pure water is not found naturally.</p> <p>Talk about water as a <b>solvent</b> (link to 12.1.3). Ask why rain water and 'pure' mountain spring water is not actually pure. Because of the idea, outside of the chemistry class, that 'pure water' is a desirable substance (one which contains beneficial dissolved minerals), you will need to emphasise this point before learners carry out the project below.</p> <p>Learners, in pairs, prepare a presentation on the beneficial and harmful substances that are found in water. Pairs of learners could team up into groups of six, and one learner presents each aspect based on their internet research.</p>
10.1.5 Water	<p>State that some of these substances are beneficial, e.g.:</p> <ul style="list-style-type: none"> <li>(a) dissolved oxygen for aquatic life</li> <li>(b) some metal compounds provide essential minerals for life</li> </ul>	
10.1.6 Water	<p>State that some of these substances are potentially harmful, e.g.:</p> <ul style="list-style-type: none"> <li>(a) some metal compounds are toxic</li> <li>(b) plastics harm aquatic life</li> <li>(c) sewage contains</li> </ul>	

Syllabus ref.	Learning objectives	Suggested teaching activities
	<p>harmful microbes which cause disease</p> <p>(d) nitrates and phosphates lead to deoxygenation of water and damage to aquatic life</p> <p>Details of the eutrophication process are <b>not</b> required</p>	
10.1.7 Water	<p>Describe the treatment of the domestic water supply in terms of:</p> <p>(a) sedimentation and filtration to remove solids</p> <p>(b) use of carbon to remove tastes and odours</p> <p>(c) chlorination to kill microbes</p>	<p>This article discusses the processes mentioned in the learning objective and provides practical activities for learners to design, build and test the best water filter:  <a href="http://www.wpi.edu/sites/default/files/inline-image/Academic-Resources/STEM-Education-Center/Water%20Treatment-Safe%20Water%20Science%20(AweSTEM).pdf">www.wpi.edu/sites/default/files/inline-image/Academic-Resources/STEM-Education-Center/Water%20Treatment-Safe%20Water%20Science%20(AweSTEM).pdf</a>            The activity uses simple and cheap materials (plastic water bottle, cotton, sand, activated charcoal).            There are printable question sheets to conclude.</p> <p><b>Experiment:</b> Water remediation lab for chlorine-contaminated water  <a href="http://www.teachengineering.org/activities/view/wst_environmental_lesson02_activity2">www.teachengineering.org/activities/view/wst_environmental_lesson02_activity2</a>            In this activity learners measure the effectiveness of water filters in purifying contaminated water. They prepare test water contaminated with chlorine, filter it and test the purified water with chlorine test strips.</p> <p><b>Extension activity: Stretch and prepare for A Level</b>            Learners reflect on why ice floats on water and why this is important for life and the environment of the Earth. They can discover why ice has a lower density than liquid water in this article:  <a href="http://www.zmescience.com/other/science-abc/reason-ice-floats/">www.zmescience.com/other/science-abc/reason-ice-floats/</a></p>
10.3.1 Air quality and climate	<p>State the composition of clean, dry air as approximately 78% nitrogen, N<sub>2</sub>, 21% oxygen, O<sub>2</sub> and the remainder as a mixture of noble gases and carbon dioxide, CO<sub>2</sub></p>	<p>Ask learners to draw a pie chart, labelling what they think is the composition of dry air in percentages. Then display the actual composition:  <a href="http://www.uihere.com/free-cliparts/air-separation-atmosphere-of-earth-gas-nitrogen-chemical-composition-others-6995070">www.uihere.com/free-cliparts/air-separation-atmosphere-of-earth-gas-nitrogen-chemical-composition-others-6995070</a>            Learners often think hydrogen is a major component.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
10.3.5 Air quality and climate	Describe photosynthesis as the reaction between carbon dioxide and water to produce glucose and oxygen in the presence of chlorophyll and using energy from light	Ask learners which gas in the atmosphere is a reactant in photosynthesis. Have the reactants and products as words on separate cards or assemble on a display screen. Piece the correct word equation together. Highlight that the percentage of carbon dioxide in the atmosphere is small but sufficient for this process to occur.
10.3.6 Air quality and climate	State the word equation for photosynthesis, carbon dioxide + water → glucose + oxygen	Learners find out why most leaves are green [due to the presence of chlorophyll]. Discuss that chlorophyll is a catalyst in photosynthesis and that it is therefore not written as a reactant or product in the word equation. Ask learners: <i>Does the reaction produce or use energy?</i> [Needs energy from sunlight].  Next piece together the symbol equation for photosynthesis. Learners should feel comfortable with the formulae for CO <sub>2</sub> , H <sub>2</sub> O, and O <sub>2</sub> . Emphasise that the product glucose has been built up from the reaction of two simpler molecules and that it contains the elements C, H and O in its molecules.  <b>Extension activity: Stretch and prepare for A Level</b> Learners who need less support can try to balance the symbol equation before revealing it to the rest of the class.  <a href="http://www.bbc.co.uk/bitesize/topics/zvrrd2p/articles/zn4sv9q">www.bbc.co.uk/bitesize/topics/zvrrd2p/articles/zn4sv9q</a> (equations for photosynthesis)
10.3.9 Air quality and climate	State the symbol equation for photosynthesis, $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$	<b>Extension activity: Stretch and prepare for A Level</b> Ask learners to justify that photosynthesis is an endothermic reaction. Next ask them to write the reverse of this reaction and name it [aerobic respiration]
10.3.2 Air quality and climate	State the source of each of these air pollutants, limited to: (a) carbon dioxide from the complete combustion of carbon-containing fuels (b) carbon monoxide and particulates from the incomplete combustion of carbon-containing fuels (c) methane from the	Learners carry out a research project for these learning objectives. They could make presentations of their work and/or display their work.  You could carry out this project to coincide with World Environment Day which occurs every year on 5 <sup>th</sup> June. This project could be part of a larger awareness in your school.

Syllabus ref.	Learning objectives	Suggested teaching activities
10.3.3 Air quality and climate	<p>decomposition of vegetation and waste gases from digestion in animals</p> <p>(d) oxides of nitrogen from car engines</p> <p>(e) sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds</p> <p>State the adverse effect of these air pollutants, limited to:</p> <p>(a) carbon dioxide: higher levels of carbon dioxide leading to increased global warming, which leads to climate change</p> <p>(b) carbon monoxide: toxic gas</p> <p>(c) particulates: increased risk of respiratory problems and cancer</p> <p>(d) methane: higher levels of methane leading to increased global warming, which leads to climate change</p> <p>(e) oxides of nitrogen: acid rain, photochemical smog and respiratory problems</p>	

Syllabus ref.	Learning objectives	Suggested teaching activities
	(f) sulfur dioxide: acid rain	
10.3.7 Air quality and climate	Describe how the greenhouse gases carbon dioxide and methane cause global warming, limited to: (a) the absorption, reflection and emission of thermal energy (b) reducing thermal energy loss to space	<p>You could study this and the following topic to coincide with Earth Day which is celebrated on 22<sup>nd</sup> April each year. If not, learners should check the site to find out what activities are happening. <b>(I)</b>  <a href="http://www.earthday.org/">www.earthday.org/</a>            The NASA website contains a section on global warming and the causes, including a short animation describing the process of global warming.  <a href="https://climate.nasa.gov/causes/">https://climate.nasa.gov/causes/</a></p> <p>Learners can perform graph plotting / spreadsheet activities on global warming trends using Google sheets or Excel, and download, display and analyse complex data:  <a href="http://www.jpl.nasa.gov/edu/teach/activity/graphing-global-temperature-trends/">www.jpl.nasa.gov/edu/teach/activity/graphing-global-temperature-trends/</a></p> <p>There are many graph matching exercises here:  <a href="https://scied.ucar.edu/activity/climate-impacts-graph-matching">https://scied.ucar.edu/activity/climate-impacts-graph-matching</a>            and more general ones here:  <a href="https://scied.ucar.edu/learning-zone/activities?field_learning_zone_category_tid=5">https://scied.ucar.edu/learning-zone/activities?field_learning_zone_category_tid=5</a></p> <p>Learners interpret a variety of graphs of actual data from the IPCC:  <a href="https://serc.carleton.edu/teachearth/activities/50192.html">https://serc.carleton.edu/teachearth/activities/50192.html</a></p>
10.3.4 Air quality and climate	State and explain strategies to reduce the effects of these environmental issues, limited to: (a) climate change: planting trees, reduction in livestock farming, decreasing use of fossil fuels, increasing use of hydrogen and renewable energy, e.g. wind, solar (b) acid rain: use of	Learners could cover these topics by a research project or presentation or combination of both.

Syllabus ref.	Learning objectives	Suggested teaching activities
	catalytic converters in vehicles, reducing emissions of sulfur dioxide by using low-sulfur fuels and flue gas desulfurisation with calcium oxide	
10.3.8 Air quality and climate	Explain how oxides of nitrogen form in car engines and describe their removal by catalytic converters, e.g. $2\text{CO} + 2\text{NO} \rightarrow 2\text{CO}_2 + \text{N}_2$	<p>Write the word equation and the symbol equation as in the learning objective. Compare related reactant–product pairs and ask learners to find out about each gas.</p> <p>Although <math>\text{CO}_2</math> is a greenhouse gas, it is much less harmful than <math>\text{CO}</math>. Nitrogen oxide is a harmful gas compared to <math>\text{N}_2</math>, the major component of the Earth's atmosphere.</p> <p>Details of the catalytic converter are at: <a href="http://www.explainthatstuff.com/catalyticconverters.html">www.explainthatstuff.com/catalyticconverters.html</a></p>
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		



### 3 Experimental techniques and chemical analysis

Syllabus ref.	Learning objectives	Suggested teaching activities
12.1.1 Experimental design	Name appropriate apparatus for the measurement of time, temperature, mass and volume, including: (a) stop-watches (b) thermometers (c) balances (d) burettes (e) volumetric pipettes (f) measuring cylinders (g) gas syringes	Cover this objective as part of learners' experimental work.  Make sure that learners are aware of the following points: <ul style="list-style-type: none"> <li>• The unit of measurement associated with each instrument.</li> <li>• That there are several instruments which can be used to measure volume (volumetric pipettes, burettes, measuring cylinders and gas syringes). Each are used in different situations depending on the precision needed.</li> <li>• That stop-watches and balances have analogue and digital versions.</li> </ul>
12.1.2 Experimental design	Suggest advantages and disadvantages of experimental methods and apparatus	Make sure that learners cover this objective as part of their evaluation of each practical experiment they carry out. In Paper 6 questions, learners should try to imagine the lab situation and think about what advantages and disadvantages could exist when carrying out a particular experiment.
12.1.3 Experimental design	Describe a: (a) solvent as a substance that dissolves a solute (b) solute as a substance that is dissolved in a solvent (c) solution as a liquid mixture composed of two or more substances (d) saturated solution as a solution containing the maximum concentration of a	These are very important terms in practical chemistry. Learners often confuse them, so use them frequently in discussions and assess learners' understanding of them often.

Syllabus ref.	Learning objectives	Suggested teaching activities
	<p>solute dissolved in the solvent at a specific temperature</p> <p>(e) residue as a substance that remains after evaporation, distillation, filtration or any similar process</p> <p>(f) filtrate as a liquid or solution that has passed through a filter</p>	
12.3.1 Chromatography	Describe how paper chromatography is used to separate mixtures of soluble coloured substances, using a suitable solvent	<p>Make sure that learners appreciate that chromatography is a widely used separation technique in industry and is not just about separating pen inks on coffee filters.</p> <p><b>Experiment:</b> Learners can carry out many investigations, including:</p> <ul style="list-style-type: none"> <li>• Separating food colourings</li> <li>• Highly coloured sweets</li> <li>• Leaf pigments – green leaves or autumn leaves – this is a more challenging investigation</li> <li>• Pen inks</li> </ul>
12.3.2 Chromatography	Interpret simple chromatograms to identify: (a) unknown substances by comparison with known substances (b) pure and impure substances	<p>You can use chromatography paper or cut filter papers to the size you need for the investigations – both work well.</p> <p><b>Resource Plus</b></p> <p>Carry out the <i>Chromatography: pigments in leaves</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>Learners should always use pencil to mark their baseline and also to indicate their solvent front at the end of the experiment. Make sure they know why pencil has to be used for the baseline.</p>
12.3.4 Chromatography	<p><b>State and use the equation for <math>R_f</math>:</b></p> $R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$	<p>Learners should demonstrate that they have made measurements on their chromatograms and calculated <math>R_f</math> values for separated components. Make sure they understand why the <math>R_f</math> value has no units.</p> <p>If possible, give learners 'unknown' substances to spot on their chromatograms so that they can compare <math>R_f</math> values with known samples.</p> <p><u>Solvents</u></p> <p>Make learners aware that solvents other than water are frequently used in chromatography. If possible, let them</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		experiment with using ethanol and/or acetone and aqueous mixtures of these.
12.3.3 Chromatography	Describe how paper chromatography is used to separate mixtures of soluble colourless substances, using a suitable solvent and a locating agent Knowledge of specific locating agents is <b>not</b> required	<p>Explain to learners that colourless substances also have different <math>R_f</math> values and that they can be chromatographed. Reagents called locating agents are used to stain the colourless substance so that they become visible. One such reagent is called ninhydrin and is commonly used in visualising amino acids. See: <a href="http://www.ecronicon.com/ecnu/nutrition-ECNU-01-000017.php">www.ecronicon.com/ecnu/nutrition-ECNU-01-000017.php</a></p> <p>General reference pages on chromatography:  <a href="http://www.gcscience.com/e8-chromatography.htm">www.gcscience.com/e8-chromatography.htm</a>  <a href="http://www.chemguide.co.uk/analysis/chromatography/paper.html">www.chemguide.co.uk/analysis/chromatography/paper.html</a></p> <p>This article might be of use to obtain better results in paper chromatography:  <a href="https://edu.rsc.org/cpd/practical-chromatography/2500327.article">https://edu.rsc.org/cpd/practical-chromatography/2500327.article</a></p>
12.4.1 Separation and purification	Describe and explain methods of separation and purification using: (a) a suitable solvent (b) filtration (c) crystallisation (d) simple distillation (e) fractional distillation	<p><u>Separation of mixtures</u>  Ask learners what they understand by the term 'mixture'. Make sure that they realise that a mixture can consist of solid, liquid and gaseous components. Discuss that mixtures can be separated to give one or more pure substance. If the substance is a solid its melting point can be determined and compared to another known pure sample of that substance. A sharp melting point indicates a high degree of purity. With liquids, boiling point can be found.</p> <p>The melting points of inorganic substances tends to be too high to measure in the laboratory. However, if you have a melting point apparatus, you can test some available organic solids from the prep room to witness that pure solids have sharp melting points.</p>
12.4.2 Separation and purification	Suggest suitable separation and purification techniques, given information about the substances involved	<p>If you do not have a melting point apparatus, it can be seen in operation here:  <a href="https://www.youtube.com/watch?v=sh-96_KfqqY">https://www.youtube.com/watch?v=sh-96_KfqqY</a></p> <p><u>Filtration and crystallisation</u>  <b>Experiment:</b> Separating insoluble sand from soluble sodium chloride</p>
12.4.3 Separation and purification	Identify substances and assess their purity using melting point and boiling point information	<p>This is a good experiment to start with which many learners will already have knowledge of. It illustrates several key aspects of working safely in a laboratory with Bunsen burners and hot solutions.  <a href="https://edu.rsc.org/resources/separating-sand-and-salt/386.article">https://edu.rsc.org/resources/separating-sand-and-salt/386.article</a> [Separating sand and salt]  The sand/salt mixture can be substituted with rock salt if available.  Learners should answer the key questions in the link given.</p> <p><b>Experiment:</b> Separating sodium chloride from rock salt and crystallising the product</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>This experiment is similar to the one above but this time the sodium chloride solution is not evaporated to dryness. Only some of the water is evaporated to the point of crystallisation and allowed to crystallise slowly. Learners compare the shape of the cubic crystals formed to those of a sample of pure salt. Ask learners why they would not test the melting point to verify the identity of the substance.</p> <p><b>Experiment:</b> Obtaining pure crystals of copper (II) sulfate Learners may have already performed this experiment related to the Acids, bases and salts topic. It yields nice, pure copper (II) sulfate crystals: <a href="https://edu.rsc.org/resources/reacting-copperii-oxide-with-sulfuric-acid/1917.article">https://edu.rsc.org/resources/reacting-copperii-oxide-with-sulfuric-acid/1917.article</a> (Reacting copper(II) oxide with sulfuric acid)</p> <p><u>Distillation</u> It is really important that learners know when it is appropriate to use simple distillation and when it is preferable or essential to use fractional distillation. Focus on whether the materials to be separated are solids or liquids and talk about boiling point as a unique property of matter.</p> <p><b>Experiments:</b></p> <ul style="list-style-type: none"> <li>• Simple distillation of coloured ink/water mixture: <a href="http://www.flinnsci.com/api/library/Download/224aed85de4d4fa287d0eceed9a40adc">www.flinnsci.com/api/library/Download/224aed85de4d4fa287d0eceed9a40adc</a></li> <li>• Simple distillation of a salt water mixture. <a href="http://www.education.com/science-fair/article/salt-water-distillation/">www.education.com/science-fair/article/salt-water-distillation/</a> (distillation of salty water)</li> <li>• This can lead to an interesting discussion about desalination. Learners might like to research where this is performed in the world and how. The fractional distillation of ethanol from a fermentation mixture: <a href="http://home.miracosta.edu/dlr/210exp5.htm">http://home.miracosta.edu/dlr/210exp5.htm</a></li> <li>• The fractional distillation of crude oil (theory discussed in the organic chemistry section): <a href="https://edu.rsc.org/resources/the-fractional-distillation-of-crude-oil/754.article">https://edu.rsc.org/resources/the-fractional-distillation-of-crude-oil/754.article</a></li> </ul> <p><b>Resource Plus</b></p> <div style="border: 1px solid black; padding: 5px;"> <p>Carry out <i>The distillation of a carbonated drink</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> </div> <p>Background information on many aspects of distillation for teachers: <a href="https://edu.rsc.org/cpd/practical-distillation/3008222.article">https://edu.rsc.org/cpd/practical-distillation/3008222.article</a></p>
7.3.2 Preparation	Describe the general solubility rule for salts:	<p><b>Please use the 'Notes for use in qualitative analysis' in the syllabus to help your learners with this section.</b> Stress that qualitative analysis in this course is mainly the testing of inorganic substances.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
<p>of Salts</p> <p>12.5.1 Identification of ions and gases</p>	<p>(a) sodium, potassium and ammonium salts are soluble (b) nitrates are soluble (c) chlorides are soluble, except lead and silver (d) sulfates are soluble, except barium, calcium and lead (e) carbonates and hydroxides are insoluble, except sodium, potassium and ammonium (f) hydroxides are insoluble, except sodium, potassium, ammonium and calcium (partially)</p> <p>Describe tests to identify the anions: (a) carbonate, <math>\text{CO}_3^{2-}</math>, by reaction with dilute acid and then testing for carbon dioxide gas (b) chloride, <math>\text{Cl}^-</math>, bromide, <math>\text{Br}^-</math>, and iodide, <math>\text{I}^-</math>, by acidifying with dilute nitric acid then adding aqueous silver nitrate (c) nitrate, <math>\text{NO}_3^-</math>, by reduction with aluminium and aqueous sodium</p>	<p>Steps to help learners feel confident and understand qualitative analysis:</p> <ol style="list-style-type: none"> <li>1. Before performing any qualitative analysis tests, ensure that learners can verify practically what the following terms mean: solution, soluble, insoluble, precipitate and in excess. Explain each of these terms using practical examples.</li> <li>2. Provide learners with a table similar to the one in the link below, explaining which ionic salts are generally soluble and insoluble: <a href="http://www.bbc.co.uk/bitesize/guides/zqxyjty/revision/4">www.bbc.co.uk/bitesize/guides/zqxyjty/revision/4</a></li> <li>3. Next, allow learners to perform each test with known substances, so that they become familiar with all of the qualitative analysis tests in this section for anions, for cations [including flame tests] and gases. After this, you can give unknown substances to learners to identify. When learners have gained more experience in performing qualitative analysis, you can give them some Paper 3 exercises and also Paper 4 Alternative to Practical questions to work through. Encourage learners to develop careful observation in this section. They should not rely on visual observation alone, but also use their sense of smell (carefully), touch (if a test tube gets warm or not) and hearing (for example, effervescence).</li> </ol> <p>For the initial practical work to familiarise learners with each test, these links contain sheets for the teacher and learner with tables to complete of observations: <a href="https://edu.rsc.org/resources/testing-for-negative-ions/758.article">https://edu.rsc.org/resources/testing-for-negative-ions/758.article</a> (testing for negative ions) <a href="https://edu.rsc.org/resources/testing-salts-for-anions-and-cations/464.article">https://edu.rsc.org/resources/testing-salts-for-anions-and-cations/464.article</a> (testing salts for anions and cations).</p> <p>Flame Tests</p> <div style="border: 1px solid black; padding: 5px; margin: 10px 0;"> <p><b>Resource Plus</b></p> <p>Carry out the <i>The identification of unknown compounds C and D, L and M and X and Y</i> experiments referring to the Teaching Packs for lesson plans and resources.</p> </div> <p><u>Aids to remembering all of the tests</u> There are a lot of tests to remember for the exam. Here are some suggested activities to help learners:</p> <ul style="list-style-type: none"> <li>• Learners create a quiz to test themselves / in pairs <a href="https://quizlet.com/en-gb">https://quizlet.com/en-gb</a></li> <li>• Create a mind-map of all of the tests as a poster</li> <li>• Create a set of flashcards (physical or virtual)</li> </ul> <p>Some links explaining each test: <a href="http://www.docbrown.info/page13/ChemicalTests/ChemicalTestsc.htm">www.docbrown.info/page13/ChemicalTests/ChemicalTestsc.htm</a> <a href="http://www.bbc.co.uk/bitesize/guides/z8fgmnb/revision/1">www.bbc.co.uk/bitesize/guides/z8fgmnb/revision/1</a></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
12.5.4 Identification of ions and gases	<p>hydroxide and then testing for ammonia gas</p> <p>(d) sulfate, <math>\text{SO}_4^{2-}</math>, by acidifying with dilute nitric acid then adding aqueous barium nitrate</p> <p>(e) sulfite, <math>\text{SO}_3^{2-}</math>, by reaction with acidified aqueous potassium manganate(VII)</p> <p>Describe the use of a flame test to identify the cations:</p> <p>(a) lithium, <math>\text{Li}^+</math></p> <p>(b) sodium, <math>\text{Na}^+</math></p> <p>(c) potassium, <math>\text{K}^+</math></p> <p>(d) calcium, <math>\text{Ca}^{2+}</math></p> <p>(e) barium, <math>\text{Ba}^{2+}</math></p> <p>(f) copper(II), <math>\text{Cu}^{2+}</math></p>	
12.5.2 Identification of ions and gases	<p>Describe tests using aqueous sodium hydroxide and aqueous ammonia to identify the aqueous cations:</p> <p>(a) aluminium, <math>\text{Al}^{3+}</math></p> <p>(b) ammonium, <math>\text{NH}_4^+</math></p> <p>(c) calcium, <math>\text{Ca}^{2+}</math></p> <p>(d) chromium(III), <math>\text{Cr}^{3+}</math></p> <p>(e) copper(II), <math>\text{Cu}^{2+}</math></p> <p>(f) iron(II), <math>\text{Fe}^{2+}</math></p> <p>(g) iron(III), <math>\text{Fe}^{3+}</math></p> <p>(h) zinc, <math>\text{Zn}^{2+}</math></p>	

Syllabus ref.	Learning objectives	Suggested teaching activities
12.5.3 Identification of ions and gases	Describe tests to identify the gases: (a) ammonia, $\text{NH}_3$ , using damp red litmus paper (b) carbon dioxide, $\text{CO}_2$ , using limewater (c) chlorine, $\text{Cl}_2$ , using damp litmus paper (d) hydrogen, $\text{H}_2$ , using a lighted splint (e) oxygen, $\text{O}_2$ , using a glowing splint (f) sulfur dioxide, $\text{SO}_2$ , using acidified aqueous potassium manganate(VII)	
10.1.1 Water	Describe chemical tests for the presence of water using anhydrous cobalt(II) chloride and anhydrous copper(II) sulfate	
10.1.2 Water	Describe how to test for the purity of water using melting point and boiling point	
10.1.3 Water	Explain that distilled water is used in practical chemistry rather than tap water because it contains	

Syllabus ref.	Learning objectives	Suggested teaching activities
	fewer chemical impurities	
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		



## 4 Atoms, elements and compounds

Syllabus ref.	Learning objectives	Suggested teaching activities
2.1.1 Elements, compounds and mixtures	Describe the differences between elements, compounds and mixtures	<p>Learners can independently research the definitions of each and compare their findings in a class discussion. Ask learners to quote examples of each type ready for a class discussion.</p> <p>Have samples of the following ready to promote discussion:</p> <ul style="list-style-type: none"> <li>• Elements: sulfur, iron, copper, carbon. Link this discussion to the Periodic Table so that learners start to use it from the start of the course.</li> <li>• Compounds: show learners a mixture of organic and inorganic compounds such as sodium chloride, paraffin wax, stearic acid and copper (II) sulfate</li> <li>• Mixtures: rock salt and iron/sulfur mixture (+ magnifying glasses to see the components of the mixture clearly).</li> </ul>
2.2.1 Atomic structure and the Periodic Table	Describe the structure of the atom as a central nucleus containing neutrons and protons surrounded by electrons in shells	<p>Before learners start a formal study of the atom they could try to appreciate the size of an atom using the 'Scale of the Universe' model: (I)  <a href="https://scaleofuniverse.com/">https://scaleofuniverse.com/</a>            Start at <math>10^0</math> at the centre of the presentation and scroll to the left            An appreciation of the size of an atom gained from exploring this presentation should help learners understand why for such a long time the notion of the atom was theoretical.</p> <p>Learners could make posters or prepare short presentations on the history of atomic structure. Alternatively you could give small groups of learners a short time to research notable scientists and philosophers, e.g. Democritus, Galileo, Newton, Boyle, Lavoisier, Dalton, J.J. Thompson, Bohr and share finding in a class discussion. Confirm with an example drawing on the board (for example a carbon atom) how an atom should be represented at this level.</p> <p>Point learners to a table of relative masses and charges of the proton, electron and neutron. Emphasise the significance of the word <u>relative</u> and how the values in the table have no units.</p>
2.2.2 Atomic structure and the Periodic Table	State the relative charges and relative masses of a proton, a neutron and an electron	
2.2.3 Atomic structure and the Periodic Table	Define proton number / atomic number as the number of protons in the nucleus of an atom	<p>Define proton number / atomic number, and mass number / nucleon number for learners.</p> <p>Give learners a copy of the Periodic Table as displayed in the back of the syllabus. They should get used to using this version as well as viewing colourful wall charts and interactive versions on the internet.</p> <p>Ask learners to write down a representation of the atom using the <math>{}^A_ZX</math> formula and explain the meaning of the symbols.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
2.2.4 Atomic structure and the Periodic Table	Define mass number / nucleon number as the total number of protons and neutrons in the nucleus of an atom	Point out that in whichever version of the Periodic Table is used, the largest number represents the mass number and that in the Cambridge version, this number is the number at the bottom, not the top as in some Periodic Tables.  After giving learners some examples of how to calculate the number of particles for example atoms, give them tables to fill in so that they can practise calculating the number of particles for different atoms.
2.3.2 Isotopes	Interpret and use symbols for atoms, e.g. $^{12}_6\text{C}$ and ions, e.g. $^{35}_{17}\text{Cl}^-$	
2.2.5 Atomic structure and the Periodic Table	Determine the electronic configuration of elements and their ions with proton number 1 to 20, e.g. 2,8,3	Explain the rules of electron filling in the Bohr model of the atom: 1st shell = max. 2 electrons, 2nd shell = max. 8 electrons, 3rd shell = max. 8 electrons For the 4th shell, only elements with Z=19 and 20 are required for Cambridge IGCSE Chemistry. Learners often ask what happens after this. You can simply tell them that the situation gets more complex at A Level and some shells split into sub-shells.  Note: In 2.2.5 regarding the electronic configuration of ions, this will be covered in ionic bonding
2.2.6 Atomic structure and the Periodic Table	State that: (a) Group VIII noble gases have a full outer shell (b) the number of outer shell electrons is equal to the group number in Groups I to VII (c) the number of occupied electron shells is equal to the period number	After explaining 'the rules' above, give learners a blank/template Periodic Table for the elements Z = 1 to 20 only. The table you give them should have just the name of the element and empty shells for each atom. Learners simply complete each atom with the correct number of electrons. The advantage of doing this is that they straightaway begin to see patterns in the Periodic Table. A correctly completed table will look something like the one here: <a href="http://www.docbrown.info/page04/4_71atom.htm">www.docbrown.info/page04/4_71atom.htm</a> Scroll down to 'The first 20 elements in the Periodic Table'  Highlight the following important points using their completed tables: <ul style="list-style-type: none"> <li>• Elements with full shells, that is, complete electronic configurations which are the noble gases have stable outer shells</li> <li>• The number of outer shells of electrons equals the number in Groups 1 to VII</li> <li>• The number of occupied electron shells is equal to the period number</li> </ul> Simulation: Build an atom: <a href="https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html">https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html</a> Start by choosing the 'Atom' tab at the bottom.

Syllabus ref.	Learning objectives	Suggested teaching activities
		<ol style="list-style-type: none"> <li>At first, encourage learners to build neutral atoms, inspecting the mass number and noting that the net charge is zero (explain the term net charge). <ul style="list-style-type: none"> <li>They should always start by adding protons to define the element.</li> <li>Next add neutrons to the nucleus.</li> <li>Finally add the electrons noting that for example, the simulation does not allow you to add more than 2 electrons to the first shell (since 2 electrons is the maximum number allowed).</li> </ul> <p>Suggest that they concentrate on the elements with proton numbers 1–20 as specified in the syllabus.</p> </li> <li>Next they repeat the above exercise relating the particles to the <math>{}^A_ZX</math> formula.</li> <li>Finally learners can play a range of games in pairs by selecting the 'Game' tab.</li> </ol> <p><u>Making 3D atomic models</u> Learners can be creative and build 3D atoms from any materials they choose. Emphasise that every atom has unique properties and uses. Once they have built their chosen atom ask them to find out something about their atom, its properties and uses etc. Here are some example models to make: <a href="http://www.ehow.com/how_7711317_make-3d-atom.html">www.ehow.com/how_7711317_make-3d-atom.html</a> <a href="https://sciencing.com/make-3d-model-atom-5887341.html">https://sciencing.com/make-3d-model-atom-5887341.html</a></p> <p>After building and displaying, learners could give a short presentation about their atom and the element's properties and uses and any other information illustrating the uniqueness of their chosen element.</p> <p><b>Extension activity: Stretch and prepare for A Level</b> In this topic, interested learners will ask many questions about other elements in the Periodic Table and how their electron shells are filled. Explain to them briefly that in the A level description of electron filling, some of the electron shells are split into sub-shells. You could encourage these learners to investigate the electronic structures of rubidium, strontium, selenium, bromine and krypton. They should notice that the outermost still corresponds to the group number.</p>
2.3.1 Isotopes	Define isotopes as different atoms of the same element that have the same number of protons but different numbers of neutrons	Present the following species with symbol 'X': ${}^{35}_{17}X$ and ${}^{37}_{17}X$  Ask learners: Which particles are the same in number? (protons and electrons). Point to the Periodic Table and ask: Which element is $Z = 16$ (sulfur) and $Z = 18$ (argon)? Ask: Therefore, what must $Z = 17$ be? (chlorine). Move learners towards the idea that there must be two 'versions' of chlorine and these are called isotopes.
2.3.4 Isotopes	Calculate the relative atomic mass of an element from the	Next ask learners: How are the two isotopes different from each other? (different numbers of neutrons)

Syllabus ref.	Learning objectives	Suggested teaching activities
2.3.3 Isotopes	<p>relative masses and abundances of its isotopes</p> <p>State that isotopes of the same element have the same chemical properties because they have the same number of electrons and therefore the same electronic configuration</p>	<p>Ask learners to try to define isotopes in their own words, saying which particles are the same and which are different in a single sentence. Finally reveal the definition of an isotope according to the learning objective.</p> <p>Next ask learners to calculate the number of particles in the following isotopes: Hydrogen, deuterium and tritium: (hydrogen-1, hydrogen-2 and hydrogen-3) Isotopes of carbon: (carbon-12, carbon-13 and carbon-14)</p> <p>Give learners tables where they should complete the number of electrons, protons and electrons. From this they can identify which are isotopes.</p> <p><u>Calculating the relative atomic mass of an element</u> Point learners towards the Periodic Table and ask them to comment on the atomic mass of chlorine [35.5] Explain that this arises because chlorine is a mixture of isotopes <math>^{35}\text{Cl}</math> and <math>^{37}\text{Cl}</math> in a ratio of 3:1 Learners should become familiar with being able to calculate relative atomic mass in this way. <a href="http://www.bbc.co.uk/bitesize/guides/zwn8b82/revision/6">www.bbc.co.uk/bitesize/guides/zwn8b82/revision/6</a></p> <p>Explain that all of these isotopes exist but some of them are stable and some are unstable. Learners can use the 'build an atom' simulation to test this. <a href="https://phet.colorado.edu/sims/html/isotopes-and-atomic-mass/latest/isotopes-and-atomic-mass_en.html">https://phet.colorado.edu/sims/html/isotopes-and-atomic-mass/latest/isotopes-and-atomic-mass_en.html</a> Learners will see that carbon-12 and -13 are stable but when carbon-14 is built, the nucleus wobbles and it says that it is unstable. Likewise hydrogen-1 and hydrogen-2 are stable but hydrogen-3 is unstable.</p> <p><b>Extension activity: Stretch and prepare for A Level</b> Learners research what it means for an isotope to be unstable and what radioisotopes are used for. Learners could find examples and make a short presentation to their peers about their findings.</p> <p><u>Plan an experiment</u> The syllabus tells us that 'isotopes of the same element have the same chemical properties because they have the same number of electrons and therefore the same electronic configuration' Ask learners to plan an experiment to verify this statement. If they need clues, you could mention the squeaky pop test (for hydrogen), or bleaching (for chlorine), etc.</p> <p><b>Extension activity: Stretch and prepare for A Level</b> Learners research why physical properties of the isotopes of the same element would be different. Then they find out which physical properties are different, e.g. density, mass, melting and boiling points, rate of diffusion.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
2.4.5 Ions and ionic bonds	Describe the giant lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions	Discuss briefly the idea of chemical bonding in chemistry. Refer learners back to 2.1.1 at the start of this topic, where a range of substances were discussed. Point out that most materials have some kind of chemical bonding (with the exception of noble gases, such as monoatomic helium atoms). You could write the broad classifications of bonding at this level (ionic, metallic, simple covalent molecules and giant covalent) for learners, giving a few examples of substances which fall into each category. This would provide a basic 'road map' for learners.
2.4.2 Ions and ionic bonds	State that an ionic bond is a strong electrostatic attraction between oppositely charged ions	Start by showing learners the lattice structure of sodium chloride. If you don't have a model of this, show the following image: <a href="https://openstax.org/books/university-physics-volume-3/pages/9-3-bonding-in-crystalline-solids">https://openstax.org/books/university-physics-volume-3/pages/9-3-bonding-in-crystalline-solids</a> [scroll to figure 9.8] At this stage learners may not know what an ion is but they can see there is a 3-dimensional array of particles of two different types (chloride ions and sodium ions).  Ask learners: What is the ratio of sodium to chloride particles? (1:1) Ask: Therefore what is the formula of sodium chloride? (NaCl).
2.4.3 Ions and ionic bonds	Describe the formation of ionic bonds between elements from Group I and Group VII, including the use of dot-and-cross diagrams	Learners could try to build their own 3-D models of lattice structures. Here is one example built from marshmallows and toothpicks: <a href="http://www.youtube.com/watch?v=dTlanwEpLFY">www.youtube.com/watch?v=dTlanwEpLFY</a>  Ask learners to suggest how the particles stay together in reality (obviously not with sticks joining them). They may come up with the correct term, or you will need to elicit the word 'attraction'. Have a discussion about opposite charges attracting (an idea they may know from static electricity, or you could use the analogy of North and South poles of magnets). Finally explain that sodium ions and chloride ions are versions of their atoms which are charged and attract each other in a regular 3-D lattice. Ensure that learners are able to use the term 'electrostatic attraction' to explain how the ions attract each other in this way.
2.4.6 Ions and ionic bonds	Describe the formation of ionic bonds between metallic and non-metallic elements, including the use of dot-and-cross diagrams	To help learners comprehend the size of the particles involved they could read this article about the world's largest lattice structure of NaCl ever built. Learners should note that even though the model is over 3m high it represents a crystal only 0.0000096mm across: <a href="http://www.bbc.com/news/science-environment-34796501">www.bbc.com/news/science-environment-34796501</a>  <b>Extension activity: Stretch and prepare for A Level</b> Like all models used in science they are never perfect. Learners could try to explain what the limitations of the model are. [for example: not to scale, the sticks may be easily interpreted as the ionic bonds but each ion attracts every other ion in the lattice structure, ions are not to scale]

Syllabus ref.	Learning objectives	Suggested teaching activities
2.4.1 Ions and ionic bonds	Describe the formation of positive ions, known as cations and negative ions, known as anions	<p>Using the example above of sodium chloride explain to learners that they are going to see how the ions are formed from atoms – in this case the oppositely charged ions in NaCl.</p> <ol style="list-style-type: none"> <li>1. Ask learners to draw atom diagrams and electron configurations of sodium and chlorine atoms.</li> <li>2. Show the transfer of the outermost electron from sodium to chlorine.</li> <li>3. Write down the new electron configurations for the resulting ions and write down their charges. (<math>\text{Na}^+</math> and <math>\text{Cl}^-</math>)</li> <li>4. Explain that each ion has now attained a noble gas structure. (<math>\text{Na}^+</math> 2, 8 is isoelectronic with neon and <math>\text{Cl}^-</math> 2, 8, 8 is isoelectronic with argon)</li> </ol> <p>Points to look out for:</p> <ol style="list-style-type: none"> <li>1. Often learners understand that when chlorine gains an electron it forms a negative ion, but they do not always understand why sodium forms a positive ion. If this is the case, make sure learners compare the total number of charged particles (protons and electrons) in the sodium atom and sodium ion before and after transfer.</li> <li>2. Learners frequently forget to show that they have formed ions – they omit the charges on the ions.</li> <li>3. Sometimes learners think electrons are different from each other because we represent them as dots and crosses. Stress that all electrons are the same.</li> <li>4. Ionic compounds are formed between metals and non-metals.</li> </ol> <p>Show learners one or two further examples of how ionic substances are formed in the same way as above, paying close attention to the points to look out for.</p> <p>As a gentle progression, learners try forming the following substances: MgO, <math>\text{CaCl}_2</math>, <math>\text{Li}_2\text{O}</math>.</p> <p>Diagrams for each of the structures: <a href="http://www.bbc.co.uk/bitesize/guides/z6k6pbk/revision/1">www.bbc.co.uk/bitesize/guides/z6k6pbk/revision/1</a></p> <p>Remind learners that once they have formed each particle MgO or <math>\text{CaCl}_2</math> or <math>\text{Li}_2\text{O}</math>, the compounds actually exist as giant ionic lattices as for NaCl.</p> <p>Interactive activity for learning about ionic bonding: <a href="https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-ionicbonding/content/index.html">https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-ionicbonding/content/index.html</a></p>
2.4.4 Ions and ionic bonds	Describe the properties of ionic compounds: (a) high melting points and boiling points	<p>This could be a mini research activity for learners.</p> <p>They will find that ionic compounds have high melting/boiling points and are good conductors of electricity as aqueous solutions or when molten. Evidence these ideas by doing the following:</p> <ul style="list-style-type: none"> <li>• Heat some sodium chloride in an ignition tube over a roaring Bunsen flame. Learners will observe the glass start to melt, but not the sodium chloride.</li> </ul>

Syllabus ref.	Learning objectives	Suggested teaching activities
2.4.7 Ions and ionic bonds	<p>(b) good electrical conductivity when aqueous or molten and poor when solid</p> <p>Explain in terms of structure and bonding the properties of ionic compounds:</p> <p>(a) high melting points and boiling points (b) good electrical conductivity when aqueous or molten and poor when solid</p>	<ul style="list-style-type: none"> <li>Take some sodium chloride and dissolve it in water. Explain that only some ionic compounds are soluble in water and so this method only works if the compound is soluble. Ask learners how its electrical conductivity could be tested. After discussion, set up a circuit and test it.</li> <li>As sodium chloride has such a high melting point, it cannot be performed in the lab. Show learners a video of molten sodium chloride conducting electricity: <a href="http://www.youtube.com/watch?v=NfNIn4R8tg4">www.youtube.com/watch?v=NfNIn4R8tg4</a></li> <li>You can also demonstrate that solid sodium chloride does not conduct electricity. Ask learners why conduction does not occur.</li> </ul> <p>During their research, learners may also write down that ionic compounds are brittle and hard which are both correct.</p>
2.5.1 Simple molecules and covalent bonds	<p>State that a covalent bond is formed when a pair of electrons is shared between two atoms leading to noble gas electronic configurations</p>	<p>Show learners a bottle of hexane (or another simple covalently bonded compound). Write down its chemical structure as: <math>C_6H_{12}</math></p> <p>Ask learners to explain why it cannot be an ionic compound. (It does not contain a metal). Other good answers might include that it is not solid at room temperature.</p> <p><u>Molecules with single covalent bonds</u> Explain how the molecules <math>H_2</math>, <math>Cl_2</math>, <math>CH_4</math>, <math>NH_3</math>, <math>HCl</math> and <math>CH_3OH</math> are formed. Guide learners through the key ideas that for hydrogen, a full outer shell means two electrons sharing, and for all other atoms at IGCSE, eight electrons sharing.</p>
2.5.2 Simple molecules and covalent bonds	<p>Describe the formation of covalent bonds in simple molecules, including <math>H_2</math>, <math>Cl_2</math>, <math>H_2O</math>, <math>CH_4</math>, <math>NH_3</math> and <math>HCl</math>. Use dot-and-cross diagrams to show the electronic configurations in these and similar molecules.</p>	<p>Simulations and interactives to aid understanding: <a href="https://javalab.org/en/covalent_bond_en/">https://javalab.org/en/covalent_bond_en/</a> (<math>H_2</math> and <math>H_2O</math> only) <a href="http://www.bbc.co.uk/bitesize/guides/zxxn82p/revision/1">www.bbc.co.uk/bitesize/guides/zxxn82p/revision/1</a> (<math>HCl</math> only)</p> <p>Stress that at this level the 3-D layout of the atoms relative to each other is not important though learners often enjoy being able to appreciate these molecules more if they build molecular models (such as Molymods). Example of methane: <a href="http://www.sciencephoto.com/media/75166/view/methane-molecular-model">www.sciencephoto.com/media/75166/view/methane-molecular-model</a></p> <p><u>Molecules with double and triple covalent bonds</u></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
2.5.4 Simple molecules and covalent bonds	Describe the formation of covalent bonds in simple molecules, including CH <sub>3</sub> OH, C <sub>2</sub> H <sub>4</sub> , O <sub>2</sub> , CO <sub>2</sub> and N <sub>2</sub> . Use dot-and-cross diagrams to show the electronic configurations in these and similar molecules	<p>When learners understand the basic concept that the octet rule is always fulfilled (for all elements except hydrogen), they should be able to try examples with multiple bonds.</p> <p>Work through an example with them, for example oxygen.</p> <p>Allow them to build oxygen with a single bond first and see that both oxygen atoms only have seven electrons sharing. Then persuade learners to draw a dot-and-cross structure with a double bond, thus fulfilling the stable octet for each oxygen atom.</p> <p>Allow learners to draw the molecules of ethene, carbon dioxide and nitrogen and build them from molecular models if available.</p> <p>Learners can check their drawings against this page (I): <a href="http://www.bbc.co.uk/bitesize/guides/zxxn82p/revision/2">www.bbc.co.uk/bitesize/guides/zxxn82p/revision/2</a></p> <p><b>Extension activity: Stretch and prepare for A Level</b></p> <p>For a deeper understanding of covalent bonding: <a href="https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-covalentbonding/content/index.html">https://pbslm-contrib.s3.amazonaws.com/WGBH/arct15/SimBucket/Simulations/chemthink-covalentbonding/content/index.html</a></p> <p>Another extension activity: Learners who are interested in the 3-D shapes of the molecules could try building their own molecules using this desktop app: <a href="http://molview.org/">http://molview.org/</a></p> <p>Learners draw the structures in 2-D and they are converted to rotatable 3-D models.</p>
2.5.3 Simple molecules and covalent bonds	Describe in terms of structure and bonding the properties of simple molecular compounds: (a) low melting points and boiling points (b) poor electrical conductivity	<p>Challenge learners to explain the properties of simple molecular compounds. You could present learners with the following statements which they have to interpret and explain in pairs:</p> <ol style="list-style-type: none"> <li>'Covalent bonds holding individual molecules together are usually strong. Despite this they have low melting points and low boiling points. Many simple covalent substances are gases at room temperature.'</li> </ol> <p>The key to being able to comment accurately on the first statement is to understand the term 'intermolecular forces' and to know that these are weak forces operating between individual molecules.</p> <p>This page presents a nice analogy of intermolecular bonds and their strengths compared to the bonds holding the individual molecules together (Note: here they use the term 'intramolecular' which some learners find confusing): <a href="http://www.khanacademy.org/test-prep/mcat/chemical-processes/covalent-bonds/a/intramolecular-and-intermolecular-forces">www.khanacademy.org/test-prep/mcat/chemical-processes/covalent-bonds/a/intramolecular-and-intermolecular-forces</a></p>
2.5.5 Simple molecules and covalent bonds	Explain in terms of structure and bonding the properties of simple molecular compounds: (a) low melting points	<ol style="list-style-type: none"> <li>'In the liquid form or even when covalent compounds dissolve in water they do not conduct electricity.'</li> </ol> <p>To interpret this statement correctly, learners must appreciate that there are no ions present and so charge cannot be</p>



Syllabus ref.	Learning objectives	Suggested teaching activities
	<p>and boiling points in terms of weak intermolecular forces (specific types of intermolecular forces are <b>not</b> required) (b) poor electrical conductivity</p>	<p>carried through the substance. Also, unlike in metals, there are no free electrons present.</p> <p>Simulation to build covalent molecules:  <a href="https://phet.colorado.edu/en/simulation/build-a-molecule">https://phet.colorado.edu/en/simulation/build-a-molecule</a>            Java will need to be installed on your computer</p> <p>Common misconceptions:            Learners often get confused about when to consider the forces between molecules and the actual covalent bonds themselves.</p>
<p>2.6.1 Giant covalent structures</p> <p>2.6.2 Giant covalent structures</p>	<p>Describe the giant covalent structures of graphite and diamond</p> <p>Relate the structures and bonding of graphite and diamond to their uses, limited to:            (a) graphite as a lubricant and as an electrode            (b) diamond in cutting tools</p>	<p>Use physical models if possible to show, and to enable learners to appreciate, the difference between these two structures. There are many commercial models available.</p> <p>Alternatively, groups of learners could build them from simple materials:  <a href="http://www.ehow.com/how_4487799_build-model-molecular-structure-diamond.html">www.ehow.com/how_4487799_build-model-molecular-structure-diamond.html</a> [made from toothpicks and candies]  <a href="http://www.rainbowresource.com/pdfs/products/prod032392_smpl1.pdf">www.rainbowresource.com/pdfs/products/prod032392_smpl1.pdf</a></p> <p>Or learners could compare the following images:  <a href="http://www.chemguide.co.uk/atoms/structures/giantcov.html">www.chemguide.co.uk/atoms/structures/giantcov.html</a> [diamond]  <a href="http://www.researchgate.net/figure/The-atomic-structure-of-graphite-The-dashed-lines-indicate-the-weak-connection-between_fig1_3811818">www.researchgate.net/figure/The-atomic-structure-of-graphite-The-dashed-lines-indicate-the-weak-connection-between_fig1_3811818</a> [graphite]</p> <p>Or pause the following video with the volume turned down initially:  <a href="http://www.youtube.com/watch?v=swssg7Mz-i8">www.youtube.com/watch?v=swssg7Mz-i8</a> (pause the video at 0.32 for diamond and at 1.23 for graphite).</p> <p>Whichever method you choose for your learners, ask them first to discuss and state the number of bonds each carbon atom has to it (make sure learners choose a central atom in each case).            Learners draw a dot-and-cross diagram for a central carbon atom for carbon and graphite. They will see the major difference between the two structures is that the carbon atom for diamond has four shared pairs of electrons (four single covalent bonds) whereas graphite only has three shared pairs (three covalent bonds).</p> <p>Explain to learners how the four strong covalent bonds in diamond extending in 3-D makes it very hard and it therefore has a use in cutting tools. It has no free electrons so does not conduct electricity.</p> <p>When discussing graphite, emphasise its layered structure and that there are free electrons (one for each carbon) which are free to move and conduct electricity when a voltage is applied. Demonstrate this using a graphite pencil. Also talk about the softness of graphite by writing and leaving layers of graphite on the page. Explain its use as a lubricant.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p><b>Extension activity: Stretch and prepare for A Level</b></p> <p>Learners could investigate the nature of the intermolecular forces holding the layers of graphite together. They could research the uses of graphene, Bucky balls and nanotubes and give a presentation about them.</p>
2.6.3 Giant covalent structures	Describe the giant covalent structure of silicon(IV) oxide, SiO <sub>2</sub>	<p>Display a piece of quartz and some sand.</p> <p>If possible, present learners with a 3-D model of silicon (IV) oxide asking them what the general shape resembles and what properties they think the substance might have.</p> <p>If a model is not available show an image of it: <a href="http://www.chm.bris.ac.uk/motm/silica/silicah.htm">www.chm.bris.ac.uk/motm/silica/silicah.htm</a> Try to zoom in on the 3-D structure only and not reveal the formula.</p>
2.6.4 Giant covalent structures	Describe the similarity in properties between diamond and silicon(IV) oxide, related to their structures	<p>Ask learners to focus on the atoms inside the structure and to try to determine the ratio of atoms present. There are twice as many oxygen atoms as silicon atoms and so the formula is SiO<sub>2</sub>.</p> <p>Also ask learners to predict the properties of SiO<sub>2</sub>. They will find that the properties are in many ways similar to diamond.</p>
2.7.1 Metallic bonding	Describe metallic bonding as the electrostatic attraction between the positive ions in a giant metallic lattice and a 'sea' of delocalised electrons	<p>Ask learners, in pairs, to make a list of the properties of typical metals. This should be revision from previous courses. For electrical conductivity, guide learners to the idea of free electrons / sea of delocalised electrons.</p> <p>Allow learners time to copy a diagram of metallic bonding: <a href="http://www.chemistrygcse.co.uk/4-2%20Bonding/7%20-%20Metallic%20Bonding%20&amp;%20Properties.html">www.chemistrygcse.co.uk/4-2%20Bonding/7%20-%20Metallic%20Bonding%20&amp;%20Properties.html</a></p> <p>This video helps explain how metallic bonds are formed: <a href="http://www.youtube.com/watch?v=BiOrUNV8mEw&amp;t=207s">www.youtube.com/watch?v=BiOrUNV8mEw&amp;t=207s</a> [start at 2.54]</p>
2.7.2 Metallic bonding	Explain in terms of structure and bonding the properties of metals: (a) good electrical conductivity (b) malleability and ductility	<p>Emphasise that the outermost electrons in metals are loosely held by their nuclei, allowing them to become delocalised throughout the piece of metal. In contrast, the electrons of non-metals are tightly held and so this situation cannot occur.</p> <p><u>Malleability and ductility</u></p> <p>These terms are often confused by learners but have specific meanings and clear differences. Chewing gum could be used to demonstrate ductility. The gum can be pulled out into an increasingly thin piece but when you stop pulling it does not return (does not spring back). Show learners a roll of copper wire, explaining that it has been produced by extrusion from a block of copper.</p> <p>You can easily demonstrate malleability by hitting copper, a soft metal, hard with a hammer.</p> <p>Watch these videos to appreciate the difference between ductility and malleability:</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p><a href="http://www.youtube.com/watch?v=yawQP474RF0">www.youtube.com/watch?v=yawQP474RF0</a> (raising a copper bowl – malleability)  <a href="http://www.youtube.com/watch?v=GaO2UikPio8">www.youtube.com/watch?v=GaO2UikPio8</a> (extruding copper wire – ductility)</p> <p>Animations which show at an atomic level why metals conduct electricity and are malleable and ductile:  <a href="http://www.usetute.com.au/metallic.html">www.usetute.com.au/metallic.html</a></p> <p><b>Extension activity: Stretch and prepare for A Level</b>  Learners who want to find out more about metals and their properties can research why metals conduct heat, have metallic lustres and are generally strong with high melting points and boiling points.</p>
Revision		<p>This provides a good revision opportunity for covalent and ionic bonding (I):  <a href="https://teachchemistry.org/classroom-resources/ionic-covalent-bonding-simulation">https://teachchemistry.org/classroom-resources/ionic-covalent-bonding-simulation</a></p>
Past and specimen papers		
<p>Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)</p>		

## 5 Metals

Syllabus ref.	Learning objectives	Suggested teaching activities
9.1.1 Properties of metals	Compare the general physical properties of metals and non-metals, including: (a) thermal conductivity (b) electrical conductivity (c) malleability and ductility (d) melting and boiling points	Learners could carry this out as a research activity. The most important word to emphasise to learners in this objective is 'general', in other words, the typical or usual properties that most metals have compared to non-metals. (a) Learners should be able to explain how they know metals are thermal conductors from everyday life such as metal saucepans. There are several different apparatus for finding out which metal, from a range, is a better conductor. Non-metals generally do not conduct heat well but diamond is an exception. (b) Learners should recall (from 2.7.1 metallic bonding) that metals are electrical conductors – you could discuss which metals are found in wires and power cables. The general properties of non-metals are that they are non-conductors but graphite is an exception. (c) Learners often get confused or find it difficult to recall these words. Therefore, demonstrating the difference is necessary (see 2.7.2). Solid non-metals are brittle but most non-metals are gases at room temperature. (d) Metals usually have high melting points and therefore boiling points, in contrast to most non-metals.
9.2.1 Uses of metals	Describe the uses of metals in terms of their physical properties, including: (a) aluminium in the manufacture of aircraft because of its low density (b) aluminium in the manufacture of overhead electrical cables because of its low density and good electrical conductivity (c) aluminium in food containers because of its resistance to	You could cover this objective as a series of questions for learners to answer. Examples: i) Why is aluminium used in the manufacture of aircraft, overhead cables and aluminium food containers? ii) For which reason(s) is copper used in electrical wiring?  <b>Extension activity: Stretch and prepare for A Level</b> Poster opportunity: learners extend their study of metals to include the first row of transition metals and their physical properties and uses.

Syllabus ref.	Learning objectives	Suggested teaching activities
	corrosion (d) copper in electrical wiring because of its good electrical conductivity and ductility	
9.3.1 Alloys and their properties  9.3.2 Alloys and their properties  9.3.5 Alloys and their properties	Describe an alloy as a mixture of a metal with other elements, including: (a) brass as a mixture of copper and zinc (b) stainless steel as a mixture of iron and other elements such as chromium, nickel and carbon  State that alloys can be harder and stronger than the pure metals and are more useful  <b>Explain in terms of structure how alloys can be harder and stronger than the pure metals because the different sized atoms in alloys mean the layers can no longer slide over each other</b>	This whole sub-unit could be completed by learners doing independent research and producing a poster and/or a presentation in any form they prefer. If this is done, prepare a marking rubric to ensure that learners comprehensively cover all key points.  Bring in a range of alloys to show learners: steel, stainless steel, brass, bronze, pewter, solder, nichrome. If possible, bring actual objects to stimulate learners' interest, not flat pieces of metal. If not available, display images of objects produced on the basis of the alloys' properties.  The first thing learners need to know is that alloys are a mixture, which consists of a main metal and other metals and/or non-metals: <a href="http://www.gcsescience.com/ex29.htm">www.gcsescience.com/ex29.htm</a> (simple diagrammatic representation) <a href="http://www.explainthatstuff.com/alloys.html">www.explainthatstuff.com/alloys.html</a> (more advanced diagrammatic representations)  The diagram in this video shows how alloys can be harder or stronger than the pure metals: <a href="http://www.youtube.com/watch?v=xqiqVDZfWAs">www.youtube.com/watch?v=xqiqVDZfWAs</a> (1:52 diagram showing how the presence of different atoms stops the layers slipping over each other as in the parent metal)  In the exam learners may need to be able to recognise alloys from diagrams of structure such as: <a href="https://igcseaid.wordpress.com/notes/coordinated-science-0654/c10-1-properties-of-metals/">https://igcseaid.wordpress.com/notes/coordinated-science-0654/c10-1-properties-of-metals/</a>  <b>Experiment: Making an alloy</b> <a href="https://edu.rsc.org/resources/making-an-alloy-solder/1742.article">https://edu.rsc.org/resources/making-an-alloy-solder/1742.article</a> (making solder from lead and tin) In this experiment lead and tin are heated together to form the alloy, solder. Then the hardness, melting point and density of the alloy are compared to that of lead.

Syllabus ref.	Learning objectives	Suggested teaching activities
9.3.3 Alloys and their properties	Describe the uses of alloys in terms of their physical properties, including stainless steel in cutlery because of its hardness and resistance to rusting	
9.3.4 Alloys and their properties	Identify representations of alloys from diagrams of structure	
9.1.2 Properties of metals	Describe the general chemical properties of metals, limited to their reactions with: (a) dilute acids (b) cold water and steam (c) oxygen	<p><b>Experiment:</b> Learners do a series of test tube reactions, adding small pieces of metal – Mg, Al, Zn, Fe, Cu – to water and observing if any reaction occurs. Next, they pour off the water and replace with dilute hydrochloric acid. Record observations. To conclude, based on the observed reactivity of the metals, they place the metals in order of reactivity.</p> <p>Use discussion, videos and learner research to find out how these metals react with steam and oxygen. Steam: magnesium reacts with steam (but not with cold water): <a href="https://mammothmemory.net/chemistry/the-metal-reactivity-series/potassium-sodium-lithium-and-calcium-reactions-with-steam/potassium-sodium-lithium-and-calcium-reactions-with-steam/magnesium-and-steam.html">https://mammothmemory.net/chemistry/the-metal-reactivity-series/potassium-sodium-lithium-and-calcium-reactions-with-steam/potassium-sodium-lithium-and-calcium-reactions-with-steam/magnesium-and-steam.html</a></p>
9.4.2 Reactivity series	Describe the reactions, if any, of: (a) potassium, sodium and calcium with cold water (b) magnesium with steam (c) magnesium, zinc, iron, copper, silver and gold with dilute hydrochloric acid and explain these reactions in terms of the position of the metals and hydrogen	<p>Oxygen: learners research the reaction (or not) of Mg, Al, Zn, Fe, Cu with oxygen and write equations. There is a difference between reacting the metal with pure oxygen or in air containing 21% oxygen but the relative reactivity should be the same.</p> <p><b>Experiment:</b> The reactions of Na, K, Ca with cold water. Learners compare these reactions using small pieces of each metal in <u>cold</u> water.</p> <p>Based on all the above reactions, learners write a reactivity series from most reactive to least reactive metal.</p> <p><u>Inclusion of carbon and hydrogen into the reactivity series</u> On the basis of metal reactions with acids, learners should be able to place hydrogen into the series. Carbon may also be placed, but depends if learners have covered the extraction of metals or not. Learners can finally compare their reactivity series with the one in their textbooks. The reactivity series including carbon and hydrogen is at: <a href="http://www.gcsescience.com/r1-reactivity-series-metals.htm">www.gcsescience.com/r1-reactivity-series-metals.htm</a></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
9.4.3 Reactivity series	in the reactivity series  Deduce an order of reactivity from a given set of experimental results	Bring learners' attention to the position of aluminium and discuss its apparent unreactivity in terms of formation of a resilient oxide layer.  This poster summarises the reactivity series, common reactions and extraction methods: <a href="https://www.compoundchem.com/2015/03/10/reactivity-series/">https://www.compoundchem.com/2015/03/10/reactivity-series/</a>
9.4.1 Reactivity series	State the order of the reactivity series as: potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, hydrogen, copper, silver, gold	
9.4.5 Reactivity series	Explain the apparent unreactivity of aluminium in terms of its oxide layer	
9.4.4 Reactivity series	Describe the relative reactivities of metals in terms of their tendency to form positive ions, by displacement reactions, if any, with the aqueous ions of magnesium, zinc, iron, copper and silver	<b>Experiment:</b> Displacement reactions of metals Learners use small quantities of chemicals on a spotting tile as described at: <a href="http://www.creative-chemistry.org.uk/documents/N-m05-03.pdf">www.creative-chemistry.org.uk/documents/N-m05-03.pdf</a> [metals used: Mg, Zn, Fe, Cu] This experiment encourages accurate observation and prediction skills. Learners write balanced equations and ionic equations for these displacement reactions. Ask learners to compare their results to the reactivity series of metals and comment on their predictions and practical outcomes.  Displacement reaction snap: a simple card game for revision: <a href="https://edu.rsc.org/download?ac=503117">https://edu.rsc.org/download?ac=503117</a> [cards are printable]  A demonstration reaction with silver nitrate and copper metal: <a href="https://edu.rsc.org/exhibition-chemistry/displacement-reaction-of-silver-nitrate-and-copper-metal/2020046.article">https://edu.rsc.org/exhibition-chemistry/displacement-reaction-of-silver-nitrate-and-copper-metal/2020046.article</a> Watch silver crystals grow.
9.5.1 Corrosion of	State the conditions required for the rusting	First, ask learners, in pairs, to discuss their ideas about the word 'corrosion' and give some examples. They will probably know iron as an example, but encourage them to search 'corrosion of .....', for a variety of metals such as copper,

Syllabus ref.	Learning objectives	Suggested teaching activities
metals	of iron and steel to form hydrated iron(III) oxide	silver and lead, to see the scope of corrosion.
9.5.3 Corrosion of metals	Describe how barrier methods prevent rusting by excluding oxygen or water	Next, learners listen to this podcast about rusting to find out why it is not just a simple oxidation reaction: <a href="http://www.chemistryworld.com/podcasts/rust/3005931.article">www.chemistryworld.com/podcasts/rust/3005931.article</a> (podcast called 'Rust') After listening to the podcast ask learners what the two ingredients of rust are. (water and oxygen) This is an opportunity to discuss many aspects of a process which occurs on an enormous scale on Earth.
9.5.2 Corrosion of metals	State some common barrier methods, including painting, greasing and coating with plastic	Next, show learners the equations for how rust is formed: <a href="http://www.thoughtco.com/how-rust-works-608461">www.thoughtco.com/how-rust-works-608461</a> (How rust and corrosion work)  <b>Experiment: Preventing rusting</b> In this experiment, learners protect iron nails using the barrier methods of painting and greasing and also sacrificial protection: <a href="https://edu.rsc.org/resources/preventing-rusting/1763.article">https://edu.rsc.org/resources/preventing-rusting/1763.article</a> (Preventing rusting experiment) Emphasise that in the experiment zinc was used as a sacrificial protector but that it could also be used to coat iron and steel as a combined barrier protector and sacrificial protector.
9.5.5 Corrosion of metals	Explain sacrificial protection in terms of the reactivity series and in terms of electron loss	Show learners a piece of corrugated galvanised sheet or a galvanised bucket either in the classroom, or show them the images on this page: <a href="http://www.wisegeek.com/what-is-galvanized-steel.htm#didyouknowout">www.wisegeek.com/what-is-galvanized-steel.htm#didyouknowout</a>
9.5.4 Corrosion of metals	Describe the use of zinc in galvanising as an example of a barrier method and sacrificial protection	<b>Extension activity: Stretch and prepare for A Level</b> Learners find out about galvanic cells to see where the term galvanising originates from. They can learn how a galvanic/voltaic cell works and the reactions which occur. They could give a short presentation to the rest of the class about this.
9.6.1 Extraction of metals	Describe the ease of obtaining metals from their ores, related to the position of the metal in the reactivity series	Start by asking learners to look up a definition of an ore (a mineral which has a metal inside it). Explain that extracting ores from rocks ranges from easy to difficult depending on the position of the metal in the reactivity series.  This poster summarises the method of extraction used to obtain common metals from their ores: <a href="http://www.compoundchem.com/2015/03/10/reactivity-series/">www.compoundchem.com/2015/03/10/reactivity-series/</a> It can be seen that metals above zinc can only be obtained by the highly energetic process, electrolysis. Iron and zinc are obtained by reduction with carbon.



Syllabus ref.	Learning objectives	Suggested teaching activities
9.6.2 Extraction of metals	<p>Describe the extraction of iron from hematite in the blast furnace, including symbol equations for each step, limited to:</p> <p>(a) the burning of carbon (coke) in air to provide heat and produce carbon dioxide</p> <p>(b) the reduction of carbon dioxide to carbon monoxide</p> <p>(c) the reduction of iron(III) oxide by carbon monoxide</p> <p>(d) the thermal decomposition of calcium carbonate / limestone to produce calcium oxide</p> <p>(e) the formation of slag</p> <p>Symbol equations are <b>not</b> required</p>	<p>Show learners a piece of hematite if you have it or display this image:  <a href="https://geology.com/minerals/hematite.shtml">https://geology.com/minerals/hematite.shtml</a></p> <p>This is the step-wise process:  <a href="https://secondaryscience4all.wordpress.com/2014/07/21/iron-extraction-blast-furnace/">https://secondaryscience4all.wordpress.com/2014/07/21/iron-extraction-blast-furnace/</a> Click on the image for a full-screen image</p> <p>Encourage learners to focus on the reduction of hematite with carbon monoxide ensuring that they notice that the reducing agent is carbon monoxide not carbon.</p> <p>For all the chemical reactions occurring give learners word equations from which they try to write balanced symbol equations. You will need to provide them with the formula for calcium silicate.</p> <p>This video shows an animation of the process:  <a href="http://www.youtube.com/watch?v=8sPYECIAb80">www.youtube.com/watch?v=8sPYECIAb80</a></p> <p>Pure iron is not a useful metal because it is too soft but learners could find out what the composition, properties and uses of cast iron, carbon steel and stainless steel are.            Connect this topic with alloys (9.3)</p> <div style="border: 1px solid black; padding: 5px;"> <p><b>Resource Plus</b></p> <p>Carry out <i>The extraction of iron on a match head</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> </div>
9.6.4 Extraction of metals	<p>State the symbol equations for the extraction of iron from hematite</p> <p>(a) <math>C + O_2 \rightarrow CO_2</math></p> <p>(b) <math>C + CO_2 \rightarrow 2CO</math></p> <p>(c) <math>Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2</math></p> <p>(d) <math>CaCO_3 \rightarrow CaO + CO_2</math></p> <p>(e) <math>CaO + SiO_2 \rightarrow</math></p>	

Syllabus ref.	Learning objectives	Suggested teaching activities
	CaSiO <sub>3</sub>	
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		

## 6 Chemical energetics

Syllabus ref.	Learning objectives	Suggested teaching activities
5.1.1 Exothermic and endothermic reactions	State that an exothermic reaction transfers thermal energy to the surroundings leading to an increase in the temperature of the surroundings	<p>Ask learners to think of any chemical reactions where heat is given out. Write some examples down. Collectively they may come up with reactions such as the following. If not you can write them down as examples:</p> <ol style="list-style-type: none"> <li><math>\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}</math></li> <li><math>\text{Zn} + \text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2</math></li> <li><math>\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}</math></li> </ol> <p>Discuss with learners how they observe that heat is given out in the above cases: 1. produces a hot white flame, 2. the test tube gets warm and 3. a hot blue flame is produced. The common thing is that heat is given out. Explain to learners that this is called exothermic and that if for example a thermometer were put into reaction 2. it would show a temperature increase.</p>
5.1.2 Exothermic and endothermic reactions	State that an endothermic reaction transfers thermal energy from the surroundings leading to a decrease in the temperature of the surroundings	<p>Ask them to do the same for chemical reactions where heat energy is taken in. Learners may not be able to think of any examples. You could give this as a research task, or give examples:</p> <ol style="list-style-type: none"> <li><math>6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2</math></li> <li><math>\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{CuSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l})</math></li> </ol> <p>Both these reactions require energy for them to occur. Mention to learners that endothermic reactions such as these are much less common than exothermic reactions.</p>
5.1.4 Exothermic and endothermic reactions	State that the transfer of thermal energy during a reaction is called the enthalpy change, $\Delta H$ , of the reaction. $\Delta H$ is negative for exothermic reactions and positive for endothermic reactions	<p>Define the term 'enthalpy change' as <math>\Delta H</math> and explain that it is negative for exothermic reactions and positive for endothermic reactions.</p> <p>Learners create a poster comparing several examples of endothermic and exothermic reactions.</p> <p>You could demonstrate some highly exothermic and endothermic reactions to learners. An example of a highly endothermic reaction is barium hydroxide + ammonium chloride:  <a href="https://chemistry.ucsd.edu/undergraduate/teaching-labs/demos/demo45.html">https://chemistry.ucsd.edu/undergraduate/teaching-labs/demos/demo45.html</a> (quantities and prep details)            If you cannot do the reaction, here is a video of it being performed:  <a href="http://www.youtube.com/watch?v=IZaGmUGBdC0">www.youtube.com/watch?v=IZaGmUGBdC0</a></p> <p>An example of a highly exothermic reaction is the thermite reaction. Note: It should only be performed outside and very carefully as if these precautions are not taken, it is dangerous.  <a href="https://edu.rsc.org/resources/the-thermite-reaction/724.article">https://edu.rsc.org/resources/the-thermite-reaction/724.article</a>            Video:</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p><a href="http://www.youtube.com/watch?v=EDUwc953GOA">www.youtube.com/watch?v=EDUwc953GOA</a> Learners might enjoy watching the thermite reaction put to good use: <a href="http://www.youtube.com/watch?v=5uxsFglz2ig">www.youtube.com/watch?v=5uxsFglz2ig</a> (used to weld railway tracks)</p> <p><b>Experiment:</b> Learners can safely carry out a series of test tube reactions to find out if they are endothermic or exothermic: <a href="https://edu.rsc.org/resources/exothermic-or-endothermic/406.article">https://edu.rsc.org/resources/exothermic-or-endothermic/406.article</a></p> <p><b>Experiment:</b> Hot packs and cold packs Give learners several safe substances; some cause endothermic reactions and some exothermic reactions. Learners perform reactions on these substances and decide if they would make good hot packs or cold packs. Discuss with learners when each are needed in everyday life. <a href="http://nobel.scas.bcit.ca/debeck_pt/science/hotColdPack/pack_p1.htm">http://nobel.scas.bcit.ca/debeck_pt/science/hotColdPack/pack_p1.htm</a></p>
<p>5.1.5 Exothermic and endothermic reactions</p> <p>5.1.3 Exothermic and endothermic reactions</p> <p>5.1.6 Exothermic and endothermic reactions</p>	<p>Define activation energy, <math>E_a</math>, as the minimum energy that colliding particles must have in order to react</p> <p>Interpret reaction pathway diagrams showing exothermic and endothermic reactions</p> <p>Draw, label and interpret reaction pathway diagrams for exothermic and endothermic reactions using information provided, to include: (a) reactants (b) products (c) enthalpy change of reaction, <math>\Delta H</math></p>	<p>Discuss that activation energy can be thought of as the energy needed to initiate a chemical reaction and once started the reaction continues.</p> <p>Ask learners if they can think of any reactions that need initiating. Hopefully they will think of the thermite reaction above. Also ask them how it was started. You could mix a small quantity of thermite mixture (iron oxide and aluminium powder). It is perfectly safe to carry around mixed together. It requires not just a little heat, but the intense heat provided by a wick of magnesium burning to initiate the reaction. Other examples of high activation energy in reactions is combustion.</p> <p>Ask learners for reactions where the activation energy is low, that is, the reaction occurs without needing to encourage it. (e.g. magnesium + hydrochloric acid) Demonstrate this.</p> <p>Show and explain pathway diagrams for exothermic and endothermic reactions: <a href="http://www.bbc.co.uk/bitesize/guides/z2gccdm/revision/6">www.bbc.co.uk/bitesize/guides/z2gccdm/revision/6</a> Then, provide learners with blank axes and a keyword bank, and ask them to fully label their pathway diagrams. Extend this to requiring them to draw diagrams with high and low <math>E_a</math>.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
	(d) activation energy, $E_a$	
5.1.7 Exothermic and endothermic reactions	State that bond breaking is an endothermic process and bond making is an exothermic process and explain the enthalpy change of a reaction in terms of bond breaking and bond making	<p>Learners frequently get confused as to whether bond making or bond breaking requires an input of energy. To illustrate this, take an old pencil and pretend it is a bond between two atoms. Break the pencil and ask if bond breaking requires energy or produces energy. It is endothermic because it needs energy.</p> <p>Show learners a list of common bond energies:  <a href="http://www.wiredchemist.com/chemistry/data/bond_energies_lengths.html">www.wiredchemist.com/chemistry/data/bond_energies_lengths.html</a></p> <p>Show learners the equation:            Enthalpy change = Energy taken in – energy given out            (be aware that there are several different versions meaning the same thing)</p>
5.1.8 Exothermic and endothermic reactions	Calculate the enthalpy change of a reaction using bond energies	<p>This may also be expressed:            Enthalpy change = <math>\sum(\text{bonds broken}) - \sum(\text{bonds formed})</math></p> <p>Give learners a simple sample calculation to perform such as <math>\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}</math>            Make sure learners get used to drawing the structures of each molecule so that all the bonds can be seen.            This example is detailed below:  <a href="http://www.gcsescience.com/rc23-bond-energy-calculation.htm">www.gcsescience.com/rc23-bond-energy-calculation.htm</a></p> <p>Here is a quiz providing further examples for learners to try:  <a href="http://www.educationquizzes.com/gcse/chemistry/energy-from-reactions/">www.educationquizzes.com/gcse/chemistry/energy-from-reactions/</a></p> <p>Further worked examples:  <a href="http://www.docbrown.info/page03/3_51energyC.htm">www.docbrown.info/page03/3_51energyC.htm</a></p> <p>Note that in these examples, only bonds which are broken and formed in the reactions are considered. You could, if you wish, break all the bonds in the reactants and form all the bonds in the products and get the same answers.</p> <p>Common misconceptions:</p> <ul style="list-style-type: none"> <li>• Forgetting to include the sign at the end of the calculation. Remember the sign shows whether the answer is exothermic or endothermic</li> <li>• Not drawing the full structures of the reactants and products</li> <li>• Remembering the equation the wrong way round</li> </ul>

**Past and specimen papers**

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## 7 Acids, bases and salts

Syllabus ref.	Learning objectives	Suggested teaching activities
7.1.1 The characteristic properties of acids and bases	Describe the characteristic properties of acids in terms of their reactions with: (a) metals (b) bases (c) carbonates	<b>Experiment:</b> explore as a series of test-tube reactions. Learners at this stage should have met some or all of the reactions. This practical is a good opportunity for them to practise observation skills, testing gases and equation writing.  These pages summarise the reactions: <a href="http://www.docbrown.info/page03/AcidsBasesSalts05.htm">www.docbrown.info/page03/AcidsBasesSalts05.htm</a>
7.1.4 The characteristic properties of acids and bases	Describe the characteristic properties of bases in terms of their reactions with: (a) acids (b) ammonium salts	
7.1.11 The characteristic properties of acids and bases	<b>State that hydrochloric acid is a strong acid, as shown by the symbol equation,</b> $\text{HCl(aq)} \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$	Ask learners to recall and list the common acids they have used or come across in previous courses. Then ask them to research and find out their formulae: $\text{HCl}$ , $\text{H}_2\text{SO}_4$ , $\text{HNO}_3$ , $\text{CH}_3\text{COOH}$ Next ask learners which element they all have in common. (hydrogen) Explain that when acids dissociate in water they produce $\text{H}^+$ ions in solution. Give examples of this and ask learners to write equations showing this also. Illustrate by using examples of both strong acids (complete dissociation) and weak acids (partial dissociation).
7.1.6 The characteristic properties of acids and bases	State that aqueous solutions of acids contain $\text{H}^+$ ions and aqueous solutions of alkalis contain $\text{OH}^-$ ions	Explain that there are several ways of showing this dissociation: For strong acids: 1. $\text{HCl(aq)} \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ 2. $\text{HCl(g)} + \text{aq} \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ 3. $\text{HCl(g)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ (This version is the most accurate and you may use it depending on your learners)  Point out to learners that acids are proton donors (and consequently bases are proton acceptors).
7.1.10	<b>Define a strong acid as</b>	For weak acids, it is important to show that the dissociation of the acid molecules is only fractional. This is done by using

Syllabus ref.	Learning objectives	Suggested teaching activities
The characteristic properties of acids and bases	an acid that is completely dissociated in aqueous solution and a weak acid as an acid that is partially dissociated in aqueous solution	a reversible sign: $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$ Explain that the equilibrium lies far to the left and that only very few ethanoic acid molecules are dissociated.  Use the following simulation to help learners understand the difference between complete and partial dissociation: <a href="https://phet.colorado.edu/sims/html/acid-base-solutions/latest/acid-base-solutions_en.html">https://phet.colorado.edu/sims/html/acid-base-solutions/latest/acid-base-solutions_en.html</a> Guidance will be required since some aspects of this simulation are aimed at A Level.
7.1.12 The characteristic properties of acids and bases	State that ethanoic acid is a weak acid, as shown by the symbol equation, $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$	
7.1.9 The characteristic properties of acids and bases	Define acids as proton donors and bases as proton acceptors	
7.1.3 The characteristic properties of acids and bases	State that bases are oxides or hydroxides of metals and that alkalis are soluble bases	It is important that learners can distinguish between the meanings of these two terms. As a visual way of doing this, encourage learners to draw a Venn diagram similar to this: <a href="https://intellectwrite.com/2018/12/22/difference-between-alkali-and-base/">https://intellectwrite.com/2018/12/22/difference-between-alkali-and-base/</a>  Take two test tubes, one containing solid CuO and the other solid NaOH. Add water to each and shake. The base copper (II) oxide does not dissolve but the alkali sodium hydroxide does. Emphasise that in fact both substances are bases and that later their reactions will be explored.



Syllabus ref.	Learning objectives	Suggested teaching activities
7.1.7 The characteristic properties of acids and bases	Describe how to compare hydrogen ion concentration, neutrality, relative acidity and relative alkalinity in terms of colour and pH using universal indicator paper	<p>Ask learners for ideas on how acids, alkalis and neutral solutions can be compared using various indicators. Ask learners to draw a vertical pH scale and label the names of a weak and a strong acid and a weak and a strong alkali indicating approximately what they think their pH values are.</p> <p>Learners research the names of common substances and their pH value and produce an infographic for display similar this: <a href="http://www.onlinemathlearning.com/acids-alkalis.html">www.onlinemathlearning.com/acids-alkalis.html</a> Alternatively, give them the names of various substances to research and learners find out the pH values.</p> <p><b>Experiment:</b> Set out around the lab various laboratory chemicals. Learners test the pH of each using universal indicator solution and complete a table. Then they have to decide whether the substances are weak/strong acids or alkalis or neutral substances. Learners should also test the solutions with red and blue litmus paper and include a column for this in their tables. In the conclusion to their experiment ask learners to compare the effectiveness of litmus to universal indicator.</p> <p>If learners have not made the red cabbage indicator before, they could do this as part of the experiment and compare the effectiveness of the red cabbage indicator to the universal indicator.</p>
7.1.8 The characteristic properties of acids and bases	Describe the neutralisation reaction between an acid and an alkali to produce water, $H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$	<p>Give learners a series of reactions of acids + alkalis and acids + bases. Ask them to write balanced equations. Some example reactions: <a href="http://www.bbc.co.uk/bitesize/guides/zgpc3k7/revision/3">www.bbc.co.uk/bitesize/guides/zgpc3k7/revision/3</a> Learners then try to identify what the reactions have in common with each other.</p> <p>State/restate the general equation: acid + base <math>\rightarrow</math> salt + water Link this exercise to Stoichiometry: ionic equations 3.1.6 and the Preparation of salts: 7.3.1</p>
7.1.2 The characteristic properties of acids and bases	Describe acids in terms of their effects on: (a) litmus (b) thymolphthalein (c) methyl orange	<p>Learners should then formally define neutralisation.</p> <p><u>Other indicators</u> Mention that there are many types of indicators used in titration experiments depending on the strength of the acid or alkali used. Explain the colour changes for thymolphthalein and methyl orange indicator. Then reference learners to the simple acid-base titration in Stoichiometry 3.3.6 and that one method of making salts is by titration (7.3.1)</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
7.1.5 The characteristic properties of acids and bases	Describe alkalis in terms of their effect on: (a) litmus (b) thymolphthalein (c) methyl orange	<b>Extension activity: Stretch and prepare for A Level</b> Learners research the typical shape of a pH curve during titration. They could find out about the typical pH range in which the indicators in 7.1.8 work, and decide the best combination of strong/weak acid   strong/weak alkali the indicators would be most useful for. The ranges of typical indicators are listed here: <a href="http://www.uq.edu.au/School_Science_Lessons/Acid-base.html">www.uq.edu.au/School_Science_Lessons/Acid-base.html</a>
7.2.1 Oxides	Classify oxides as acidic, including SO <sub>2</sub> and CO <sub>2</sub> , or basic, including CuO and CaO, related to metallic and non-metallic character	<b>Experiment:</b> Testing the pH of oxides <a href="https://edu.rsc.org/resources/testing-the-ph-of-oxides/405.article">https://edu.rsc.org/resources/testing-the-ph-of-oxides/405.article</a> Learners test the pH of the oxides of nitrogen, phosphorus, sulfur, potassium, sodium and calcium using universal indicator solution. They look for patterns in the colour of the solutions produced. Carbon dioxide can also be tested by bubbling carbon dioxide with a straw into limewater.
7.2.2 Oxides	Describe amphoteric oxides as oxides that react with acids and with bases to produce a salt and water	<b>Resource Plus</b> Carry out the <i>Types of oxide: reactions with acids and bases</i> experiment referring to the Teaching Pack for lesson plans and resources.
7.2.3 Oxides	Classify Al <sub>2</sub> O <sub>3</sub> and ZnO as amphoteric oxides	Amphoteric oxides: Define the term amphoteric as in 7.2.2  Zinc and aluminium, being metals, react with acids in the usual manner to produce a salt and water. However, they also react with bases. Give learners the word equations. The important point to note is that a salt + water is produced, as with acids:  zinc oxide + sodium hydroxide → sodium zincate + water [a salt]  aluminium oxide + sodium hydroxide → sodium aluminate + water [a salt]
7.3.3 Preparation of salts	Define a hydrated substance as a substance that is chemically combined with water and an	Start by looking at the definitions of a salt: <ul style="list-style-type: none"> <li>an ionic compound that can be formed by replacing one or more of the hydrogen ions of an acid with another positive ion</li> <li>an ionic compound which is made up of two groups of oppositely charged ions.</li> </ul>

Syllabus ref.	Learning objectives	Suggested teaching activities
7.3.5 Preparation of salts	<p>anhydrous substance as a substance containing no water</p> <p>Define the term water of crystallisation as the water molecules present in crystals, e.g. <math>\text{CuSO}_4 \cdot 5\text{H}_2\text{O}</math> and <math>\text{CoCl}_2 \cdot 6\text{H}_2\text{O}</math></p>	<p>Discuss both versions of the definition with learners to show that they are both correct.</p> <p>If learners have not come across these hydrated salts during the topic of equilibrium explain the significance of the 'dot' signifying that water molecules are present in the crystals but can be removed by gentle heating and replaced again by adding water. Explain the terms hydrated and anhydrous.</p> <p>Refer learners to 6.3.2 in Reversible reactions and equilibrium.</p>
7.3.1 Preparation of salts	<p>Describe the preparation, separation and purification of soluble salts by reaction of an acid with:</p> <p>(a) an alkali by titration (b) excess metal (c) excess insoluble base (d) excess insoluble carbonate</p>	<p><b>Experiment:</b> Preparation of soluble salts</p> <p>(a) Acid + alkali by titration: Link to discussion of titration in neutralisation reactions (7.1.6) and to practical work using titration (3.3.6 concentration of solutions).</p> <p>(b) Acid + excess metal: <a href="https://edu.rsc.org/resources/metals-and-acids-experiment/446.article">https://edu.rsc.org/resources/metals-and-acids-experiment/446.article</a> (see Lesson 2 for preparation of zinc sulfate from zinc and sulfuric acid)</p> <p>(c) Acid + excess insoluble base: <a href="https://edu.rsc.org/resources/preparing-salts-by-neutralisation-of-oxides-and-carbonates/1762.article">https://edu.rsc.org/resources/preparing-salts-by-neutralisation-of-oxides-and-carbonates/1762.article</a> (see preparation 1: preparation of copper (II) sulfate from copper oxide and sulfuric acid)</p> <p>(d) Acid + excess insoluble carbonate <a href="https://edu.rsc.org/resources/preparing-salts-by-neutralisation-of-oxides-and-carbonates/1762.article">https://edu.rsc.org/resources/preparing-salts-by-neutralisation-of-oxides-and-carbonates/1762.article</a> (see preparation 2: preparation of magnesium sulfate from magnesium carbonate and sulfuric acid)</p> <p>It is important that learners can do the following related to the above practical work:</p> <ul style="list-style-type: none"> <li>• make and accurately describe observations during the experiments</li> <li>• name each process used (filtration, evaporation, crystallisation)</li> <li>• name the equipment used</li> <li>• be able to draw labelled diagrams</li> <li>• write word and balanced symbol equations for the reactions</li> <li>• be able to explain hazards and safety issues in the experiment.</li> </ul> <p><b>Extension activity: Stretch and prepare for A Level</b></p> <p>Link practical work above to stoichiometry. The instructions give quantities of reagents for the preparations. In each case one reagent is in excess and the other is the limiting reagent. Learners could verify that the quantities given correspond</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>to excess reagent and limiting reagent. As a further step in the practical work, learners could isolate and dry the products and calculate a percentage yield.</p>
7.3.4 Preparation of salts	Describe the preparation of insoluble salts by precipitation	<p><b>Experiment:</b> Preparation of insoluble salts by precipitation  <a href="https://edu.rsc.org/resources/preparing-an-insoluble-salt/1761.article">https://edu.rsc.org/resources/preparing-an-insoluble-salt/1761.article</a> (the preparation of lead chloride from lead nitrate and sodium chloride)            Make sure that learners know the meaning of the word precipitation in the chemistry sense.</p> <p>All of the comments for the preparation of soluble salts in the above activity apply to this learning objective.</p>
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		

## 8 The Periodic Table

Syllabus ref.	Learning objectives	Suggested teaching activities
8.1.1 Arrangement of elements	Describe the Periodic Table as an arrangement of elements in periods and groups and in order of increasing proton / atomic number	Print off and give learners a copy of the Periodic Table from the 5070 syllabus. Learners stick it in the middle of an A3 sheet of paper or double page of a notebook so that there is plenty of room to annotate around the outside.
8.1.2 Arrangement of elements	Describe the change from metallic to non-metallic character across a period	Learners: <ul style="list-style-type: none"> <li>Highlight the word 'group' and indicate where periods 1, 2, 3 and 4 are.</li> <li>Colour the metallic elements, non-metallic and metalloids different colours lightly in coloured pencils.</li> <li>For groups I, II, III, VI and VII indicate using a label example charges on the ions. Learners could include atom diagrams and electron configurations to help them.</li> </ul>
8.1.3 Arrangement of elements	Describe the relationship between group number and the charge on ions formed from elements in that group	Using their annotated Periodic Table, learners answer the following questions (based on the first 20 elements only): <ol style="list-style-type: none"> <li>How is electron configuration related to the position of an element in the Periodic Table?</li> <li>What is the relationship between atomic number and the position of an element?</li> <li>What is the relationship between group number and the charge on the ions formed from elements in that group?</li> <li>What are the similarities in the chemical properties of the elements in the same group in terms of electron configuration?</li> <li>How can the position of an element be used to predict its properties?</li> </ol>
8.1.4 Arrangement of elements	Explain similarities in the chemical properties of elements in the same group of the Periodic Table in terms of their electronic configuration	Interactive Periodic Tables: <a href="http://www.webelements.com/">www.webelements.com/</a> <a href="http://www.rsc.org/periodic-table">www.rsc.org/periodic-table</a>
8.1.5 Arrangement of elements	Explain how the position of an element in the Periodic Table can be used to predict its properties	

Syllabus ref.	Learning objectives	Suggested teaching activities
8.1.6 Arrangement of elements	Identify trends in groups, given information about the elements	
8.2.1 Group I properties	Describe the Group I alkali metals, lithium, sodium and potassium, as relatively soft metals with general trends down the group, limited to: (a) decreasing melting point (b) increasing density (c) increasing reactivity	Demonstration: Reaction of the alkali metals with water Explain that learners will look at the physical and chemical properties of the alkali metals in detail. Ask learners which of melting point, density and reactivity are physical properties and which are chemical properties. Revise what the difference is between these two terms. Next demonstrate the reactions of each metal with water making sure to highlight the necessary trends to learners: <a href="https://edu.rsc.org/resources/reactivity-trends-of-the-alkali-metals/731.article">https://edu.rsc.org/resources/reactivity-trends-of-the-alkali-metals/731.article</a>  Additional things to do: <ul style="list-style-type: none"> <li>• mention the trend in hardness</li> <li>• show learners that the alkali metals are typical metals in some respects: they conduct electricity (you can test with a simple one-bulb circuit) and they are shiny when freshly cut</li> <li>• add some universal indicator to the water the metals react with and elicit from learners why they are named 'alkali metals'.</li> </ul>
8.2.2 Group I properties	Predict the properties of other elements in Group I, given information about the elements	If you do not have access to the metals, this video shows the reactions with water: <a href="https://www.youtube.com/watch?v=y0hrqLTubDM">https://www.youtube.com/watch?v=y0hrqLTubDM</a>  To show learners more about the chemical reactivity of these elements, this video shows the increasing reactivity of the metals, i) heating in oxygen, ii) reacting with chlorine: <a href="http://www.youtube.com/watch?v=0KonBvfnzdo">www.youtube.com/watch?v=0KonBvfnzdo</a> Both these reactions provide evidence that the reactivity of the elements increases going down the group.  Ask learners to make predictions about the physical and chemical properties of the other Group I elements. There are plenty of videos available showing the reactions of the lower members of the group.  <b>Extension activity: Stretch and prepare for A Level</b> Learners try to explain why the lower members of the group are more reactive. They write balanced equations for the reactions with water, oxygen and chlorine.
8.3.1 Group VII properties	Describe the Group VII halogens, chlorine, bromine and iodine, as	If you do not have access to samples of each of the three halogens to show learners, show the following video comparing their properties: <a href="http://www.youtube.com/watch?v=u2ogMUDBaf4&amp;t=102s">www.youtube.com/watch?v=u2ogMUDBaf4&amp;t=102s</a>

Syllabus ref.	Learning objectives	Suggested teaching activities
8.3.2 Group VII properties	<p>diatomic non-metals with general trends down the group, limited to: (a) increasing density (b) decreasing reactivity</p> <p>State the appearance of the halogens at r.t.p. as: (a) chlorine, a pale yellow-green gas (b) bromine, a red-brown liquid (c) iodine, a grey-black solid</p>	<p>The video shows: i) their trend in colour and their physical state at room temperature (ask learners what the trend in their densities must be) ii) reaction with hydrogen iii) reaction with aluminium</p> <p>This video shows the halogens' reactions with sodium: <a href="http://www.youtube.com/watch?v=saLvwX3_p1s">www.youtube.com/watch?v=saLvwX3_p1s</a></p> <p>The properties and reactions of the Group VII elements: <a href="http://www.bbc.co.uk/bitesize/guides/ztjy6yc/revision/2">www.bbc.co.uk/bitesize/guides/ztjy6yc/revision/2</a> [discusses the reactions with sodium and hydrogen]</p> <p>Note: make sure that learners are not confused that the halogens get less reactive going down the group (whereas Group I elements get more reactive going down the group).</p> <p><b>Extension activity: Stretch and prepare for A Level</b> Learners can find out, in terms of their electronic structures, why the halogens get less reactive going down the group. They could use this page to help their understanding: <a href="http://www.docbrown.info/page03/The_Halogens.htm">www.docbrown.info/page03/The_Halogens.htm</a></p>
8.3.3 Group VII properties	Describe and explain the displacement reactions of halogens with other halide ions	<p><b>Experiment:</b> Reactions of halogens as aqueous solutions <a href="https://edu.rsc.org/resources/reactions-of-halogens-as-aqueous-solutions/733.article">https://edu.rsc.org/resources/reactions-of-halogens-as-aqueous-solutions/733.article</a> This experiment can be done with very small quantities of materials on a spotting tile.</p> <p>Learners write balanced chemical equations and ionic equations for the changes that occur.</p> <p>Afterwards they try to identify whether the halogen is an oxidising agent or reducing agent and justify this by looking at the changes in oxidation state (number). Halogens are oxidising agents which become reduced, and the halide ion is a reducing agent, which becomes oxidised. Link to the 'elephants' toothpaste' demonstration in 6.4.6 Redox in which iodide ions act as a reducing agent. The reactions are detailed in this page: <a href="http://www.docbrown.info/page07/ASA2group7a.htm">www.docbrown.info/page07/ASA2group7a.htm</a></p> <p>Common misconception:</p> <ul style="list-style-type: none"> <li>• Potassium grabs the chlorine because it is very reactive.</li> </ul>

Syllabus ref.	Learning objectives	Suggested teaching activities
8.3.4 Group VII properties	Predict the properties of other elements in Group VII, given information about the elements	Based on the above pattern, that the reactivity of the halogens decreases going down the group, ask learners to predict: <ul style="list-style-type: none"> <li>the most reactive element (fluorine)</li> <li>the reactivity of elements below iodine (less reactive)</li> </ul>
8.4.1 Transition elements	Describe the transition elements as metals that: <p>(a) have high densities</p> <p>(b) have high melting points</p> <p>(c) form coloured compounds</p> <p>(d) often act as catalysts as elements and in compounds</p>	Ask learners to search for images of the first row of transition elements, Ti, V, Cr, Mn, Fe, Co, Ni and Cu, noting that they are in an area of the Periodic Table called the 'd-block'. Ask them to stick the images (or paste if doing on the computer) in atomic number order, as in the Periodic Table. They research and find the following information: <ul style="list-style-type: none"> <li>densities</li> <li>melting points</li> <li>number of oxidation numbers displayed in their compounds and most common oxidation number displayed</li> <li>the range of colours displayed in their compounds</li> <li>if the metal itself, or compounds of it, have catalytic activity.</li> </ul> <p>From this collected information, elicit from learners the properties of transition elements in the learning objective.</p> <p>Common misconception:</p> <ul style="list-style-type: none"> <li>Learners often believe that transition metals are coloured rather than their compounds. Looking at the pictures of the metals, they will see that most of them are silvery, typical metallic-looking substances. However, in contrast, their compounds are often brightly coloured.</li> </ul> <p>Another thing to highlight is that iron is used as a catalyst in the Haber process, and vanadium as a catalyst in the Contact process (6.3 Reversible reactions and equilibrium).</p> <p><b>Experiment:</b> Properties of the transition metals and their compounds Learners test metal samples for: hardness; ability to bend without breaking; if they are magnetic; if they react with water; and observe coloured compounds. <a href="https://edu.rsc.org/resources/properties-of-the-transition-metals-and-their-compounds/472.article">https://edu.rsc.org/resources/properties-of-the-transition-metals-and-their-compounds/472.article</a> (Classic chemistry experiments: properties of the transition metals and their compounds)</p> <p><b>Extension activity: Stretch and prepare for A Level</b> Learners could find out:</p> <ul style="list-style-type: none"> <li>Why transition elements often act as catalysts</li> <li>The reason why transition metal compounds are often coloured</li> </ul>
8.4.2 Transition elements	Describe transition elements as having ions with variable oxidation numbers, including iron(II) and iron(III)	



Syllabus ref.	Learning objectives	Suggested teaching activities
		<ul style="list-style-type: none"> <li>Why they have variable oxidation states</li> </ul> <p>Quizzes:  <a href="http://www.educationquizzes.com/gcse/chemistry/periodic-table-transition-elements/">www.educationquizzes.com/gcse/chemistry/periodic-table-transition-elements/</a>  <a href="https://quizlet.com/">https://quizlet.com/</a> [create your own quiz]</p>
8.5.1 Noble gases	Describe the Group VIII noble gases as unreactive, monatomic gases and explain this in terms of electronic configuration	<p>Ask learners to write down the electronic configurations of He, Ne, Ar and comment on them. They should then be able to explain why they are monoatomic gases.</p> <p>Learners predict the trend in densities of the gases descending Group VIII:  <a href="http://www.youtube.com/watch?v=QLrofyj6a2s">www.youtube.com/watch?v=QLrofyj6a2s</a></p> <p>Learners could find about some of the uses of the noble gases:  <a href="http://www.youtube.com/watch?v=Lid8BsbqTDQ">www.youtube.com/watch?v=Lid8BsbqTDQ</a></p>
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		

## 9 Stoichiometry

Syllabus ref.	Learning objectives	Suggested teaching activities
3.1.1 Formulae	State the formulae of the elements and compounds named in the subject content	Using the air as the basis for discussion, ask learners to note down the components in air from previous learning/ general knowledge. They should write the names as well as their formulae. Learners should write $N_2$ and $O_2$ for the elements if they exist as diatomic molecules, not 'N' and 'O'.
3.1.2 Formulae	Define the molecular formula of a compound as the number and type of different atoms in one molecule	Between them, learners should come up with: $N_2$ , $O_2$ , $CO_2$ , $H_2O$ and you may need to remind them that about 1% of the air is Ar.  Elicit from learners that $N_2$ and $O_2$ are element molecules and $CO_2$ and $H_2O$ are molecules but also compounds because they consist of more than one element bonded together. Also elicit from learners that the bonding is simple covalent. Finally, highlight Argon as 'the odd one out' and ask why it is monoatomic.
3.1.3 Formulae	Deduce the formula of a simple compound from the relative numbers of atoms present in a model or a diagrammatic representation	Working in pairs, learners use their textbooks and/or internet to research the names and formulae of five covalently bonded substances and five ionically bonded substances. Alternatively, display a range of ionic and covalent substances.  Compare and share learners' findings, noting that many of the covalently bonded substances are organic and that organic chemistry is a significant topic in Cambridge IGCSE Chemistry.  Next formally define 'molecular formula' and explain that this term should strictly not be used for ionic compounds. Explain this by quoting examples.
3.1.5 Formulae	Define the empirical formula of a compound as the simplest whole number ratio of the different atoms or ions in a compound	Work through the process for deducing the formula from a diagram: <ul style="list-style-type: none"> <li>• decide if the bonding in the substance is ionic or covalent</li> <li>• if it is covalent, then all that needs to be done is to count the numbers of atoms and write them down (in the right order)</li> <li>• if it is ionic, look for the simplest ratio of ions present, as explained here: <a href="http://www.youtube.com/watch?v=o7KGUUlycP0">www.youtube.com/watch?v=o7KGUUlycP0</a></li> </ul>
3.1.6 Formulae	Deduce the formula of an ionic compound from the relative numbers of the ions present in a model or a diagrammatic representation or from the charges on the ions	Learners practise making the formulae of ionic compounds using these games and quizzes: <a href="https://archive.learner.org/interactives/periodic/bonding/">https://archive.learner.org/interactives/periodic/bonding/</a> <a href="http://www.acs.org/dam/acsorg/education/outreach/kidschemistry">www.acs.org &gt; dam &gt; acsorg &gt; education &gt; outreach &gt; kidschemistry</a> <a href="http://www.rsc.org/learn-chemistry/resources/gridlocks/puzzles/level-1/NamingCompounds.html">www.rsc.org/learn-chemistry/resources/gridlocks/puzzles/level-1/NamingCompounds.html</a> <a href="http://www.bbc.co.uk/bitesize/guides/z8d2bk7/test">www.bbc.co.uk/bitesize/guides/z8d2bk7/test</a>

Syllabus ref.	Learning objectives	Suggested teaching activities
3.1.4 Formulae	Construct word equations and symbol equations to show how reactants form products, including state symbols	<p><u>Word equations</u></p> <p>To remind learners about word equations, ask them to work in pairs for 5 minutes and write down any chemical reactions they can think of as word equations.</p> <p>Some example reactions that learners have probably come across before:</p> <p>carbon + oxygen → carbon dioxide</p> <p>sulfur + iron → iron sulfide</p> <p>hydrochloric acid + sodium hydroxide → sodium chloride + water</p>
3.1.8 Formulae	Deduce the symbol equation with state symbols for a chemical reaction, given relevant information	<p>Notes:</p> <ul style="list-style-type: none"> <li>Use the terms 'reactants' and 'products' when discussing each side of the equations.</li> <li>Encourage learners to read the reaction from left to right for example 'Sulfur reacts with iron to produce iron sulfide'. Ask learners to avoid saying 'equals' and not to use an '=' sign instead of an arrow.</li> </ul>
3.1.7 Formulae	Construct symbol equations with state symbols, including ionic equations	<p>Ask learners why word equations, although sometimes very useful, are not enough to fully describe chemical processes.</p> <p>Explain that sometimes word equations are the best option for describing complex chemical reactions so are definitely useful.</p> <p>Practice sheets:  <a href="https://www.rsc.org/education/teachers/resources/aflchem/resources/46/index.htm">https://www.rsc.org/education/teachers/resources/aflchem/resources/46/index.htm</a>  This page contains several worksheets with answers. There are extensive examples and ideas for lessons on this topic.</p> <p><u>Symbol equations</u></p> <p>Introduce this topic, assuming no prior knowledge (although most learners will have probably written or at least seen simple symbol equations before). Start by discussing a simple, familiar chemical reaction:</p> <p>carbon + oxygen → carbon dioxide</p> <p>Ask learners to replace the words with symbols. Allow them access to a Periodic Table.</p> <p>Some learners will write the correct answer:</p> $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ <p>Others may write: <math>\text{C} + \text{O} \rightarrow \text{CO}_2</math> (It is important at this early stage to point out that the chemical symbol for oxygen is 'O' in the Periodic Table, but it exists as a diatomic molecule 'O<sub>2</sub>')</p> <p>Introduce state symbols (s), (l), (g) and (aq) and explain what each of them mean. Ask learners which ones to add to the equation, giving:</p> $\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$ <p>Although not specifically mentioned in the syllabus, mention the law of conservation of mass as in this page:</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p><a href="http://www.my-gcse-science.com/balancing-chemical-equations/">www.my-gcse-science.com/balancing-chemical-equations/</a>            After displaying the first part of this page, emphasise that the number of atoms on the left-hand side must equal the number of atoms on the right-hand side of any chemical equation (otherwise, mass is not conserved).            Lead learners through an atom count for the above equation explaining that in this case it is balanced and complete.</p> <p>Next display this PhET simulation, starting with the introduction tab:  <a href="https://phet.colorado.edu/sims/html/balancing-chemical-equations/latest/balancing-chemical-equations_en.html">https://phet.colorado.edu/sims/html/balancing-chemical-equations/latest/balancing-chemical-equations_en.html</a>            Start with separating water:            Ask learners to try writing down the symbol reaction for the splitting of water into its elements before starting this simulation.</p> $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2(\text{g}) + \text{O}_2(\text{g})$ <p>Explain how to use balancing coefficients for equations and ask learners to write down the complete equation (with state symbols). Encourage an atom count/tally at this early stage of learning.</p> <p>Next, learners work independently solving and writing down the other reactions. (I)            Then they can play the game, each time writing down the equation in their notebooks. There are three different levels which learners may progress through.</p> <p>An alternative to using the PhET simulation above is to use models. You could use purpose-made molecular models such as 'Molymod' kits, or use, for example, common objects such as coloured sweets and toothpicks:  <a href="https://ashleysciencespot.weebly.com/uploads/4/6/3/8/46388125/balancing_equations_lab_activity.pdf">https://ashleysciencespot.weebly.com/uploads/4/6/3/8/46388125/balancing_equations_lab_activity.pdf</a> or  <a href="https://betterlesson.com/lesson/631007/balancing-chemical-reaction-equations-using-models">https://betterlesson.com/lesson/631007/balancing-chemical-reaction-equations-using-models</a> or  <a href="http://www.npsd.k12.nj.us/cms/lib/NJ01001216/Centricity/Domain/472/Balancing%20Chemical%20Equations%20Using%20Models.pdf">www.npsd.k12.nj.us/cms/lib/NJ01001216/Centricity/Domain/472/Balancing%20Chemical%20Equations%20Using%20Models.pdf</a></p> <p><u>Ionic equations (sometimes called net ionic equations)</u>            Emphasise to learners that ionic equations are only applicable to ionic compounds, specifically those that are soluble in water to form solutions of ions.</p> <p>1. Start this topic by asking learners to write down the balanced symbol equation, including state symbols, for the reaction between hydrochloric acid and sodium hydroxide:  <math display="block">\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})</math></p> <p>Then ask them to write similar equations for combinations of other mineral acids (sulfuric and nitric acids) reacting with lithium hydroxide and potassium hydroxide.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>2. Next, split the species with (aq) (species soluble in water) into their component ions (so <u>not</u> water). This will give:  <math display="block">\text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})</math></p> <p>3. Identify the spectator ions (define this), and cross them out.</p> <p>4. Write the ionic equation: <math>\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})</math></p> <p>Ask learners to reflect on all of the reactions they wrote in 1) asking them what they all have in common. They all contain 'H' and 'OH' on the left-hand side and the products are always water and a salt – learners may recall learning 'acid + base → salt + water'.</p> <p>This page explains the process in detail:  <a href="http://www.onlinemathlearning.com/ionic-equation.html">www.onlinemathlearning.com/ionic-equation.html</a> There are several examples which learners could try or be guided through.</p> <p>Note that ionic equations must also be balanced in the same way as ordinary symbol equations.</p> <p>Practice examples:  <a href="http://www.bbc.co.uk/bitesize/guides/zsm2k2p/revision/6">www.bbc.co.uk/bitesize/guides/zsm2k2p/revision/6</a></p>
3.2.1 Relative masses of atoms and molecules	Describe relative atomic mass, $A_r$ , as the average mass of the isotopes of an element compared to 1/12 <sup>th</sup> of the mass of an atom of $^{12}\text{C}$	<p>Ask learners where they have met the idea of relative mass before in chemistry. They should be able to explain that it was when the relative masses of protons, electrons and neutrons were considered in 2.2.2.</p> <p>Explain that every atom has its unique relative atomic mass. As this comparison is relative, you will need to explain relative to what – and the answer to this is, to the carbon-12 isotope. Learners should recall that C-13 and C -14 also exist.</p> <p>Learners research and write down the textbook definition for <math>A_r</math>.</p>
3.2.2 Relative masses of atoms and molecules	Define relative molecular mass, $M_r$ , as the sum of the relative atomic masses. Relative formula mass, $M_r$ , will be used for ionic compounds.	<p>Next go to the Periodic Table and learners write down a few examples of relative atomic masses, noting that hydrogen has the smallest <math>A_r = 1</math>.</p> <p>Bring learners' attention (if they don't notice) to the <math>A_r</math> value for chlorine which is 35.5. Explain to them that it is derived from the fact that two isotopes of chlorine exist in different proportions.</p> <p><b>Extension activity: Stretch and prepare for A Level</b>            Challenge learners to research and mathematically explain exactly why chlorine has an <math>A_r = 35.5</math>.            Useful link: <a href="http://www.bbc.co.uk/bitesize/guides/zwn8b82/revision/6">www.bbc.co.uk/bitesize/guides/zwn8b82/revision/6</a></p>
3.2.3 Relative masses of	Calculate reacting masses in simple proportions.	<p>Define relative molecular mass (<math>M_r</math>) / relative formula mass and explain the subtle difference in use to learners.</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
atoms and molecules	Calculations will <b>not</b> involve the mole concept	<p>Work through example <math>M_r</math> and formula mass calculations with simple covalently bonded molecules and ionic substances.</p> <p>Give learners plenty of practice, increasing in complexity to larger molecules/particles. Ensure that learners understand how to treat substances containing brackets in their formulae.</p> <p>Webpages with examples including solutions:  <a href="http://www.docbrown.info/page04/4_73calcs02rfm.htm">www.docbrown.info/page04/4_73calcs02rfm.htm</a>  <a href="http://www.bbc.co.uk/bitesize/guides/z84wfrd/revision/1">www.bbc.co.uk/bitesize/guides/z84wfrd/revision/1</a>  <a href="http://www.onlinemathlearning.com/molecular-mass.html">www.onlinemathlearning.com/molecular-mass.html</a></p> <p><u>Reacting masses</u>            At this point, it will be useful for learners to perform simple calculations involving reacting masses. It should be noted that use of the mole concept is not needed in solving these problems involving simple proportional relationships.            There are some simple examples to solve here:  <a href="https://www.bbc.co.uk/bitesize/guides/zmgj2nb/revision/2">https://www.bbc.co.uk/bitesize/guides/zmgj2nb/revision/2</a></p>
3.3.2 The mole and the Avogadro constant	State that the mole, mol, is the unit of amount of substance and that one mole contains $6.02 \times 10^{23}$ particles, e.g. atoms, ions, molecules: this number is the Avogadro constant	<p>The most important aspect of this topic is that learners understand that the mole is a unit for the amount of substance. Learners often think that mass is the same thing so it is important to establish what a mole actually is. It is straightforward to define a mole in terms of the number of elementary particles in a substance – the value of the Avogadro constant – but harder for learners to understand its magnitude.</p> <p>This song has several analogies to help learners appreciate the size of a mole:  <a href="http://www.youtube.com/watch?v=1R7Nilum2TI">www.youtube.com/watch?v=1R7Nilum2TI</a> (A mole is a unit)</p> <p>This simulation will also help learners appreciate the magnitude of the mole:  <a href="https://interactives.ck12.org/simulations/chemistry.html?referrer=simulation&amp;simulationName=decomposition-reaction">https://interactives.ck12.org/simulations/chemistry.html?referrer=simulation&amp;simulationName=decomposition-reaction</a> (search for 'Mole Carnival')</p>
3.3.3 The mole and the Avogadro constant	Use the relationship $\text{amount of substance (mol)} = \frac{\text{mass (g)}}{\text{molar mass (g/mol)}}$ to calculate: (a) amount of substance (b) mass (c) molar mass	<p>By definition one mole of a substance is the mass equal to the relative atomic mass or molecular or formula mass of the substance.</p> <p>Show learners what one mole of a range of substances looks like by weighing them out and placing them on a table:            18g water, 58.5g NaCl, 180g glucose, 12g carbon, 56g iron</p> <p>Learners practise calculating the mass of one mole of any substance using the equation given.            Here are some pages with worked examples:  <a href="http://www.docbrown.info/page04/4_73calcs07mam.htm">www.docbrown.info/page04/4_73calcs07mam.htm</a></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
	(d) relative atomic mass or relative molecular / formula mass (e) number of particles using the Avogadro constant	<a href="http://www.bbc.co.uk/bitesize/guides/z24xcj6/revision/1">www.bbc.co.uk/bitesize/guides/z24xcj6/revision/1</a> <a href="http://www.gcsescience.com/imoles.htm">www.gcsescience.com/imoles.htm</a>
3.3.4 The mole and the Avogadro constant	Use the molar gas volume, taken as 24 dm <sup>3</sup> at room temperature and pressure, r.t.p. in calculations involving gases	Discuss that gases can be measured in grams but it is inconvenient. Explain to learners that there is a relationship equating the mole to volume: 1 mole of any gas occupies a volume of 24dm <sup>3</sup> at room temperature and pressure (r.t.p.).  Learners practise calculations involving molar gas volume using the following: <a href="http://www.gcsescience.com/m20.htm">www.gcsescience.com/m20.htm</a> <a href="http://www.docbrown.info/page04/4_73calcs09mvg.htm">www.docbrown.info/page04/4_73calcs09mvg.htm</a> <a href="https://www.onlinemathlearning.com/molar-volume.html">https://www.onlinemathlearning.com/molar-volume.html</a>
3.3.1 The mole and the Avogadro constant	State that concentration can be measured in g / dm <sup>3</sup> or mol / dm <sup>3</sup>	First, learners explore the simple relationship between volume, amount and concentration using this simulation: <a href="https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html">https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html</a> Point out to learners that the units used in it are litres but the preferred unit is dm <sup>3</sup> (1dm <sup>3</sup> = 1l). Also note that the term 'molarity' is used for the concentration but in calculations mol/dm <sup>3</sup> is the preferred unit. Learners start off setting the amount at 1 mol and the volume at 1l and therefore see that the concentration is 1mol/dm <sup>3</sup> . Then, learners randomly change the values and do calculations to verify if the values displayed are correct.  The unit of concentration most commonly used is mol/dm <sup>3</sup> but learners need to be able to convert between mol/dm <sup>3</sup> and g/cm <sup>3</sup> : <a href="http://www.gcsescience.com/m30.htm">www.gcsescience.com/m30.htm</a> (worked example calculations)
3.3.5 The mole and the Avogadro constant	Calculate stoichiometric reacting masses, limiting reactants, volumes of gases at r.t.p., volumes of solutions and concentrations of solutions expressed in g / dm <sup>3</sup> and mol / dm <sup>3</sup> ,	Before introducing learners to problems on limiting reactants make sure they are able to balance chemical equations and convert between the amount of substance and the volume of gases / concentration of solutions.  Discuss test tube reactions learners may have done in the past. Ask them for example: What happened when you put pieces of reactive metals such as magnesium or zinc into dilute hydrochloric acid – which reagent got used up? Which reagent sometimes remains?  Demonstration: Limiting reactants Get some small pieces of zinc (or another reactive metal), place it in 1cm <sup>3</sup> of 1mol/dm <sup>3</sup> hydrochloric acid. After the fizzing

Syllabus ref.	Learning objectives	Suggested teaching activities
	including conversion between $\text{cm}^3$ and $\text{dm}^3$	<p>and bubbling stops, learners will note that some of the zinc remains. Now you can ask:</p> <ul style="list-style-type: none"> <li>• Which reagent is limiting in this case? [Hydrochloric acid].</li> <li>• Which reagent was in excess? [zinc]</li> <li>• How could hydrochloric acid be the <u>excess</u> reagent? [use a greater volume or more concentrated]</li> <li>• How could zinc be the <u>limiting</u> reagent? [use a smaller piece]</li> </ul> <p>After this discussion, tell learners that, in fact, chemists don't use guesswork; they perform calculations to decide which reagent is going to be limiting and which is going to be in excess. It is possible to combine reactants in stoichiometric amounts so that neither reactant is left over.</p> <p>Point out that the method for calculating the limiting reagent depends on whether it is a solid, liquid, gas or solution.</p> <p>This activity could be used to help learners grasp the idea of limiting reagents without doing any practical chemistry or just as an alternative way to understand the concept:  <a href="https://wisc.pb.unizin.org/chemactivities/chapter/limiting-reagents/">https://wisc.pb.unizin.org/chemactivities/chapter/limiting-reagents/</a></p> <p>Similar to the previous activity but using computer simulation:  <a href="https://phet.colorado.edu/sims/html/reactants-products-and-leftovers/latest/reactants-products-and-leftovers_en.html">https://phet.colorado.edu/sims/html/reactants-products-and-leftovers/latest/reactants-products-and-leftovers_en.html</a></p>
3.3.6 The mole and the Avogadro constant	Use experimental data from a titration to calculate the moles of solute, or the concentration or volume of a solution	Learners may have seen burettes and pipettes before but may not have used them to perform accurate titrations in order to calculate the concentration of a solution.
12.2.1 Acid-base titrations	Describe an acid–base titration to include the use of a: (a) burette (b) volumetric pipette (c) suitable indicator	<p><b>Experiment:</b> A simple acid-base titration:  A step-by-step guide:  <a href="http://dept.harpercollege.edu/chemistry/chm/100/dgodambe/thedisk/labtech/titrate2.htm">http://dept.harpercollege.edu/chemistry/chm/100/dgodambe/thedisk/labtech/titrate2.htm</a>  Discussion of suitable indicators is in Unit 7 Acids, bases and salts</p> <p><b>Experiment:</b> Titration of sodium hydroxide with hydrochloric acid  This practical can be linked to the formation and isolation of a salt in Unit 7 Acids, bases and salts  <a href="https://edu.rsc.org/resources/titrating-sodium-hydroxide-with-hydrochloric-acid/697.article">https://edu.rsc.org/resources/titrating-sodium-hydroxide-with-hydrochloric-acid/697.article</a></p>
12.2.2 Acid-base titrations	Describe how to identify the end-point of a titration using an indicator	For those not able to perform the experiment, this simulation allows you to conduct a titration virtually: <a href="https://edu.rsc.org/resources/titration-screen-experiment/2077.article">https://edu.rsc.org/resources/titration-screen-experiment/2077.article</a>



Syllabus ref.	Learning objectives	Suggested teaching activities
3.3.8 The mole and the Avogadro constant	Calculate percentage yield, percentage composition by mass and percentage purity, given appropriate data	<p>Define the terms: percentage yield, percentage composition by mass, and percentage purity.</p> <p>Worked examples for percentage yield calculations:  <a href="https://opentextbc.ca/chemistry/chapter/4-4-reaction-yields/">https://opentextbc.ca/chemistry/chapter/4-4-reaction-yields/</a>  <a href="http://www.bbc.co.uk/bitesize/guides/z3n64qt/revision/2">www.bbc.co.uk/bitesize/guides/z3n64qt/revision/2</a></p> <p><b>Experiment:</b> Prepare a sample of chalk and calculate the percentage yield.  <a href="http://www.hoodriver.k12.or.us/cms/lib/OR01000849/Centricity/Domain/1199/Chalk_percent_yield.pdf">www.hoodriver.k12.or.us/cms/lib/OR01000849/Centricity/Domain/1199/Chalk_percent_yield.pdf</a></p> <p><b>Experiment:</b> The experiment mentioned below in 3.3.7 for finding the empirical formula of magnesium oxide can easily be adapted to find the percentage yield.</p> <p><b>Resource Plus</b></p> <p>Carry out the <i>Finding the empirical formula by displacement</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>Percentage purity:  <math display="block">\% \text{ purity} = \frac{\text{mass of product formed}}{\text{total mass of sample}} \times 100</math></p> <p>Sample calculations are given here:  <a href="http://www.docbrown.info/page04/4_73calcs14other1.htm">www.docbrown.info/page04/4_73calcs14other1.htm</a></p>
3.1.5 Formulae	Define the empirical formula of a compound as the simplest whole number ratio of the different atoms or ions in a compound	<p>Define empirical formula and give some examples. Point out to learners that the formula of an ionic compound is always its empirical formula. Learners should now know that in a crystal of <math>\text{MgCl}_2</math> for example there are a vast number of ions attracting each other in a lattice, but the formula we write down, the simplest, is effectively the empirical formula.</p> <p>For covalent molecules the empirical formula may be different. For example, <math>\text{C}_6\text{H}_6</math> is a substance called benzene. Its simplest ratio of elements 'CH' is the empirical formula although the substance 'CH' does not exist.</p>
3.3.7 The mole and the Avogadro constant	Calculate empirical formulae and molecular formulae, given appropriate data	<p>Worked examples of empirical formula calculations:  <a href="http://www.bbc.co.uk/bitesize/guides/z8d2bk7/revision/4">www.bbc.co.uk/bitesize/guides/z8d2bk7/revision/4</a> [steps how to work out empirical formulae]  <a href="https://opentextbc.ca/chemistry/chapter/3-2-determining-empirical-and-molecular-formulas/">https://opentextbc.ca/chemistry/chapter/3-2-determining-empirical-and-molecular-formulas/</a>  <a href="http://www.thoughtco.com/definition-of-empirical-formula-605084">www.thoughtco.com/definition-of-empirical-formula-605084</a></p> <p><b>Experiment:</b> Determine the empirical formula of magnesium oxide  <a href="https://edu.rsc.org/resources/the-change-in-mass-when-magnesium-burns/718.article">https://edu.rsc.org/resources/the-change-in-mass-when-magnesium-burns/718.article</a></p>

**Past and specimen papers**

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

## 10 Chemical reactions

Syllabus ref.	Learning objectives	Suggested teaching activities
6.1.1 Physical and chemical changes	Identify physical and chemical changes, and understand the differences between them	As learners will probably have covered this topic in previous courses it would be a good subject for a revision poster or presentation.
6.2.1 Rate of reaction	Describe the effect on the rate of reaction of: (a) changing the concentration of solutions (b) changing the pressure of gases (c) changing the surface area of solids (d) changing the temperature (e) adding or removing a catalyst, including enzymes	Establish what the rate of reaction means and that rate is the preferred word instead of 'speed'. In pairs, learners think of two fast and two slow reactions. Discuss the examples as a class.  Ask learners to suggest ways in which the rate of a reaction can be increased (or decreased). Lead learners to all the following factors that influence the rate of a reaction: a) concentration of solutions b) pressure of gases c) surface area of solids d) temperature e) using catalysts  Explain to learners that a very important aspect of this unit is being able to describe and evaluate practical methods for investigating the rate of reaction. Learners need to draw and interpret graphs in order to visualise, calculate and compare rates of reaction, therefore practical work is a vital aspect of this topic.
6.2.2 Rate of reaction	State that a catalyst increases the rate of a reaction and is unchanged at the end of a reaction	
6.2.7 Rate of reaction	State that a catalyst decreases the activation energy, $E_a$ , of a reaction	Link this back to 5.1.4 and 5.1.5 Exothermic and endothermic reactions Ask learners to sketch energy diagrams for exothermic and endothermic reactions and label $E_a$ on both diagrams.

Syllabus ref.	Learning objectives	Suggested teaching activities
6.2.5 Rate of reaction	Describe collision theory in terms of: (a) number of particles per unit volume (b) frequency of collisions between particles (c) kinetic energy of particles (d) activation energy, $E_a$	Learners can explore the collision theory using the following simulation: <a href="https://phet.colorado.edu/sims/cheerj/reactions-and-rates/latest/reactions-and-rates.html?simulation=reactions-and-rates">https://phet.colorado.edu/sims/cheerj/reactions-and-rates/latest/reactions-and-rates.html?simulation=reactions-and-rates</a> This website explains the factors affecting the rate of reaction in terms of collision theory: <a href="http://www.docbrown.info/page03/3_31rates2.htm">http://www.docbrown.info/page03/3_31rates2.htm</a>
6.2.3 Rate of reaction	Describe practical methods for investigating the rate of a reaction including change in mass of a reactant or a product and the formation of a gas	<b>Practical Investigations</b> Plotting and interpreting graphs are very important in this topic, so give learners several opportunities to practise these skills. They should calculate average rates of reaction from graphs.  <u>Effect of changing a) the concentration of solutions, b) pressure of gases</u> <b>Experiment:</b> Reacting magnesium ribbon with different concentrations of hydrochloric acid solution <a href="https://edu.rsc.org/resources/the-rate-of-reaction-of-magnesium-with-hydrochloric-acid/1916.article">https://edu.rsc.org/resources/the-rate-of-reaction-of-magnesium-with-hydrochloric-acid/1916.article</a> (collection over water method)  <b>Experiment:</b> Reacting marble chips (calcium carbonate) with hydrochloric acid of varying concentrations <a href="http://www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/6">www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/6</a> (gas syringe method)
6.2.4 Rate of reaction	Interpret data, including graphs, from rate of reaction experiments	<b>Resource Plus</b> Carry out <i>The effect of changing the concentration of hydrochloric acid on the rate of reaction with calcium carbonate</i> experiment referring to the Teaching Pack for lesson plans and resources.
6.2.8 Rate of reaction	Evaluate practical methods for investigating the rate of a reaction including change in mass of a reactant or a product and the formation of a gas	<b>Experiment:</b> The effect of concentration on the rate of reaction between sodium thiosulfate and hydrochloric acid. <a href="https://edu.rsc.org/resources/the-effect-of-concentration-on-reaction-rate/743.article">https://edu.rsc.org/resources/the-effect-of-concentration-on-reaction-rate/743.article</a> [disappearing cross experiment] <a href="http://www.york.ac.uk/org/seg/salters/ChemistryArchive/ResourceSheets/thiosulphate_acid.PDF">www.york.ac.uk/org/seg/salters/ChemistryArchive/ResourceSheets/thiosulphate_acid.PDF</a> (alternative to above)
6.2.6 Rate of reaction	Describe and explain the effect on the rate of reaction of:	<b>Experiment:</b> The loss in mass method for measuring rate of reaction <a href="http://www.youtube.com/watch?v=Ui_74hXRuGl">www.youtube.com/watch?v=Ui_74hXRuGl</a>  It is not necessary to perform all these experiments and for whichever one or more you choose for your learners, make sure that they consider why the rate of reaction increases with increasing concentration of the solutions in terms of (a) and (b) in this learning objective.  <b>Extension activity: Stretch and prepare for A Level</b> This is a more in-depth explanation of how concentration affects the rate of chemical reactions: <a href="https://www.chemguide.co.uk/physical/basicrates/concentration.html">https://www.chemguide.co.uk/physical/basicrates/concentration.html</a>  If you have no access to chemicals and equipment use resources that teach practical and ideas such as the following

Syllabus ref.	Learning objectives	Suggested teaching activities
	<p>(a) changing the concentration of solutions</p> <p>(b) changing the pressure of gases</p> <p>(c) changing the surface area of solids</p> <p>(d) changing the temperature</p> <p>(e) adding or removing a catalyst, including enzymes using collision theory</p>	<p>simulations:  <a href="https://teachchemistry.org/classroom-resources/reaction-rates-simulation">https://teachchemistry.org/classroom-resources/reaction-rates-simulation</a>  <a href="https://phet.colorado.edu/en/simulation/reactions-and-rates">https://phet.colorado.edu/en/simulation/reactions-and-rates</a>            Ensure you have Java installed on your computer</p> <p><b>Extension activity: Stretch and prepare for A Level</b>            These simulations might interest learners who wish to learn more:  <a href="https://chemdemos.uoregon.edu/Topics/Rates-of-Reaction">https://chemdemos.uoregon.edu/Topics/Rates-of-Reaction</a></p> <p>c) <u>Effect of changing surface area</u>  <b>Experiment:</b> How surface area affects the rate of reaction  <a href="https://makezine.com/laboratory-122-determine-the-effect/">https://makezine.com/laboratory-122-determine-the-effect/</a></p> <p>Information and diagrams to explain the surface area effect:  <a href="http://www.chemguide.co.uk/physical/basicrates/surfacearea.html#top">www.chemguide.co.uk/physical/basicrates/surfacearea.html#top</a></p> <p>d) <u>Effect of changing the temperature</u>  <b>Experiment:</b> The effect of temperature on the rate of reaction between sodium thiosulfate and hydrochloric acid  <a href="https://edu.rsc.org/resources/the-effect-of-temperature-on-reaction-rate/448.article">https://edu.rsc.org/resources/the-effect-of-temperature-on-reaction-rate/448.article</a></p> <p><b>Experiment:</b> Investigate if temperature affects the glow stick / light stick reaction  <a href="https://chemdemos.uoregon.edu/demos/Lightstick-Reaction-Rates-versus-Temperature">https://chemdemos.uoregon.edu/demos/Lightstick-Reaction-Rates-versus-Temperature</a></p> <p>Other possible experiments. This link suggests other reaction systems to investigate how temperature affects the rate of reaction, including the decomposition of hydrogen peroxide and calcium carbonate reacting with hydrochloric acid:  <a href="http://www.docbrown.info/page03/3_31rates3d.htm">www.docbrown.info/page03/3_31rates3d.htm</a></p> <p>Basic ideas concerning collision theory and activation to explain the increase in rate of reaction when the temperature increases:  <a href="http://www.chemguide.co.uk/physical/basicrates/temperature.html">www.chemguide.co.uk/physical/basicrates/temperature.html</a></p> <p>e) <u>Effect of adding a catalyst</u>  <b>Experiment:</b> Which catalyst affects the rate of decomposition of hydrogen peroxide?  <a href="http://www.rsc.org/education/teachers/resources/aflchem/resources/63/index.htm">www.rsc.org/education/teachers/resources/aflchem/resources/63/index.htm</a>            A range of potential catalysts are tested and the best identified</p> <p>Catalyst theory is discussed here:  <a href="http://www.docbrown.info/page03/3_31rates3e.htm">www.docbrown.info/page03/3_31rates3e.htm</a></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
6.3.1 Reversible reactions and equilibrium	State that some chemical reactions are reversible as shown by the symbol $\rightleftharpoons$	Demonstration: Start this topic with a demonstration of the reversible reaction between hydrated and anhydrous copper(II) sulfate.
6.3.2 Reversible reactions and equilibrium	Describe how changing the conditions can change the direction of a reversible reaction for: (a) the effect of heat on hydrated compounds (b) the addition of water to anhydrous compounds limited to copper(II) sulfate and cobalt(II) chloride	<ol style="list-style-type: none"> <li>Place some hydrated copper(II) sulfate in a porcelain crucible. Ask learners to note the colour.</li> <li>Heat strongly.</li> <li>Ask what is happening during heating (becoming white)</li> <li>Allow to cool</li> <li>Ask the class to be very quiet as you add drops of water to the anhydrous salt. (observe fizzing and a colour change back to blue)</li> </ol> <p>Write the reversible reaction on the board for learners and explain the use of the reversible symbol. Note: You could link this discussion back to exothermic and endothermic reactions.</p> <p><b>Experiment:</b> Making cobalt chloride papers as a humidity detector  <a href="https://edu.rsc.org/resources/preparing-and-using-cobalt-chloride-indicator-papers/1919.article">https://edu.rsc.org/resources/preparing-and-using-cobalt-chloride-indicator-papers/1919.article</a>  <a href="https://chlorine.americanchemistry.com/Science-Center/Chlorine-Compound-of-the-Month-Library/Cobalt-Chloride-Colorful-Moisture-Detector/">https://chlorine.americanchemistry.com/Science-Center/Chlorine-Compound-of-the-Month-Library/Cobalt-Chloride-Colorful-Moisture-Detector/</a>  Learners can test their papers in humid and dry conditions over time (stick strip in book) and/or learn the colour changes by placing on a heating plate and then adding a drop of water. Write down the reversible reaction and discuss.</p> <p>Alternative experiment using cobalt chloride:</p>
6.3.3 Reversible reactions and equilibrium	State that a reversible reaction in a closed system is at equilibrium when: (a) the rate of the forward reaction is equal to the rate of the reverse reaction (b) the concentrations of reactants and products are no longer changing	<p><b>Resource Plus</b></p> <p>Carry out <i>The reversible reaction between two cobalt species</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> <p>Demonstration: The reversible reaction between ammonia and hydrogen chloride Learners should remember this reaction from the classic 'long-tube' experiment they performed on diffusion of gases. For this demonstration there is no need to set up the long tube again, merely bring two reagent bottles together, one with concentrated hydrochloric acid and one with concentrated ammonia. A white cloud will form which learners should be able to name as ammonium chloride. Establish / remind learners that this 'cloud' is actually fine particles of a white solid.</p> <p>Next, take some ammonium chloride and heat it strongly as in this video:  <a href="http://www.youtube.com/watch?v=xs7B_7hteCU">www.youtube.com/watch?v=xs7B_7hteCU</a>  You may be able to show the presence of HCl and NH<sub>3</sub> by testing the gases with moist red and blue litmus papers.</p> <p>Next discuss how, if the reaction were in a closed system, the products could not escape and that eventually an equilibrium would be established between products forming and breaking down. Extend the discussion to apply the same</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>idea to the copper(II) sulfate and cobalt(II) chloride reversible reactions.</p> <p>This video models dynamic equilibrium and may help learners appreciate that at dynamic equilibrium, the rate of the forward reaction = the rate of the back reaction:  <a href="http://www.youtube.com/watch?v=n91fyEmT-s">www.youtube.com/watch?v=n91fyEmT-s</a></p>
6.3.4 Reversible reactions and equilibrium	<p>Predict and explain, for any reversible reaction, how the position of equilibrium is affected by:</p> <p>(a) changing temperature            (b) changing pressure            (c) changing concentration            (d) using a catalyst using information provided</p>	<p>Learners are not required to recall Le Chatelier's principle but need to be aware of what it is and its significance.</p> <p>This article gives a brief explanation of how (a) to (d) affect the position of equilibrium:  <a href="http://www.chemguide.co.uk/physical/equilibria/lechatelier.html">www.chemguide.co.uk/physical/equilibria/lechatelier.html</a> [contains downloadable questions and answers]</p> <p>Play the equilibrium game:  <a href="http://www.ocr.org.uk/Images/179794-equilibrium-activity-game-and-pieces-.pdf">www.ocr.org.uk/Images/179794-equilibrium-activity-game-and-pieces-.pdf</a></p> <p>A game transferring water to illustrate equilibrium:  <a href="http://www.profpaz.com/Files/chem52/Exp_6.pdf">www.profpaz.com/Files/chem52/Exp_6.pdf</a> and <a href="https://uwaterloo.ca/chem13-news-magazine/may-2016/feature/equilibrium-concept-through-interactive-analogies">https://uwaterloo.ca/chem13-news-magazine/may-2016/feature/equilibrium-concept-through-interactive-analogies</a></p> <p>Common misconceptions in understanding equilibrium reactions:</p> <ul style="list-style-type: none"> <li>• Often learners think that equilibrium means that there must be 50% of products and reactants.</li> <li>• Many learners assume that at equilibrium, the reaction has stopped. Therefore explaining 'dynamic' equilibrium may help.</li> <li>• Often learners think that equilibrium can be approached from either direction.</li> </ul>
6.3.5 Reversible reactions and equilibrium	<p>State the symbol equation for the production of ammonia in the Haber process,  <math display="block">\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})</math></p>	<p>Before learners look at textbooks, give them the word equation and ask them to write a balanced chemical equation from it. Emphasise the importance of state symbols and the reversible sign.</p> <p>Next, ask them to apply what they learnt in 6.3.4 above, and to predict what happens if the temperature and pressure were changed. You will need to tell them that the reaction is exothermic in the forward direction.</p>
6.3.6 Reversible reactions and equilibrium	<p>State the sources of the hydrogen (methane) and nitrogen (air) in the Haber process</p>	<p>If possible, get some dilute ammonia and remind learners of the characteristic smell. Ask them if they know what its major use in industry is. 80% of world use is in the production of fertilisers (see section 10.2)</p> <p>Ask learners to research where such large quantities of hydrogen and nitrogen come from. (hydrogen from natural gas and nitrogen from the air)</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
6.3.7 Reversible reactions and equilibrium	State the typical conditions in the Haber process as 450 °C, 20 000 kPa / 200 atm and an iron catalyst	This video provides learners with useful background information on the process and about the chemist who discovered it, Fritz Haber: <a href="http://www.youtube.com/watch?v=o1_D4FscMnU">www.youtube.com/watch?v=o1_D4FscMnU</a> (The chemical reaction that feeds the world)
6.3.11 Reversible reactions and equilibrium	Explain, in terms of rate of reaction and position of equilibrium, why the typical conditions stated are used in the Haber process and in the Contact process, including safety considerations and economics	Next discuss with learners that they are going to compare the ideal theoretical conditions (for producing the maximum proportion of ammonia in the equilibrium mixture in the shortest possible time) with the compromise conditions used in industry (feasible economically and practically).  This page explains the Haber process in detail: <a href="http://www.chemguide.co.uk/physical/equilibria/haber.html#top">www.chemguide.co.uk/physical/equilibria/haber.html#top</a> (contains downloadable questions and answer sheets)  This video explains the process: <a href="http://www.youtube.com/watch?v=wiwl4eoHbig">www.youtube.com/watch?v=wiwl4eoHbig</a> (RSc video)  With the following simulation, learners can explore the amount of ammonia produced by changing the pressure and temperature: <a href="https://demonstrations.wolfram.com/ChemicalEquilibriumInTheHaberProcess/">https://demonstrations.wolfram.com/ChemicalEquilibriumInTheHaberProcess/</a> (simulation of Haber process)
10.2.1 Fertilisers	State that ammonium salts and nitrates are used as fertilisers	Learners could carry out a mini-research project to find out: <ul style="list-style-type: none"> <li>• why nitrogen, phosphorus and potassium are essential to plant growth</li> <li>• example ratios of N:P:K used (ask them to include images of labels of fertiliser sacks showing the ratio)</li> <li>• the names and formulae of various fertilisers (such as ammonium nitrate, ammonium sulfate, ammonium phosphate, potassium nitrate and urea).</li> </ul> References: <a href="http://www.bbc.co.uk/bitesize/guides/zxy9ng8/revision/1">www.bbc.co.uk/bitesize/guides/zxy9ng8/revision/1</a> <a href="http://www.essentialchemicalindustry.org/materials-and-applications/fertilizers.html">www.essentialchemicalindustry.org/materials-and-applications/fertilizers.html</a> <a href="http://www.fertilizerseurope.com/fertilizers-in-europe/types-of-fertilizer/">www.fertilizerseurope.com/fertilizers-in-europe/types-of-fertilizer/</a>
10.2.2 Fertilisers	Describe the use of NPK fertilisers to provide the elements nitrogen, phosphorus and potassium for improved plant growth	
6.3.8 Reversible reactions and equilibrium	State the symbol equation for the Contact process, $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$	First discuss why the world needs to make so much sulfuric acid. (fertiliser industry - see section 10.2)  The overall process involves several steps and is outlined here: <a href="http://www.dynamicscience.com.au/tester/solutions1/chemistry/sulfuricacid.html">www.dynamicscience.com.au/tester/solutions1/chemistry/sulfuricacid.html</a> However, you should focus on the equilibrium step of the process. Learners just need to know the sources of $\text{SO}_2$ .
6.3.9 Reversible	State the sources of the sulfur dioxide	This page contrasts the optimum and typical industrial conditions in the production of $\text{SO}_3(\text{g})$ : <a href="http://www.chemguide.co.uk/physical/equilibria/contact.html">www.chemguide.co.uk/physical/equilibria/contact.html</a> (with downloadable question and answer sheets)



Syllabus ref.	Learning objectives	Suggested teaching activities
reactions and equilibrium	(burning sulfur or roasting sulfide ores) and oxygen (air) in the Contact process	
6.3.10 Reversible reactions and equilibrium	State the typical conditions for the conversion of sulfur dioxide to sulfur trioxide in the Contact process as 450 °C, 200 kPa / 2 atm and a vanadium(V) oxide catalyst	
6.3.11 Reversible reactions and equilibrium	Explain, in terms of rate of reaction and position of equilibrium, why the typical conditions stated are used in the Haber process and in the Contact process, including safety considerations and economics	
6.4.3 Redox	Define oxidation as gain of oxygen and reduction as loss of oxygen	There are several definitions of oxidation and reduction reactions which are used in different circumstances. This often causes problems for learners. The oldest of these is the gain of oxygen by a substance. Ask learners to think of a metal they know that becomes oxidised. They will probably think of iron rusting, or a more reactive metal such as magnesium or zinc which oxidises more quickly:
6.4.4 Redox	Identify redox reactions as reactions involving gain and loss of oxygen	$\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$  Contrast this reaction by defining reduction as oxygen loss. If oxygen atoms are lost from a substance then it is reduction: $2\text{CuO} + \text{C} \rightarrow 2\text{Cu} + \text{CO}_2$

Syllabus ref.	Learning objectives	Suggested teaching activities
6.4.2 Redox	Define redox reactions as involving simultaneous reduction and oxidation	However, many more reactions than these are redox reactions and so the definitions were expanded/modified. Emphasise that oxidation and reduction occur simultaneously in redox reactions. Once learners become familiar with identifying oxidation and reduction, they should be able to show that this is the case using equations.
6.4.5 Redox	Identify oxidation and reduction in redox reactions	<p><u>Definition by loss or gain of electrons</u></p> <p>In electrochemistry (Electrolysis 4.1) learners write ionic half-equations for the reactions occurring at the anode and cathode.</p> <p>For example:  <math>\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})</math> At the cathode. Ask learners if this is gain or loss of electrons? [gain, so it is reduction]  <math>\text{Mg}(\text{s}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-}</math> At the anode. Ask learners if this is gain or loss of electrons? [magnesium is losing electrons so this is oxidation]</p> <p>Learners can use 'OIL RIG' to remember that Oxidation Is Loss, Reduction is Gain.</p>
6.4.6 Redox	Define oxidation in terms of: (a) loss of electrons (b) an increase in oxidation number	<p>Define an oxidising agent and reducing agent.</p> <p>Give learners redox equations from which they identify the oxidation, reduction, oxidising agent and reducing agent.</p>
6.4.7 Redox	Define reduction in terms of: (a) gain of electrons (b) a decrease in oxidation number	<p>This page helps learners to identify the oxidation and reduction by linking pairs of species:  <a href="http://www.chemguide.co.uk/inorganic/redox/definitions.html">www.chemguide.co.uk/inorganic/redox/definitions.html</a></p> <p>There are plenty of examples to show and discuss with learners here:  <a href="http://www.docbrown.info/page03/Reactivitya.htm">www.docbrown.info/page03/Reactivitya.htm</a></p>
6.4.8 Redox	Identify redox reactions as reactions involving gain and loss of electrons	<p>Questions and answers to check this knowledge:  <a href="http://www.bbc.co.uk/bitesize/guides/zy3xcj6/revision/1">www.bbc.co.uk/bitesize/guides/zy3xcj6/revision/1</a></p> <p><u>Definition by an increase or decrease in oxidation number</u></p> <p>This method for determining if a redox reaction has occurred is briefly covered in 6.4.7 below.</p>
6.4.11 Redox	Define an oxidising agent as a substance that oxidises another substance and is itself reduced	
6.4.12 Redox	Define a reducing agent as a substance that reduces another substance and is itself	

Syllabus ref.	Learning objectives	Suggested teaching activities
6.4.13 Redox	oxidised  Identify oxidising agents and reducing agents in redox reactions	
6.4.10 Redox	Identify redox reactions by the colour changes involved when using acidified aqueous potassium manganate(VII) or aqueous potassium iodide	In terms of specific reagents, learners must know that acidified potassium manganate(VII) is a powerful oxidising agent and potassium iodide is a reducing agent.  <u>Acidified potassium manganate (VII)</u> <b>Experiment:</b> Acidified potassium manganate (VII) and iron (II) sulfate Add a few drops of acidified potassium manganate(VII) solution to a solution of iron (II) sulfate ions. The purple colour of potassium manganate (VII) changes to an almost colourless solution.
6.4.1 Redox	Use a Roman numeral to indicate the oxidation number of an element	Explain that 'manganate (VII)' means that the manganese ion is in an oxidation state [has an oxidation number] of (VII) = +7 and changes to manganese in an oxidation state of (II) = +2 Explain that this is a useful reaction for quantitative titrimetric analysis (at A level).  <b>Experiment:</b> Learners could carry out a colourful redox reaction with potassium manganate (VII) and sucrose as described here: <a href="http://www.scienceinschool.org/content/colourful-chemistry-redox-reactions-lollipops">www.scienceinschool.org/content/colourful-chemistry-redox-reactions-lollipops</a>
6.4.9 Redox	Identify redox reactions by changes in oxidation number using: (a) the oxidation number of elements in their uncombined state is zero (b) the oxidation number of a monatomic ion is the same as the charge on the ion (c) the sum of the oxidation numbers in a compound is zero (d) the sum of the	Learners should know and be able to apply the rules for identifying reactions by changes in oxidation number as in 6.4.6.  Learners should also draw 'linking pairs' to show the oxidation and reduction taking place as in this page: <a href="http://www.chemguide.co.uk/inorganic/redox/definitions.html#top">www.chemguide.co.uk/inorganic/redox/definitions.html#top</a> In applying the 'linking pairs' method above, learners can then identify <b>oxidising agents</b> and <b>reducing agents</b> .  <u>Potassium iodide</u> Aqueous potassium iodide solution is colourless but when it is oxidised, brown iodine is produced in solution. To be consistent with the explanation for potassium manganate (VII) above, you can just tell learners that iodide is in the -1 oxidation state which changes to an oxidation state of zero in iodine.  Show an example of potassium iodide acting as a reducing agent – a simple reaction between chlorine and potassium iodide: <a href="http://www.youtube.com/watch?v=o9ZKcTVVMng">www.youtube.com/watch?v=o9ZKcTVVMng</a> Ask learners what would happen if acidified potassium manganate (VII) and potassium iodide were combined. [a redox

Syllabus ref.	Learning objectives	Suggested teaching activities
	oxidation numbers in an ion is equal to the charge on the ion	<p>reaction would occur]</p> <p><b>Demonstration:</b> Elephants' toothpaste  <a href="http://www.flinnsci.com/elephant-toothpaste/dc91098/">www.flinnsci.com/elephant-toothpaste/dc91098/</a>            The reaction is quite complex, but learners can see colourless iodide changing to brown iodine in this dramatic demonstration.</p> <p><b>Experiment:</b> The hydrogen peroxide rainbow            This reaction utilises potassium permanganate solution, potassium iodide and hydrogen peroxide in a complex series of redox reactions:  <a href="http://www.flinnsci.com/api/library/Download/4b0adac1e0bf4a50b4a9d10ca5d9a7ee">www.flinnsci.com/api/library/Download/4b0adac1e0bf4a50b4a9d10ca5d9a7ee</a></p> <p>Note: For all the above reactions, learners should also try to explain the reactions in terms of electron gain or loss as well as a change in oxidation number (state).</p>
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		

## 11 Electrochemistry

Syllabus ref.	Learning objectives	Suggested teaching activities
4.1.1 Electrolysis	Define electrolysis as the decomposition of an ionic compound, when molten or in aqueous solution, by the passage of an electric current	Define electrolysis and highlight the fact that it is a process which requires an input of energy in order to break down ionic substances. Ask learners for reasons why ionic substances in the solid state do not conduct electricity. Ions are tightly held in a lattice structure. Lead learners to the idea that in molten compounds the ions are free to move and electrolysis can occur.
4.1.2 Electrolysis	Identify in simple electrolytic cells: (a) the anode as the positive electrode (b) the cathode as the negative electrode (c) the electrolyte as the molten or aqueous substance that undergoes electrolysis	<u>Demonstration: The electrolysis of molten zinc chloride</u> Set up the following demonstration for the electrolysis of molten zinc chloride. This solid has a relatively low melting point for an ionic solid (732°C) and can be melted with a Bunsen burner flame. It is preferable to use this instead of lead bromide which is toxic and tends to decompose only with heating, but it must still be performed in a fume cupboard as chlorine is evolved.  While learners are gathered around the fume cupboard and the crucible is being heated explain the following to learners: <ul style="list-style-type: none"> <li>• The terms anode, cathode – which is positive and which is negative.</li> <li>• What the electrolyte is.</li> <li>• That in the external circuit, electrons flow, and in the electrolyte, ions carry the current.</li> <li>• That the graphite electrodes are part of the external circuit. Connect with 2.6 giant covalent structures and ask them how graphite conducts electricity.</li> </ul>
4.1.8 Electrolysis	<b>Describe the transfer of charge during electrolysis to include:</b> (a) the movement of electrons in the external circuit (b) the loss or gain of electrons at the electrodes (c) the movement of ions in the electrolyte	When electrolysis begins and the bulb lights up discuss/ask: <ul style="list-style-type: none"> <li>• Which ions zinc chloride contains. (<math>Zn^{2+}</math> and <math>Cl^-</math>)</li> <li>• What they think the bubbles are forming at the anode. (then test the gas)</li> <li>• Why they can't see anything happening at the cathode.</li> </ul> <p>If you cannot perform the experiment learners can watch this video: <a href="https://edu.rsc.org/resources/electrolysis-of-molten-zinc-chloride/826.article">https://edu.rsc.org/resources/electrolysis-of-molten-zinc-chloride/826.article</a></p> <div style="border: 1px solid black; padding: 5px;"> <p><b>Resource Plus</b> Carry out <i>Electrolysis of molten zinc chloride</i> experiment referring to the Teaching Pack for lesson plans and resources.</p> </div>
4.1.3 (part) Electrolysis	Identify the products formed at the electrodes and describe the	Show the following video for the electrolysis of molten lead bromide: <a href="http://www.youtube.com/watch?v=Cf8zjla8euQ">www.youtube.com/watch?v=Cf8zjla8euQ</a> Turn off the sound and ask learners to make predictions and explain observations about the process.  <u>Ionic half-equations</u>

Syllabus ref.	Learning objectives	Suggested teaching activities
4.1.5 Electrolysis	<p>observations made during the electrolysis of:</p> <p>(a) molten lead(II) bromide using inert electrodes made of platinum or carbon/graphite</p> <p>Predict the identity of the products at each electrode for the electrolysis of a binary compound in the molten state</p>	<p>Learners may have already come across net ionic equations during this course (3.1.6). If so it is important to emphasise that ionic half-equations always involve electrons.</p> <p>Here is a link to how they are constructed for the lead bromide electrolysis mentioned above: <a href="http://www.chemguide.co.uk/inorganic/electrolysis/melts.html#top">www.chemguide.co.uk/inorganic/electrolysis/melts.html#top</a>. This page contains downloadable question and answer sheets.</p> <p>The above link also provides helpful analogies to help learners appreciate how and why current flows in the external circuit.</p> <p>Note: It is helpful if learners have already covered 6.4 Redox before attempting these equations. Learners can use 'OIL RIG' to remember at which electrode oxidation and reduction are occurring.</p>
4.1.11 Electrolysis	<p>Construct ionic half-equations for reactions at the anode (to show oxidation) and at the cathode (to show reduction)</p>	
4.1.3 (part) Electrolysis	<p>Identify the products formed at the electrodes and describe the observations made during the electrolysis of:</p> <p>(b) concentrated aqueous sodium chloride</p> <p>(c) dilute sulfuric acid using inert electrodes made of platinum or carbon/graphite</p>	<p>The electrolysis of ionic solutions is best understood if learners have studied the reactivity series of metals (9.4) although they should already have some background of this topic from previous courses.</p> <p>Explain why the electrolysis of ionic solutions is more complex than for molten substances.</p> <p>Next discuss how pure water is actually a very poor conductor of electricity but that a very small amount of ions are generated due to the auto-ionisation of water:</p> $\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$ <p>Then explain to learners that if water contains ionic salt impurities it can conduct electricity.</p> <p>Show learners the following simulation: <a href="https://sepuplhs.org/high/hydrogen/electrolysis_sim.html">https://sepuplhs.org/high/hydrogen/electrolysis_sim.html</a></p> <p>Explain to them that this is similar to electrolysis of a dilute acid solution as in the following example.</p> <p><b>Experiment:</b> The electrolysis of dilute sulfuric acid</p> <p>There are several methods to do this depending on the availability of equipment. If a dedicated apparatus such as a Hoffman apparatus is not available then there are several ways to improvise as detailed in the pages below:</p>
4.1.10	<p>Predict the identity of</p>	

Syllabus ref.	Learning objectives	Suggested teaching activities
Electrolysis  4.1.4 Electrolysis	the products at each electrode for the electrolysis of halide in dilute or concentrated aqueous solution  State that metals or hydrogen are formed at the cathode and that non-metals (other than hydrogen) are formed at the anode	<p><a href="http://chemed.chem.purdue.edu/demos/main_pages/20.2.html">http://chemed.chem.purdue.edu/demos/main_pages/20.2.html</a> [Hoffman apparatus]  <a href="http://www.academicstar.us/UploadFile/Picture/2014-3/2014319215114816.pdf">www.academicstar.us/UploadFile/Picture/2014-3/2014319215114816.pdf</a> [several alternatives]  <a href="http://www.digipac.ca/chemical/mtom/contents/chapter3/electrolysis.htm">www.digipac.ca/chemical/mtom/contents/chapter3/electrolysis.htm</a> [using pencils]</p> <p><b>Extension activity: Stretch and prepare for A Level:</b>  <b>Resource Plus</b>  Carry out <i>The electrolysis of acidified water using a Hofmann voltameter</i> experiment in Resource Plus for AS&amp;A Level Chemistry 9701, referring to the Teaching Pack for lesson plans and resources.</p> <p><u>Rules for the discharge of ions in aqueous electrolyses</u>  As the electrolysis of aqueous solutions is complicated by the additional H<sup>+</sup> and OH<sup>-</sup> ions due to the presence of water, there are some rules which help chemists predict the products that will be formed at the electrodes. These rules are summarised here:  <a href="http://www.docbrown.info/page01/ExIndChem/electrochemistry01.htm">www.docbrown.info/page01/ExIndChem/electrochemistry01.htm</a>  and the products of a number of aqueous electrolyses detailed here:  <a href="http://www.docbrown.info/page01/ExIndChem/electrochemistry08.htm">www.docbrown.info/page01/ExIndChem/electrochemistry08.htm</a></p> <p>When learners understand the above rules, they can perform further electrolysis experiments.</p> <p><b>Experiment:</b> The electrolysis of concentrated sodium chloride (also called brine)  The following page contains instructions:  <a href="https://edu.rsc.org/resources/colourful-electrolysis/735.article">https://edu.rsc.org/resources/colourful-electrolysis/735.article</a>  If a U-tube is not available, a petri dish can be used as shown in the following video:  <a href="http://www.youtube.com/watch?v=CMW9r_L-CQA">www.youtube.com/watch?v=CMW9r_L-CQA</a></p> <p>Use half-equations to explain how the products of the electrolysis are formed and refer to the rules for discharge as explained above.  Note that this is also a very important industrial process yielding the useful products hydrogen, chlorine and sodium hydroxide.</p>
9.6.3 Extraction of metals	State that the main ore of aluminium is bauxite and that aluminium is extracted by electrolysis	<p>Show learners a sample of bauxite or display the following image:  <a href="https://geology.com/minerals/bauxite.shtml">https://geology.com/minerals/bauxite.shtml</a></p> <p>With reference to the reactivity series of metals, ask learners why aluminium may not be obtained by reduction with carbon. (higher than carbon)</p>
9.6.5 Extraction of	Describe the extraction of aluminium from	<p>Show learners this video explaining the process:  <a href="https://www.youtube.com/watch?v=6P90li2PHfA">https://www.youtube.com/watch?v=6P90li2PHfA</a></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
metals	<p>purified bauxite / aluminium oxide, including:</p> <p>(a) the role of cryolite</p> <p>(b) why the carbon anode needs to be regularly replaced</p> <p>(c) the reactions at the electrodes, including ionic half-equations</p> <p>Details of purification of bauxite are <b>not</b> required</p>	<p>The process occurring in industry can be seen here:  <a href="http://www.youtube.com/watch?v=NW1k4wNEq14">www.youtube.com/watch?v=NW1k4wNEq14</a></p> <p>Learners should concentrate on finding out:</p> <ul style="list-style-type: none"> <li>• The reason for needing cryolite</li> <li>• Why the carbon anodes need to be replaced on a regular basis</li> <li>• The ionic half-reactions that occur at each electrode</li> </ul> <p>The cell reactions are explained on this page:  <a href="http://www.ibchem.com/IB/ibnotes/full/open_cell.htm">www.ibchem.com/IB/ibnotes/full/open_cell.htm</a></p> <p>Learners may be able to write these half-reactions with assistance.</p>
4.1.9 Electrolysis	<p>Identify the products formed at the electrodes and describe the observations made during the electrolysis of aqueous copper(II) sulfate using inert carbon/graphite electrodes and when using copper electrodes</p>	<p><b>Experiment:</b> The electrolysis of copper(II) sulfate solution  Learners can use this page that details the experiment:  <a href="https://edu.rsc.org/resources/electrolysis-of-copperii-sulfate-solution/476.article">https://edu.rsc.org/resources/electrolysis-of-copperii-sulfate-solution/476.article</a></p> <p>Learners should try to:</p> <ul style="list-style-type: none"> <li>• explain the observations at each electrode and any changes in the electrolyte</li> <li>• write half-equations for the reactions at each electrode.</li> </ul> <p><b>Extension activity: Stretch and prepare for A Level</b>  Learners find out why the anode starts to break down during the electrolysis. [oxygen produced reacts with the carbon anode to produce carbon dioxide]</p>
4.1.6 Electrolysis	<p>State that metal objects are electroplated to improve their appearance and resistance to corrosion</p>	<p><b>Experiment:</b> Electroplating  Learners follow this procedure to electroplate an object with copper:  <a href="https://sites.prairiesouth.ca/legacy/chemistry/chem30/6_redox/labs/electroplating.htm">https://sites.prairiesouth.ca/legacy/chemistry/chem30/6_redox/labs/electroplating.htm</a></p> <p>Alternative / supporting details:  <a href="http://www.scienceproject.com/projects/detail/senior/SC050.asp">www.scienceproject.com/projects/detail/senior/SC050.asp</a>  <a href="http://www.chemedx.org/blog/easy-copper-electroplating-demo-your-redox-unit">www.chemedx.org/blog/easy-copper-electroplating-demo-your-redox-unit</a></p>
4.1.7 Electrolysis	<p>Describe how metals are electroplated</p>	<p>Other metals can be electroplated, for example:  <a href="http://www.savemyexams.co.uk/igcse-chemistry-cie-new/revision-notes/electricity-and-chemistry/electricity-and-chemistry-electroplating/">www.savemyexams.co.uk/igcse-chemistry-cie-new/revision-notes/electricity-and-chemistry/electricity-and-chemistry-electroplating/</a> [plating iron with tin]</p> <p>Learners should write ionic half-equations for the electrode reactions for all the examples chosen.</p>



Syllabus ref.	Learning objectives	Suggested teaching activities
		<p><b>Extension activity: Stretch and prepare for A Level:</b> Learners investigate Faraday's laws of electrolysis and perform some simple calculations. You could link this to the practical work above or as a separate theoretical activity.</p>
<p>4.2.1 Hydrogen fuel cells</p> <p>4.2.2 Hydrogen fuel cells</p>	<p>State that a hydrogen–oxygen fuel cell uses hydrogen and oxygen to produce electricity with water as the only chemical product</p> <p>Describe the advantages and disadvantages of using hydrogen–oxygen fuel cells in comparison with gasoline/petrol engines in vehicles</p>	<p>The most important point to bring out here (especially if you are teaching this sub-topic directly after electrolysis), is that an input of energy is needed to drive electrolysis reactions whereas in fuel cells, electrical energy is produced from spontaneous chemical reactions.</p> <p>Display the following images from the NASA space program:  <a href="http://www.nasa.gov/content/liquid-hydrogen-the-fuel-of-choice-for-space-exploration">www.nasa.gov/content/liquid-hydrogen-the-fuel-of-choice-for-space-exploration</a> (image of hydrogen storage tank)  <a href="https://blogs.nasa.gov/groundsystems/2017/10/03/liquid-oxygen-tanking-operations-begin-at-launch-pad-39b/">https://blogs.nasa.gov/groundsystems/2017/10/03/liquid-oxygen-tanking-operations-begin-at-launch-pad-39b/</a> (oxygen storage tanks)            Explain to learners that for decades NASA has used these substances to fuel space missions. Ask learners to suggest how the liquid oxygen and hydrogen were used.</p> <p>This page explains 'Fuel cells essentially a device to release the chemical potential energy of combustible fuels as electrical energy at a much lower temperature and without the flame!':  <a href="http://www.docbrown.info/page01/ExIndChem/electrochemistry11.htm">www.docbrown.info/page01/ExIndChem/electrochemistry11.htm</a></p> <p>Ask learners to write down the two half-equations and the overall cell reaction. These are in the page above.</p> <p>Learners work in pairs to research the advantages and disadvantages of using these fuel cells in cars compared to using gasoline/petrol. They could present their findings as a poster and/or give a short presentation.            Useful reference:  <a href="https://getrevising.co.uk/grids/hydrogen_fuel_cells_2">https://getrevising.co.uk/grids/hydrogen_fuel_cells_2</a>            Learners could also include current information about hydrogen vehicles in terms of cost, how widespread their use is and what the future looks like for this industry.</p> <p><b>Extension activity: Stretch and prepare for A Level</b>            Learners build their own fuel cell. There are many videos and pages describing this. Here are a couple of examples:  <a href="https://sci-toys.com/scitoys/scitoys/echem/fuel_cell/fuel_cell.html">https://sci-toys.com/scitoys/scitoys/echem/fuel_cell/fuel_cell.html</a>  <a href="http://www.wikihow.com/Build-a-Fuel-Cell">www.wikihow.com/Build-a-Fuel-Cell</a></p>
<p><b>Past and specimen papers</b></p>		
<p>Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)</p>		

## 12 Organic chemistry

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>Ask learners to locate carbon in the Periodic Table and write down its electron configuration. Next, discuss which type of bonding carbon has. (It is covalent). Discuss that carbon is unique in that carbon can bond with itself, forming very long chains of carbon atoms.</p> <p>This article explains why organic compounds are so widespread:  <a href="https://science.jrank.org/pages/1202/Carbon-Why-carbon-special.html">https://science.jrank.org/pages/1202/Carbon-Why-carbon-special.html</a>            Learners identify and discuss the other reasons discussed in the article which make carbon so special.</p> <p>Finally explain that organic compounds always contain the element hydrogen in their molecules and that other elements such as oxygen, nitrogen and sulfur are sometimes present.</p>
11.1.1 Formulae, functional groups and terminology	Draw and interpret the displayed formula of a molecule to show all the atoms and all the bonds	Check that learners recall how to represent single, double and triple bonds from the topic of covalent bonding, and that each bond represents two electrons being shared.
11.1.7 Formulae, functional groups and terminology	State that a structural formula is an unambiguous description of the way the atoms in a molecule are arranged, including CH <sub>2</sub> =CH <sub>2</sub> , CH <sub>3</sub> CH <sub>2</sub> OH, CH <sub>3</sub> COOCH <sub>3</sub>	<p>Show learners a bottle of ethanol and write down its molecular formula as: C<sub>2</sub>H<sub>6</sub>O            Learners could draw the molecule using a dot-and-cross diagram to practise covalent bonding. Learners will see that all of the bonds in the molecule are single covalent bonds.            The following way of drawing the molecule is the displayed (skeletal) formula:</p> $\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$ <p>Now rewrite the unambiguous <b>structural formula</b> for ethanol as CH<sub>3</sub>CH<sub>2</sub>OH. Mention that it is often written as C<sub>2</sub>H<sub>5</sub>OH for short.            Going back to the molecular formula C<sub>2</sub>H<sub>6</sub>O, challenge learners to draw or build using molecular models, a different molecule. Ask them at first to draw the displayed structure:</p>
11.1.4 Formulae, functional groups and terminology	State that a homologous series is a family of similar compounds with similar chemical properties due to the presence of the same functional group	<p>methoxymethane</p> $\begin{array}{c} \text{H} \quad \quad \text{H} \\   \quad \quad   \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\   \quad \quad   \\ \text{H} \quad \quad \text{H} \end{array}$ <p>They should then write the structural formula CH<sub>3</sub>OCH<sub>3</sub></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
11.1.9 Formulae, functional groups and terminology	Describe the general characteristics of a homologous series as: (a) having the same functional group (b) having the same general formula (c) differing from one member to the next by a $-CH_2-$ unit (d) displaying a trend in physical properties (e) sharing similar chemical properties	Finally discuss the other examples presented in this objective. Briefly explain to learners that many organic compounds contain functional groups which are the reactive parts of the molecules. Learners draw a table including the functional groups included in this syllabus: $-OH$ , $-COOH$ , $C=C$ , $-NH_2$  Explain that each homologous series has the same functional group and same general formula. These points will be detailed below. Also point out that members differ by one methylene unit $-CH_2-$  Given that the functional groups remain the same for each homologous series, ask learners if they would expect the physical properties to be similar or very different. Also ask learners to predict whether the chemical properties would be similar or different.
11.1.3 Formulae, functional groups and terminology	Identify a functional group as an atom or group of atoms that determine the chemical properties of a homologous series	
11.2.2 Naming organic compounds	State the type of compound present given the chemical name ending in $-ane$ , $-ene$ , $-ol$ , or $-oic$ acid or from a molecular or displayed formula	Most aspects of naming organic compounds will be discussed under alkanes, alkenes, alcohols and carboxylic acids individually. For now, you can just mention that the name endings determine the type of compound present as stated in learning objective 11.2.2.
11.2.4 Naming organic compounds	Name and draw the displayed formulae of the unbranched esters which can be made from unbranched alcohols and carboxylic	

Syllabus ref.	Learning objectives	Suggested teaching activities
	acids, each containing up to four carbon atoms	
11.3.1 Fuels	Name the fossil fuels: coal, natural gas and petroleum	Check that learners recall the names of the fossil fuels from previous study and briefly discuss their origins. They may not know that methane is the main constituent of natural gas however.
11.3.2 Fuels	Name methane as the main constituent of natural gas	Introduce the term 'hydrocarbons' and draw a couple of examples on the board.
11.3.3 Fuels	State that hydrocarbons are compounds that contain hydrogen and carbon only	Discuss with learners that petroleum is a rich source of hydrocarbons not only as fuel but is a starting point for many chemical industries.
11.3.4 Fuels	State that petroleum is a mixture of hydrocarbons	
11.3.5 Fuels	Describe the separation of petroleum into useful fractions by fractional distillation	If possible show learners a sample of crude oil explaining that in this state it is not useful but that after processing, many useful products can be obtained. This video explains what crude oil is like: <a href="http://www.youtube.com/watch?v=L99EybpORkK">www.youtube.com/watch?v=L99EybpORkK</a> [Will a gas engine run on crude oil?]
11.3.6 Fuels	Describe how the properties of fractions obtained from petroleum change as they are collected in a fractionating column from the bottom to the top of the column, limited to: (a) decreasing chain	<b>Experiment:</b> Small scale fractional distillation in the lab <a href="https://edu.rsc.org/resources/fractional-distillation/2248.article">https://edu.rsc.org/resources/fractional-distillation/2248.article</a> [this article contains instructions, an apparatus guide, an animation and downloadable video]  Animations/simulations of fractional distillation: <a href="http://www.footprints-science.co.uk/index.php?type=Fractional%20distillation&amp;section=Section1&amp;info=6">www.footprints-science.co.uk/index.php?type=Fractional%20distillation&amp;section=Section1&amp;info=6</a> [drag and drop the correct fractions]  A detailed look at what happens inside the fractionating tower: <a href="http://resources.schoolscience.co.uk/Exxonmobil/infobank/4/flash/distillation.htm">http://resources.schoolscience.co.uk/Exxonmobil/infobank/4/flash/distillation.htm</a>

Syllabus ref.	Learning objectives	Suggested teaching activities
11.3.7 Fuels	<p>length (b) higher volatility (c) lower boiling points (d) lower viscosity</p> <p>Name the uses of the fractions as: (a) refinery gas fraction for gas used in heating and cooking (b) gasoline/petrol fraction for fuel used in cars (c) naphtha fraction as a chemical feedstock (d) kerosene/paraffin fraction for jet fuel (e) diesel oil/gas oil fraction for fuel used in diesel engines (f) fuel oil fraction for fuel used in ships and home heating systems (g) lubricating fraction for lubricants, waxes and polishes (h) bitumen fraction for making roads</p>	<p>Ask learners to research the uses of the various fractions. If samples are available show them to learners. Learners will probably easily understand many of the fuel uses, but the use of naphthas in the chemical industry may be more difficult for them. This article explains the uses of naphtha: <a href="https://energyeducation.ca/encyclopedia/Naphtha">https://energyeducation.ca/encyclopedia/Naphtha</a></p> <p><b>Extension activity: Stretch and prepare for A Level</b> Learners try to find out why the boiling points of the hydrocarbons increase with increasing chain length in terms of intermolecular bonding.</p>
11.1.2 (part) Formulae, functional groups and terminology	<p>Write and interpret general formulae of compounds in the same homologous series, limited to: (a) alkanes, <math>C_nH_{2n+2}</math></p>	<p><u>The alkanes</u> Link this discussion with crude oil and fractional distillation explaining that a large percentage of this black, viscous substance contains a mixture of alkanes. Draw the first member of the series, methane and make a molecular model of it. Learners should be able to draw a dot-and-cross diagram for it and explain why the bonding is single covalent. Define the term saturated hydrocarbons during this discussion.</p>
11.4.1 Alkanes	<p>State that the bonding in alkanes is single covalent and that</p>	<p><u>Molecular model-building activity</u> If you have access to plenty of molecular modelling kits, learners in pairs, build and name the first 4 or 5 members of the homologous series. If fewer kits are available, then each group could build one model and hold it up once finished. They</p>

Syllabus ref.	Learning objectives	Suggested teaching activities
11.1.5 Formulae, functional groups and terminology	alkanes are saturated hydrocarbons  State that a saturated compound has molecules in which all carbon-carbon bonds are single bonds	may build longer-chain alkanes, but emphasise that learners only need to be able to name homologues as long as 4 carbon atoms.  Discuss with learners the differences in the way the molecules look as models compared to the way they are usually drawn in textbooks.  If molecular model kits are not available then learners could use this virtual molecule-building app: <a href="http://molview.org/">http://molview.org/</a> First you construct a model in 2-D which is then converted into a 3-D rotatable model.
11.2.1 (part) Naming organic compounds	Name and draw the displayed formulae of: (a) methane and ethane	When they have constructed and drawn several members of the series, challenge learners to determine the general formula for the alkane homologous series and then predict the formula of some longer-chain alkanes.
11.2.3 (part) Naming organic compounds	Name and draw the structural and displayed formulae of unbranched: (a) alkanes containing up to four carbon atoms per molecule	<u>Reactivity of the alkanes</u> Once you have taught learners about the alkenes, alcohols and carboxylic acids, they may be able to postulate why the alkanes are relatively unreactive molecules. However, at this stage, it is probably best to explain that C-C and C-H bonds are strong bonds and there is no particular weakness or site for attack in alkane molecules.  <u>Substitution reactions of the alkanes with chlorine</u> Learners can build models of alkanes where one of the atoms is substituted at various positions in the alkane chain. Explain that the mechanism of the reaction is complex and beyond the scope of IGCSE chemistry. However, learners will appreciate that UV light is of high energy and provides the $E_a$ for the reaction to proceed. If you have already taught Chemical Energetics, learners should be able to draw a reaction pathway diagram (see 5.1.5)
11.4.2 Alkanes	Describe the properties of alkanes as being generally unreactive, except in terms of combustion and substitution by chlorine	<b>Extension activity: Stretch and prepare for A Level</b> Learners justify the shapes of the molecules in terms of their bond angles and research the shape of methane.  If you have not discussed the increase in boiling point with increase in chain length / molecular mass already, this would be an appropriate time to do so. Also, if you have samples of alkanes, it would be helpful for learners to see them. Even pointing to a liquefied/pressurised canister, lighter etc. of the shorter alkanes and showing a bottle of pentane or hexane would be helpful to learners.
11.4.3 Alkanes	State that in a substitution reaction one atom or group of atoms is replaced by another atom or group of atoms	<u>Isomer model-building activity</u> This could be a separate activity or part of the previous one, depending on time constraints. Ask learners to build a model of butane, $C_4H_{10}$ .  Explain to learners that there is another way to use the same number of carbon and hydrogen atoms to build a different

Syllabus ref.	Learning objectives	Suggested teaching activities
11.4.4 Alkanes	Describe the substitution reaction of alkanes with chlorine as a photochemical reaction, with ultraviolet light providing the activation energy, $E_a$ , and draw the structural or displayed formulae of the products, limited to monosubstitution	<p>structure. Challenge them to do this. Learners should also draw the examples they come up with in their notebooks. Learners will probably build this structure: <math>\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_3</math></p> <p>Learners may be confused by writing the displayed structure with the methyl group up or down and not realising that the structures are the same as each other. Flipping their models should help learners understand they are identical.</p> <p>If molecular model kits are not available then learners could use this virtual molecule-building app: <a href="http://molview.org/">http://molview.org/</a> First you construct a model in 2-D which is then converted into a 3-D rotatable model.</p> <p>Learners conclude by writing a definition of structural isomers.</p>
11.1.8 Formulae, functional groups and terminology	Define structural isomers as compounds with the same molecular formula, but different structural formulae, including $\text{C}_4\text{H}_{10}$ as $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ and $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_3$ and $\text{C}_4\text{H}_8$ as $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$ and $\text{CH}_3\text{CH}=\text{CHCH}_3$	
11.5.1 Alkenes	State that the bonding in alkenes includes a double carbon-carbon covalent bond and that alkenes are unsaturated hydrocarbons	<p><u>The alkenes</u> Check that learners recall how to draw a dot-and-cross diagram for the first member of the homologous series, ethene. Explain that the <math>\text{C}=\text{C}</math> double bond is reactive and that the molecule is termed 'unsaturated' because of its presence in the molecule. Add that carbon-carbon triple bonds also exist.</p> <p>Molecular model-building activity: If you have access to plenty of molecular modelling kits, learners in pairs, build and name the first 4 or 5 members of the homologous series. If fewer kits are available, then each group could build one model and hold it up when finished. Learners should name each member of the series.</p>
11.1.6 Formulae, functional	State that an unsaturated compound has molecules in which	As with the alkanes, learners should inspect the shape of the molecule in 3-D space and compare to the standard representation in school textbooks.

Syllabus ref.	Learning objectives	Suggested teaching activities
groups and terminology	one or more carbon-carbon bonds are not single bonds	If molecular model kits are not available then learners could use this virtual molecule-building app: <a href="http://molview.org">http://molview.org</a> First you construct a model in 2-D which is then converted into a 3-D rotatable model.
11.1.2 (part) Formulae, functional groups and terminology	Write and interpret general formulae of compounds in the same homologous series limited to: (b) alkenes, $C_nH_{2n}$	Learners try to write a general formula for the alkenes homologous series and test it to write the formulae of higher members of the series.  Learners could read this article about ethene (old name, ethylene) in the ripening of bananas: <a href="http://www.nationalgeographic.com/environment/urban-expeditions/food/food-journeys-graphic/">www.nationalgeographic.com/environment/urban-expeditions/food/food-journeys-graphic/</a>
11.2.1 (part) Naming organic compounds	Name and draw the structural and displayed formulae of unbranched: (b) ethene	
11.2.3 (part) Naming organic compounds	Name and draw the structural and displayed formulae of unbranched: (b) alkenes, including but-1-ene and but-2-ene containing up to four carbon atoms per molecule	
11.5.2 Alkenes	Describe the manufacture of alkenes and hydrogen by the cracking of larger alkane molecules using a high temperature and a catalyst  Describe the reasons	<u>Cracking</u> Learners research why cracking continues to be a major industrial process worldwide. Discuss that there is an excess of large hydrocarbons produced during the fractional distillation of crude oil. Large hydrocarbons are cracked to produce smaller alkanes that can be converted into petrol. Short chain length alkenes are also produced during this process which are very useful intermediates in industry.  <b>Experiment:</b> Cracking hydrocarbons in liquid paraffin with a catalyst: <a href="https://edu.rsc.org/resources/cracking-hydrocarbons/681.article">https://edu.rsc.org/resources/cracking-hydrocarbons/681.article</a> Perform the experiment and/or watch the video within the link. In the experiment,



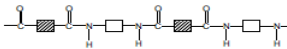
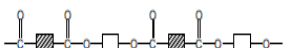
Syllabus ref.	Learning objectives	Suggested teaching activities
11.5.3 Alkenes	for the cracking of larger alkane molecules	liquid paraffin (containing alkanes of chain length 5-15 carbon atoms), is cracked producing short chain length alkenes. These are tested with bromine water (which becomes decolourised).
11.5.4 Alkenes	Describe the test to distinguish between saturated and unsaturated hydrocarbons by their reaction with aqueous bromine	<b>Experiment:</b> Testing for unsaturation This video shows how to do the test for unsaturated hydrocarbons using bromine water: <a href="http://www.youtube.com/watch?v=ZXcS3oY9wQo">www.youtube.com/watch?v=ZXcS3oY9wQo</a>
11.5.5 Alkenes	State that in an addition reaction only one product is formed	a) <u>With bromine</u> Illustrate the addition reaction with bromine and ethene first. Since the reaction, mechanistically, is complex for this level, the explanation and equation shown in the following page is sufficient: <a href="http://www.bbc.co.uk/bitesize/guides/z3v4xfr/revision/2">www.bbc.co.uk/bitesize/guides/z3v4xfr/revision/2</a> (go to 'Reactions of alkenes') Learners could use molecular models to help them remember this reaction.
11.5.6 Alkenes	Describe the properties of alkenes in terms of addition reactions with: (a) bromine or bromine water (b) hydrogen in the presence of a nickel catalyst (c) steam in the presence of an acid catalyst and draw the structural or displayed formulae of the products	Emphasise that this reaction occurs because the double bond is the reactive part of the molecule and that alkanes cannot undergo this reaction. As in the page above, ask learners to predict the structure of the products formed when propene and but-1-ene react with aqueous bromine.  b) <u>Hydrogenation</u> This reaction cannot easily be performed in the laboratory. Learners need to know that an alkene, in the presence of a nickel catalyst, undergoes an addition reaction with hydrogen, producing the saturated analogue: <a href="http://www.bbc.co.uk/bitesize/guides/z3v4xfr/revision/2">www.bbc.co.uk/bitesize/guides/z3v4xfr/revision/2</a> (go to 'Reactions of alkenes')  c) <u>Hydration</u> This is the name given to the reaction of an alkene with steam at 300°C and a catalyst. This reaction cannot easily be performed in the laboratory: <a href="http://www.bbc.co.uk/bitesize/guides/z3v4xfr/revision/2">www.bbc.co.uk/bitesize/guides/z3v4xfr/revision/2</a> (go to 'Reactions of alkenes')  <b>Extension: Stretch and prepare for A level</b> Learners investigate the reaction of propene with HCl. They find out why there are two possible products and why one is the major product and one is produced in much lesser quantities. <a href="http://www.chemguide.co.uk/organicprops/alkenes/hhal.html">www.chemguide.co.uk/organicprops/alkenes/hhal.html</a> (go to 'Addition to unsymmetrical alkenes')

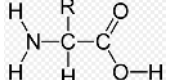
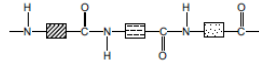
Syllabus ref.	Learning objectives	Suggested teaching activities
11.1.2 (part) Formulae, functional groups and terminology	Write and interpret general formulae of compounds in the same homologous series limited to: (c) alcohols $C_nH_{2n+1}OH$	<u>The Alcohols</u> Molecular model-building activity: Using kits or virtually, learners build the first few members of the series. You can either provide them with the formula for the homologous series or they can determine it afterwards. Guide learners on how to name the alcohols.  <u>Ethanol</u> Explain the significance of ethanol industrially and that it has many uses, for example as a solvent and a fuel. Details in this page: <a href="http://www.essentialchemicalindustry.org/chemicals/ethanol.html">www.essentialchemicalindustry.org/chemicals/ethanol.html</a>
11.2.1 (part) Naming organic compounds	Name and draw the displayed formulae of unbranched: (c) ethanol	You could ask learners to research the uses of ethanol as a solvent for a short assignment (for example: cosmetics, food colourings and flavourings, medicinal preparations, cleaning agents and as an industrial solvent).  There are two main methods of preparing ethanol industrially:
11.2.3 (part) Naming organic compounds	Name and draw the structural and displayed formulae of unbranched: (c) alcohols, including propan-1-ol, propan-2- ol, butan-1-ol and butan-2-ol containing up to four carbon atoms per molecule	a) <u>Manufacture of ethanol by fermentation</u> <b>Experiment:</b> Fermentation of sucrose Learners set up this experiment and after about a week, distil the ethanol produced. The preparation is at: <a href="http://home.miracosta.edu/dlr/210exp5.htm">http://home.miracosta.edu/dlr/210exp5.htm</a> You could link this to anaerobic respiration, for learners studying biology.  Learners who need less support could calculate the amounts of reagents involved in the preparation and the percentage yield of ethanol produced.
11.6.3 Alcohols	State the uses of ethanol as: (a) a solvent (b) a fuel	b) <u>Manufacture of ethanol by the catalytic addition of steam to ethene.</u> Learners need to know the basic chemical equation for the reaction. They also need to appreciate that a high temperature and pressure is required and a catalyst.
11.6.1 Alcohols	Describe the manufacture of ethanol by: (a) fermentation of aqueous glucose at 25–35 °C in the presence of yeast and in the	<b>Extension activity: Stretch and prepare for A Level</b> Learners investigate what type of process this is. (a dynamic equilibrium) They make predictions about changing the effects of pressure and temperature: <a href="http://www.chemguide.co.uk/physical/equilibria/ethanol.html">www.chemguide.co.uk/physical/equilibria/ethanol.html</a>  Because ethanol is such an important substance, learners should compare the advantages and disadvantages of the two processes: <a href="http://www.bbc.co.uk/bitesize/guides/z8sb2p3/revision/3">www.bbc.co.uk/bitesize/guides/z8sb2p3/revision/3</a> The advantages and disadvantages of making ethanol by each method

Syllabus ref.	Learning objectives	Suggested teaching activities
11.6.4 Alcohols	<p>absence of oxygen (b) catalytic addition of steam to ethene at 300 °C and 6000 kPa / 60 atm in the presence of an acid catalyst</p> <p>Describe the advantages and disadvantages of the manufacture of ethanol by: (a) fermentation (b) catalytic addition of steam to ethene</p>	
11.6.2 Alcohols	Describe the combustion of ethanol	<p><u>Complete combustion</u> If possible, perform the experiment below to determine the products of complete combustion.</p> <p><b>Experiment:</b> Determination of the products of combustion Limewater is used to detect CO<sub>2</sub>(g) and cobalt chloride paper is used to detect H<sub>2</sub>O: <a href="https://edu.rsc.org/resources/identifying-the-products-of-combustion/707.article">https://edu.rsc.org/resources/identifying-the-products-of-combustion/707.article</a> (Identifying the products of combustion)</p> <p><b>Experiment:</b> Calculating the energy produced per gram of fuel for a range of alcohols Methanol, ethanol, propanol and butanol are burned and the heat produced used to raise the temperature of a known mass of water: <a href="http://www.bbc.co.uk/bitesize/guides/z2jndx/revision/4">www.bbc.co.uk/bitesize/guides/z2jndx/revision/4</a></p> <p>Learners write and balance equations for a range of different alcohols: <a href="http://www.passmyexams.co.uk/GCSE/chemistry/combustion-of-alcohols.html">www.passmyexams.co.uk/GCSE/chemistry/combustion-of-alcohols.html</a> [equations for burning methanol, ethanol, propanol and butanol]</p> <p>For learners who find balancing equations difficult this reference is useful: <a href="http://www.open.edu/openlearn/ocw/mod/oucontent/view.php?id=83424&amp;section=2.2.1">www.open.edu/openlearn/ocw/mod/oucontent/view.php?id=83424&amp;section=2.2.1</a></p> <p><u>Incomplete combustion</u></p>

Syllabus ref.	Learning objectives	Suggested teaching activities
		<p>Encourage learners to find out about what happens when there is not enough oxygen available for complete combustion. Discuss the formation of carbon (soot) and carbon monoxide.</p> <p>Talk about smoky (yellow) flames and how they are created.</p> <p>Demonstrate with a bunsen burner. Discuss what difference it makes to the colour and nature of the flame when the air hole is open and closed.</p>
11.1.2 (part) Formulae, functional groups and terminology	Write and interpret general formulae of compounds in the same homologous series, limited to: (d) carboxylic acids $C_nH_{2n+1}COOH$	<p><u>Carboxylic acids</u> <u>Molecular model-building activity</u></p> <p>As with the homologous series above, build models or explore them using computer simulations. Write down the first four unbranched members of the homologous series and show that the general formula for this series is <math>C_nH_{2n+1}COOH</math></p> <p>Carboxylic acids are weak acids. Ask learners for examples of weak acids. They will probably know ethanoic acid (acetic acid).</p> <p>Show them a sample from the lab and/or a bottle of vinegar. Let them smell it to help recall this substance.</p>
11.2.1 (part) Naming organic compounds	Name and draw the displayed formulae of unbranched: (d) ethanoic acid	Learners can do test-tube reactions with reactive metals (such as magnesium), with bases and carbonates. They name the salts produced. Naming and writing formulae of the salts of carboxylic acids can be confusing for learners. For example, when magnesium reacts with ethanoic acid, the salt formed $(CH_3COO)_2Mg$ is called magnesium ethanoate.
11.2.3 (part) Naming organic compounds	Name and draw the structural and displayed formulae of unbranched: (d) carboxylic acids containing up to four carbon atoms per molecule	<p><b>Experiment:</b> The acidic reactions of ethanoic acid compared to hydrochloric acid of the same concentration <a href="https://edu.rsc.org/resources/the-acidic-reactions-of-ethanoic-acid/462.article">https://edu.rsc.org/resources/the-acidic-reactions-of-ethanoic-acid/462.article</a> [reactions with Mg, sodium carbonate, copper carbonate, sodium hydroxide).</p>
11.7.1 Carboxylic acids	Describe the reactions of ethanoic acid with: (a) metals (b) bases (c) carbonates including names and formulae of the salts produced	

Syllabus ref.	Learning objectives	Suggested teaching activities
11.7.2 Carboxylic acids	Describe the formation of ethanoic acid by the oxidation of ethanol: (a) with acidified aqueous potassium manganate(VII) (b) by bacterial oxidation during vinegar production	This video shows the method to carry out a test-tube reaction: <a href="http://www.youtube.com/watch?v=d7pCdCg84_E">www.youtube.com/watch?v=d7pCdCg84_E</a>  For the oxidation of ethanol to ethanoic acid using bacteria (acetobacter), oxygen must be present for this process to occur. This page discusses the balanced chemical equation for the reaction: <a href="http://www.savemyexams.co.uk/igcse-chemistry-edexcel-new/revision-notes/alcohols/alcohols-oxidation-reactions-of-ethanol/">www.savemyexams.co.uk/igcse-chemistry-edexcel-new/revision-notes/alcohols/alcohols-oxidation-reactions-of-ethanol/</a>  <b>Experiment:</b> The oxidation of ethanol to ethanoic acid (via ethanal) <a href="https://edu.rsc.org/resources/oxidation-of-ethanol/1757.article">https://edu.rsc.org/resources/oxidation-of-ethanol/1757.article</a>
11.7.3 Carboxylic acids	Describe the reaction of a carboxylic acid with an alcohol using an acid catalyst to form an ester	Since the structures are relatively complicated for this level, start with an example pair of molecules and show how a molecule of water is lost, producing an ester. After writing the structure, explain how the ester is named. <a href="http://www.docbrown.info/page04/OilProducts10b.htm">www.docbrown.info/page04/OilProducts10b.htm</a> [explains the reaction, chemical equation and how to name esters]  <b>Experiment:</b> Making esters from alcohols and acids <a href="https://edu.rsc.org/resources/making-esters-from-alcohols-and-acids/1743.article">https://edu.rsc.org/resources/making-esters-from-alcohols-and-acids/1743.article</a> A range of alcohols and acids are reacted to produce various esters. The esters are characterised by their odour.
11.2.4 Naming organic compounds	Name and draw the displayed formulae of the unbranched esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms	<b>Resource Plus</b> Carry out the <i>Making esters</i> experiment referring to the Teaching Pack for lesson plans and resources.
11.8.1 Polymers	Define polymers as large molecules built up from many smaller molecules called monomers	<u>Addition Polymers</u> Provide an example of a polymer, such as the polymerisation of ethene to give polythene, and use this to give the definition.  Mention that ethene is produced in large quantities via the cracking of alkanes discussed in section 11.5.2 Alkenes. Also mention that plastics are made from polymers and that there are many types of plastics depending on the monomer used.
11.8.2 Polymers	Describe the formation of poly(ethene) as an example of addition polymerisation using ethene monomers	Polyethene: draw several ethene monomer units and then the resulting polymer, pointing out that the unsaturated monomer starting material becomes a saturated product with an extremely long chain.  Next, give learners plenty of practice drawing the formation of polymer molecules using, for example: chloroethene,

Syllabus ref.	Learning objectives	Suggested teaching activities
11.8.3 Polymers	State that plastics are made from polymers	propene, chloroethene and phenylethene (styrene).
11.8.6 Polymers	Identify the repeat units and/or linkages in addition polymers and in condensation polymers	After this, provide learners with polymer molecule structures where they have to work in reverse to identify the monomer which was used to produce the polymer.
11.8.7 Polymers	Deduce the structure or repeat unit of an addition polymer from a given alkene and vice versa	This page highlights how the repeating unit in polychloroethene is identified: <a href="http://www.bbc.co.uk/bitesize/guides/zyfgmnb/revision/1">www.bbc.co.uk/bitesize/guides/zyfgmnb/revision/1</a>
11.8.8 Polymers	Deduce the structure or repeat unit of a condensation polymer from given monomers and vice versa, limited to: (a) polyamides from a dicarboxylic acid and a diamine (b) polyesters from a dicarboxylic acid and a diol	<u>Polyamides</u> Demonstration: The nylon rope trick Nylon can be made in the laboratory as a demonstration experiment using the starting materials, 1,6-diaminohexane and decanedioyl dichloride: <a href="https://edu.rsc.org/resources/making-nylon-the-nylon-rope-trick/755.article">https://edu.rsc.org/resources/making-nylon-the-nylon-rope-trick/755.article</a>
11.8.10 Polymers	Describe and draw the structure of (a) nylon, a polyamide  (b) PET, a polyester  The full name for PET, polyethylene terephthalate	<b>Resource Plus</b> Carry out the <i>Making nylon</i> experiment referring to the Teaching Pack for lesson plans and resources.
		If the experiment cannot be performed in the classroom, learners can watch the synthesis in this video: <a href="http://www.youtube.com/watch?v=INWc6xUf6U4">www.youtube.com/watch?v=INWc6xUf6U4</a> (nylon synthesis)
		When drawing the structures of the reactants and products of these type of reactions, only the reactive parts of the molecule need be drawn. The rest of the molecule can be represented by a 'block' as shown in the learning objective. It is important to highlight the fact that a small molecule is lost or 'condensed' during the process of condensation polymerisation as shown in this page: <a href="http://www.chemguide.uk/organicprops/amides/polyamides.html">www.chemguide.uk/organicprops/amides/polyamides.html</a> (nylon and Kevlar)
		Make sure that learners know that proteins contain the same amide linkage because they are natural polyamides.
		<u>Polyesters</u> Draw the structures hexanedioic acid and ethane diol on the board. Replace the unreactive parts with blocks as shown in the learning objective. Next, highlight the –OH group in the diacid and the –H atom in the diol

Syllabus ref.	Learning objectives	Suggested teaching activities
11.8.9 Polymers	terephthalate, is <b>not</b> required.  Describe the difference between addition and condensation polymerisation	Finally draw the polymer, this time highlighting the ester linkage and the molecules of water that have been condensed/eliminated from the molecule.  As with addition polymers, learners should be able to identify the monomers when given a polyester or polyamide of different structure.
11.8.12 Polymers	Describe proteins as natural polyamides and that they are formed from amino acid monomers with the general structure,  where R represents different types of side chain	<b>Resource Plus</b> Carry out the <i>Natural polymers - The hydrolysis of starch by acid and enzyme</i> experiment referring to the Teaching Pack for lesson plans and resources.
11.8.13 Polymers	Describe and draw the structure of proteins as: 	
11.8.4 Polymers	Describe how the properties of plastics have implications for their disposal	<u>Research project</u> Learners could carry out a project on this topic to coincide with Earth Day (which occurs on 22 <sup>nd</sup> April annually). It is also important to relate this topic to your local environment which will engage learners more fully.
11.8.5 Polymers	Describe the environmental challenges caused by plastics, limited to: (a) disposal in land fill sites (b) accumulation in	Learners research the current situation regarding recycling plastics, the methods implemented in their countries, the environmental challenges caused by burning plastics, plastic accumulation in the oceans and in landfill sites. They could also present information about PET and how it can be converted back into monomers and recycled. Learners could present their findings by making a video or podcast, drawing posters on paper or using computers, or making presentations to the class/assembly. Learners should focus on presenting a balanced view for each aspect of this project and should also put forward ideas of their own and how they feel the plastic problem might be solved.  Some useful links:

Syllabus ref.	Learning objectives	Suggested teaching activities
11.8.11 Polymers	oceans (c) formation of toxic gases from burning  State that PET can be converted back into monomers and re-polymerised	<a href="http://www.rsc.org/globalassets/04-campaigning-outreach/policy/environment-health-safety-policy/plastics-sustainability.pdf">www.rsc.org/globalassets/04-campaigning-outreach/policy/environment-health-safety-policy/plastics-sustainability.pdf</a> (Sustainable Plastics – the role of chemistry) <a href="https://theoceancleanup.com/great-pacific-garbage-patch/">https://theoceancleanup.com/great-pacific-garbage-patch/</a> (The ocean garbage patch) <a href="http://www.nationalgeographic.com/environment/2019/03/should-we-burn-plastic-waste/">www.nationalgeographic.com/environment/2019/03/should-we-burn-plastic-waste/</a> (burning plastics) <a href="http://www.nationalgeographic.com/news/2017/07/plastic-produced-recycling-waste-ocean-trash-debris-environment/">www.nationalgeographic.com/news/2017/07/plastic-produced-recycling-waste-ocean-trash-debris-environment/</a> (plastic waste/landfill) <a href="http://www.theguardian.com/environment/2019/aug/17/plastic-recycling-myth-what-really-happens-your-rubbish">www.theguardian.com/environment/2019/aug/17/plastic-recycling-myth-what-really-happens-your-rubbish</a> (plastic recycling is a myth)
<b>Past and specimen papers</b>		
Past/specimen papers and mark schemes are available to download at <a href="http://www.cambridgeinternational.org/support">www.cambridgeinternational.org/support</a> (F)		



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