Edexcel GCSE (9–1) Chemistry (separate sciences)
2-year scheme of work

This document provides a scheme of work for teaching the Pearson Edexcel GCSE (9-1) Chemistry specification in 2 years.

Bold text indicates that the content is for Higher Tier only. An asterisk indicates that you may have covered the specification point if you have been using our transition materials.

The document currently contains exemplar teaching activities and notes on differentiation, but not for all topics. We will update it with this level of detail for the remainder of the course over the coming months. The suggested length for each lesson is indicated next to the title.

Not all of the suggested practicals from the specification have been covered in this scheme of work. Alternative suggested practicals could be substituted into the lessons given here.

C1 States of matter				
Lesson SC1a: States of matter (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C2.1: Describe the arrangement, movement and the relative energy of particles in each of the three states of matter: solid, liquid and gas • *C2.2: Recall the names used for the interconversions between the three states of matter, recognising that these are physical changes: contrasted with chemical reactions that result in chemical changes • *C2.3: Explain the changes in arrangement, movement and energy of particles during these interconversions • *C2.4: Predict the physical state of a substance under specified conditions, given suitable data	*Starter* In pairs, students draw and write what they know about the particles in the three states of matter. *Exploring* Students draw a cooling curve for water from its gas state to its solid state. They add labels to show the state at each temperature range, where the state changes are happening and what they are, and sketch particle diagrams for each state. *Explaining* Teacher demonstration of sublimation and deposition of iodine. Discuss the changes in arrangement, closeness and movement of the particles in the state changes.	*Exploring* Support: Show a heating curve for water but without particle diagrams. Stretch: Challenge students to think about the limitations of the particle model diagrams. *Explaining* Support: Sublimation is usually easier to explain than deposition, as energy must be transferred from the surroundings to separate the particles. Stretch: Introduce idea of molecules and weak intermolecular forces. Energy transferred to the surroundings by heating from the store of chemical energy in the particles.	• Make estimates of the results of simple calculations • Translate information between graphical and numeric forms • Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	Teacher demonstration of sublimation and deposition of iodine. (See *Explaining*.)

C2 Methods of separating and purifying substances				
Lesson SC2a: Mixtures (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C2.5: Explain the difference between the use of 'pure' in chemistry compared with its everyday use and the differences in chemistry between a pure substance and a mixture • C2.6: Interpret melting point data to distinguish between pure substances which have a sharp melting point and mixtures which melt over a range of temperatures	*Starter* Match the melting points to the materials. *Exploring* Students draw a cooling curve for water from its gas state to its solid state. They add labels to show the state at each temperature range, where the state changes are happening and what they are, and sketch particle diagrams for each state. *Explaining* Demonstrate the melting of a pure and an impure substance.	*Exploring* Support: Show a heating curve for water but without particle diagrams. Stretch: Challenge students to think about the limitations of the particle model diagrams. *Explaining* Support: Show students a video of melting displaying the temperature against time data for the substance used. Stretch: Discuss how to extract data from a datalogger into a spreadsheet and then present this in graphical form.	• Recognise and use expressions in decimal form	Demonstrate the difference between the way pure and impure samples of a solid melt. (See *Explaining*.)

Lesson SC2b: Filtration and crystallisation (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C2.7: Explain the experimental techniques for separation of mixtures by ... c) filtration d) crystallisation ... • C0.6: Evaluate the risks in a practical procedure and suggest suitable precautions for a range of practicals including those mentioned in the specification	*Starter* Hold up a range of pieces of apparatus and ask what each one is. Ask students to show how they would draw each as part of a diagram. *Exploring* Students plan an investigation to identify which one of three samples of rock salt contains the largest quantity of salt. *Explaining* Demonstrate how to heat to dryness safely. Use the demonstration to compare the crystal sizes produced when forming crystals quickly, using a Bunsen burner, and those produced by slow evaporation.	*Exploring* Support: Give students equal volumes of salt solutions of different concentrations. The task could then be refocused on just the separation technique. Stretch: Allow students to record the mass of the rock salt before, and after crystallisation. *Explaining* Support: Ask students to note down any words they do not understand as you carried out the demonstration. Use these words as the basis for planning for the next lesson, to ensure full understanding of these key words. Stretch: Challenge students to draw annotated diagrams to explain why crystals are bigger when their crystallisation time is slower.	n/a	Demonstrate how to heat to dryness safely. (See *Explaining*.)

Lesson SC2c: Paper chromatography (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C2.7: Explain the experimental techniques for separation of mixtures by ... e) paper chromatography • C2.9: Describe paper chromatography as the separation of mixtures of soluble substances by running a solvent (mobile phase) through the mixture on the paper (the paper contains the stationary phase), which causes the substances to move at different rates over the paper • C2.10: Interpret a paper chromatogram a) to distinguish between pure and impure substances b) to identify substances by comparison with known substances c) to identify substances by calculation and the use of R_f values • *C2.11: Core Practical: Investigate the composition of inks using simple distillation and paper chromatography*	*Starter* Pre-prepare a chromatogram. Show the chromatogram to students and ask them for key words to help in describing how this has been created. *Exploring* Students use chromatography to compare the mixtures of dyes in the inks used in black marker pens or felt-tip pens. (*Core Practical.)* *Explaining* Demonstrate to students how to use chromatography to analyse mixtures of amino acids.	*Exploring* Support: Help students to write a simple plan for their investigation, and check that their apparatus is set up correctly to obtain suitable chromatograms. Stretch: Some of the pens provided could contain water-soluble inks and some could contain permanent inks. *Explaining* Support: Ask students to suggest why water isn't used in the procedure – elicit the idea that different substances may need different solvents to dissolve them. Stretch: Ask students to list the differences between this procedure and the one they carried out in *Exploring*, and to suggest reasons for as many differences as they can.	• Understand and use the symbols: $=$, $<>$, $>$, $\propto$, $\sim$ • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Translate information between graphical and numeric form	*Core Practical: Investigate the composition of inks using simple distillation and paper chromatography.* (See *Exploring*.) Demonstrate to students how to use chromatography to analyse mixtures of amino acids. (See *Explaining*.)

Lesson SC2d: Distillation (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C2.7: Explain the experimental techniques for separation of mixtures by … b) fractional distillation c) filtration … • C0.6: Evaluate the risks in a practical procedure and suggest suitable precautions for a range of practicals including those mentioned in the specification • *C2.11: Core practical: Investigate the composition of inks using simple distillation and paper chromatography*	*Starter* Show students a bottle or flask containing a solution. Ask students if you can separate the water from the dissolved solid by filtering the solution. Discuss why not. *Exploring* Students use simple distillation apparatus to purify ink. (*Core practical*.) *Explaining* Demonstrate the fractional distillation process using a Liebig condenser and an ethanol/water mixture.	*Exploring* Support: Demonstrate the procedure first, showing how to clamp the flask and how to heat it gently. Stretch: Give students a list of available apparatus and ask them to design their own set-up. *Explaining* Support: You could ask students to write down one thing they feel they know well and one thing about which they would like further clarification. Stretch: Set a challenge for students to make a quantitative estimate of the composition based on the density figures given on the worksheet.	n/a	*Core practical: Investigate the composition of inks using simple distillation and paper chromatography.* (See *Exploring*.) Demonstrate the fractional distillation process using a Liebig condenser and an ethanol/water mixture. (See *Explaining*.)

Lesson SC2e: Drinking water (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C2.8: Describe an appropriate experimental technique to separate a mixture, knowing the properties of the components of the mixture • C0.6: Evaluate the risks in a practical procedure and suggest suitable precautions for a range of practicals including those mentioned in the specification • C2.12: Describe how: a) waste and ground water can be made potable, including the need for sedimentation, filtration and chlorination b) sea water can be made potable by using distillation c) water used in analysis must not contain any dissolved salts	*Starter* In pairs, students write down ways in which tap water is used. *Exploring* Complete an organising squares activity about the main stages of the water treatment process. *Explaining* Demonstrate a simple solar still.	*Exploring* Support: Give students an annotated diagram summarising the main stages in water treatment. Stretch: Challenge students to devise their own organising squares activity. It must have a unique solution and the clues must be sufficient to solve the puzzle. *Explaining* Support: Show the standard laboratory equipment for simple distillation for comparison with the components of the solar still. Stretch: Challenge students to identify and evaluate the advantages and disadvantages of the solar still compared with standard laboratory apparatus.	n/a	Demonstrate a simple solar still. (See *Explaining*.)

C3 Atomic structure				
Lesson SC3a: Structure of an atom (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C1.1: Describe how the Dalton model of an atom has changed over time because of the discovery of subatomic particles • *C1.2: Describe the structure of an atom as a nucleus containing protons and neutrons, surrounded by electrons in shells • *C1.3: Recall the relative charge and relative mass of: a) a proton b) a neutron c) an electron • *C1.4: Explain why atoms contain equal numbers of protons and electrons • *C1.5: Describe the nucleus of an atom as very small compared to the overall size of the atom	*Starter* Write the word 'atoms' in the centre of the board, then write the words 'matter', 'elements', 'compounds', 'particles', 'structure' and 'John Dalton', around them in a rough circle. Ask students to write down as many links as they can between the term 'atoms' and the words around it. *Exploring* Ask students to use a variety of resources to make an atomic model. The model should be three-dimensional and show the arrangement of the subatomic particles. *Explaining* Construct a model of an atom for students to consider.	*Exploring* Support: Some students may need support by having access to drawings of atomic models or one or two pre-prepared models to look at. Stretch: Some students could be asked to evaluate their model in terms of the relative size of the particles and spaces between them. *Explaining* Support: Show students drawings of the nuclear atom. Stretch: Challenge students to suggest ways in which the model could be altered to make it better.	• Make estimates of the results of simple calculations	n/a

Lesson SC3b: Atomic mass and number (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.6: Recall that most of the mass of an atom is concentrated in the nucleus • *C1.7: Recall the meaning of the term mass number of an atom • *C1.8: Describe atoms of a given element as having the same number of protons in the nucleus and that this number is unique to that element • C1.10: Calculate the numbers of protons, neutrons and electrons in atoms given the atomic number and mass number	*Starter* Students brainstorm everything they know about the periodic table and produce a diagram or bulleted list of points. *Exploring* Students work in small groups to role play the structure of atoms of simple elements (restrict to hydrogen, helium, lithium and beryllium). *Explaining* Display the nuclide notation (symbol) for some simple atoms on the board, and initiate a class discussion on how models of the nuclei of these atoms could be made.	*Exploring* Support: Some students may need reminding of the meaning of atomic number (*Z*) and mass number (*A*) and may also need help in working out the numbers of subatomic particles. Stretch: Challenge students to evaluate their models and suggest how they could improve them in terms of scale. *Explaining* Support: Some students may need more detailed help with calculations of atomic numbers and mass numbers. Stretch: Ask students to construct a GCSE-type question, and marking scheme, on atomic structures and notations. The question should be in the form of a table with missing information to complete.	• Change the subject of an equation	n/a

Lesson SC3c: Isotopes (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C1.9: Describe isotopes as different atoms of the same element containing the same number of protons but different numbers of neutrons in their nuclei • *C1.10: Calculate the numbers of protons, neutrons and electrons in atoms given the atomic number and mass number • *C1.11: Explain how the existence of isotopes results in some relative atomic masses of some elements not being whole numbers • ***C1.12: Calculate the relative atomic mass of an element from the relative masses and abundances of its isotopes**	*Starter* Write the following terms on the board: element, atom, nucleus, protons, neutrons, electrons and electron shells. Ask students to work in pairs to write one sentence that contains all the terms. *Exploring* Give students six boxes containing a set number of heavy gauge washers (e.g. 1 box containing 2 washers, 3 boxes containing 4 washers and 2 boxes containing 6 washers). Tell students the mass of the *empty* boxes. Working in groups, students measure the masses of the boxes and work out the mass of their contents. Students then carry out calculations on the relative masses of the contents of the boxes. *Explaining* Ask students to write down their definition of an element. Then, using polystyrene balls and sticky pads, demonstrate the structure of the nuclei of different isotopes of lithium (Li-6 and Li-7). Electrons could be added to the models but would need to be removed before measuring their masses.	*Exploring* Support: Go through exemplar calculations before encouraging students to do the remaining calculations independently. Stretch: Students could evaluate the model they have used. *Explaining* Support: Some students will need help wording their best definition of an element to include the idea of isotopes. You could give them particular words to include in their definition. Stretch: Challenge students to do some research to find out why some isotopes are described as being 'stable' and to find the name of the element with the largest number of stable isotopes (tin).	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Understand and use the symbols: $=$, $<$, $\ll$, $\gg$, $>$, $\propto$, $\sim$ • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities	n/a

<table>
<tr><td colspan="5">C4 The periodic table</td></tr>
<tr><td colspan="5">Lesson SC4a: Elements and the periodic table (1 hour)</td></tr>
<tr><td>Specification points</td><td>Exemplar teaching activities</td><td>Differentiation</td><td>Maths skills</td><td>Practicals</td></tr>
<tr><td>• *C1.13: Describe how Mendeleev arranged the elements, known at that time, in a periodic table by using properties of these elements and their compounds
• *C1.14: Describe how Mendeleev used his table to predict the existence and properties of some elements not then discovered
• C0.1: Recall the formulae of elements, simple compounds and ions</td><td>Starter
Draw nine shapes on the board, e.g. three squares, three circles and three triangles. For each shape, leave one unshaded, one half shaded, and one completely shaded. Students sort the shapes into groups, thinking about different ways of grouping.

Exploring
Students predict the properties of three elements (sodium, germanium and bromine) using the properties of the two elements above and below them.

Explaining
Show how properties of an element in groups 1 and 7 can be predicted using the properties of nearby elements in the same group.</td><td>Exploring
Support: Work through the process of making one prediction for the students to use as a model in order to complete the other predictions.
Stretch: Describe germanium as a 'semi-metal' or 'metalloid', and ask the students to suggest what this means.

Explaining
Support: Suggest why these properties were chosen for these two groups.
Stretch: Challenge students to identify and evaluate the limits of these predictions.</td><td>n/a</td><td>Show samples of lithium, potassium, sodium, chlorine, iodine, bromine. (See Explaining.)</td></tr>
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Lesson SC4b: Atomic number and the periodic table (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C1.15: Explain that Mendeleev thought he had arranged elements in order of increasing relative atomic mass but this was not always true because of the relative abundance of isotopes of some pairs of elements in the periodic table • *C1.16: Explain the meaning of atomic number of an element in terms of position in the periodic table and number of protons in the nucleus • *C1.17: Describe that in the periodic table a) elements are arranged in order of increasing atomic number, in rows called periods b) elements with similar properties are placed in the same vertical columns called groups • *C1.18: Identify elements as metals or non-metals according to their position in the periodic table, explaining this division in terms of the atomic structures of the elements	*Starter* Write key words to do with atomic structure on the board; students write (or match) definitions for the words. *Exploring* Complete an organising squares activity about the atomic numbers and the periodic table. *Explaining* Demonstration to compare the reactions of calcium and magnesium with those of aluminium and sulfur, to illustrate group properties and changes across a period.	*Exploring* Support: Sow students how to complete one of the squares using the clues. Stretch: Challenge students to devise their own organising squares activity. It must have a unique solution and the clues must be sufficient so that the puzzle can be solved. *Explaining* Support: Discuss the reasons for choosing these particular elements. Stretch: Identify the products and write equations for the reactions.	n/a	Demonstration to compare the reactions of calcium and magnesium with those of aluminium and sulfur, to illustrate group properties and changes across a period. (See *Explaining*.)

Lesson SC4c: Electronic configurations and the periodic table (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C1.19: Predict the electronic configurations of the first 20 elements in the periodic table as diagrams and in the form, for example, 2.8.1 • *C1.20: Explain how the electronic configuration of an element is related to its position in the periodic table	*Starter* Draw diagrams to show the electronic configurations for sodium and oxygen, and write their configurations as 2.8.1 and 2.6. Challenge students to spot the links between these models. *Exploring* Chalk four circles on the ground to represent electron shells. Students occupy each circle following rules for electronic configurations, to illustrate given atoms. *Explaining* Students produce element sheets for the first 20 elements (one per student) then the class arranges the sheets into atomic number order.	*Exploring* Support: Direct students to occupy a particular circle (‘shell’); e.g. by calling out the name of an element and then reading out the number of electrons in each successive shell. Stretch: Give groups of students an element, then they build their electronic configuration without assistance. *Explaining* Support: Give students an 'easier' element to do, e.g. H to Ne. Direct students where to place their sheets on the floor. Stretch: Give students a more 'difficult' element to do, e.g. Na to Ca.	• Translate information between graphical and numeric form • Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	n/a

C5 Ionic bonding				
Lesson SC5a: Ionic bonds (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.21: Explain how ionic bonds are formed by the transfer of electrons between atoms to produce cations and anions, including the use of dot and cross diagrams • C1.22: Recall that an ion is an atom or group of atoms with a positive or negative charge • C1.23: Calculate the numbers of protons, neutrons and electrons in simple ions given the atomic number and mass number • C1.24: Explain the formation of ions in ionic compounds from their atoms, limited to compounds of elements in groups 1, 2, 6 and 7 • C0.1: Recall the formulae of elements, simple compounds and ions	*Starter* Demonstrate electrostatic forces using polythene and acetate rods. *Exploring* Students work in groups to devise a script for a role-play on the formation of ions. *Explaining* Demonstrate the electrolysis of copper chloride solution. Give students the atomic number, mass number and ion charges of the ions ($^{63}_{29}Cu^{2+}$ and $^{35}_{17}Cl^{-}$). Ask students to write a description of the change at each electrode by writing symbols of ions and atoms, with numbers of protons, neutrons and electrons.	*Exploring* Support: Show students what they are going to model, using a dot and cross diagram on the board, before they start their challenge. Stretch: Ask students to model a compound with multiple ionic bonds rather than just MgO or NaCl. *Explaining* Support: Some students will need help with using the information (nuclide notation) to work out the number of protons, neutrons and electrons. Stretch: Ask students to find out about ion electron half equations and how they represent the changes that are occurring.	• Use ratios, fractions and percentages • Change the subject of an equation • Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	Demonstrate electrostatic forces. (See *Starter*.) Demonstrate the electrolysis of copper chloride solution. (See *Explaining*.)

Lesson SC5b: Ionic lattices (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.25: Explain the use of the endings –ide and –ate in the names of compounds • C1.26: Deduce the formulae of ionic compounds (including oxides, hydroxides, halides, nitrates, carbonates and sulfates) given the formulae of the constituent ions • C1.27: Explain the structure of an ionic compound as a lattice structure a) consisting of a regular arrangement of ions b) held together by strong electrostatic forces (ionic bonds) between oppositely-charged ions • C0.1: Recall the formulae of elements, simple compounds and ions	*Starter* Write up sets of key words on the board: atom/molecule/bond; element/compound /react; ions/electrons/atoms; metal/non-metal/periodic table; atom/ion/noble gas. Students write a sentence using the words in each set. *Exploring* Students follow instructions and use information about ionic bonds, ion size and electrostatic forces to make and evaluate a model of the ion structure in sodium chloride. *Explaining* Demonstrate how ionic formulae can be worked out using the cross-over method. Students work in groups to try further examples.	*Exploring* Support: Some students will need help to follow the instructions and start their models. Stretch: Students make a poster to explain the lattice to other students. *Explaining* Support: Some students may need help with the cross over method and working through additional examples before attempting them on their own or in small groups. Stretch: Students carry out research to find out about the lattice structure of more complex compounds.	• Use ratios, fractions and percentages • Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	n/a

Lesson SC5c: Properties of ionic compounds (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.33: Explain the properties of ionic compounds limited to: a) high melting points and boiling points, in terms of forces between ions b) whether or not they conduct electricity as solids, when molten and in aqueous solution	*Starter* Demonstration to show that solid sodium chloride crystals do not conduct electricity but that sodium chloride solution does. *Exploring* Investigation to identify ionic compounds. (*Suggested practical.*) *Explaining* Demonstrate the electrolysis of molten zinc chloride, and explain what happens during the electrolysis using a model or digital animation.	*Exploring* Support: Students may need help in setting up the circuit, and in recording their results. Stretch: Students design their own results tables and write their own conclusions. *Explaining* Support: Show a video of the experiment so you can stop it at intervals to give further explanation. Stretch: Challenge students to suggest ways in which the model is good and ways in which it is weak.	• Translate information between graphical and numeric form	Demonstration to show that solid sodium chloride crystals do not conduct electricity but that sodium chloride solution does. (See *Starter*.) *Suggested practical:* Investigate the typical properties of simple and giant covalent compounds and ionic compounds. (Partially covered in *Exploring*.) Demonstrate the electrolysis of molten zinc chloride, and explain what happens during the electrolysis using a model or digital animation. (See *Explaining*.)

C6 Covalent bonding				
Lesson SC6a: Covalent bonding (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.28: Explain how a covalent bond is formed when a pair of electrons is shared between two atoms • C1.29: Recall that covalent bonding results in the formation of molecules • C1.30: Recall the typical size (order of magnitude) of atoms and small molecules • C1.31: Explain the formation of simple molecular, covalent substances, using dot and cross diagrams, including: a) hydrogen b) hydrogen chloride c) water d) methane e) oxygen f) carbon dioxide	*Starter* Students compare sodium chloride and carbon dioxide by writing down as much as they can about them in three minutes. *Exploring* Students look at different ways that molecules are represented in textbooks and on the internet. They then fill in a table with the names, molecular formulae, dot and cross diagrams, structural formulae and 3D models of given simple molecules, following an example. *Explaining* Students work in groups using sets of pipe cleaners and coloured beads to model the outer shells of electrons and the formation of covalent bonds.	*Exploring* Support: Some students may need to be guided through the most difficult dot and cross diagrams. Stretch: Ask students to draw up another table to include more challenging examples. *Explaining* Support: Some students may need to be given the dot and cross diagrams for the molecules they are modelling. Stretch: Ask students to revise their models to represent the different sizes of atoms in the molecules.	• Make estimates of the results of simple calculations • Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	n/a

C7 Types of substance				
Lesson SC7a: Molecular compounds (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.34: Explain the properties of typical covalent, simple molecular compounds limited to a) low melting points and boiling points, in terms of forces between molecules (intermolecular forces) b) poor conduction of electricity • C1.39: Describe, using poly(ethene) as the example, that simple polymers consist of large molecules containing chains of carbon atoms	*Starter* Show students molecular models of the following: hydrogen chloride, water, methane, carbon dioxide and poly(ethene). Tell students which colours represent which type of atoms and ask them to use this information to identify the molecules. *Exploring* Students explore the relationship between chain length of straight-chain carbon-based molecules and melting point. They should set up a water bath and measure the melting points of the four substances, analyse their results and draw conclusions. (*Suggested practical*.) *Explaining* Show students a model of a molecule, such as water, to highlight the covalent bonds and the weak forces of attraction (intermolecular forces). Explain the relative strengths of the forces and what happens when ice melts and when water freezes.	*Exploring* Support: Demonstrate how to perform the practical for one set of readings - remind students how to use a thermometer and water bath correctly. Use a scaffolded set of questions for students to answer in order to record their results and draw conclusions. Stretch: Challenge students to draw up their own tables of results, draw conclusions and evaluate the experiment. *Explaining* Support: Write key words/ideas on a display board as a prompt to develop student confidence. Stretch: Challenge students to suggest ways in which the models are good and ways in which they don’t represent the molecules accurately.	• Translate information between graphical and numeric form • Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*Suggested practical:* Investigate the typical properties of simple and giant covalent compounds and ionic compounds. (Partially covered in *Exploring*.)

Lesson SC7b: Allotropes of carbon (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.35: Recall that graphite and diamond are different forms of carbon and that they are examples of covalent giant molecular substances • C1.36: Describe the structures of graphite and diamond • C1.37: Explain, in terms of structure and bonding, why graphite is used to make electrodes and as a lubricant, whereas diamond is used in cutting tools • C1.38: Explain the properties of fullerenes (e.g. C_{60}) and graphene in terms of their structures and bonding	*Starter* Show students a graphite crystal and the structure of graphite either in diagrammatic form or a 3D model. Ask students to indicate the carbon atoms and covalent bonds in the structure. *Exploring* Students use models to represent the structures of graphene, graphite and diamond. Modelling clay, straws and/or dry spaghetti may be used in this activity, or other similar materials. (*Suggested practical*.) *Explaining* Use prepared models of some allotropes of carbon including: C_{60}, graphite and diamond. Add sticky notes to the models of the allotropes with information about structure, bonding, properties and uses.	*Exploring* Support: You could provide examples of the structures to help students, or work through creating the models as a group. Stretch: A model of C_{60} might be harder to achieve, but not impossible. If model kits are available these may also be used. *Explaining* Support: Go through each allotrope one at a time. Summarise the discussion and check students' understanding before moving on. Stretch: Ask students to justify their responses when they suggest properties of a carbon allotrope.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*Suggested practical:* Investigate the typical properties of simple and giant covalent compounds and ionic compounds. (Partially covered in *Exploring*.)

Lesson SC7c: Properties of metals (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.40: Explain the properties of metals, including malleability and the ability to conduct electricity • C1.42: Describe most metals as shiny solids which have high melting points, high density and are good conductors of electricity whereas most non-metals have low boiling points and are poor conductors	*Starter* Demonstrate the difference in melting points and electrical conductivity for one metal and one non-metal. *Exploring* Test the properties of a metal and a non-metal then test an unknown substance and deduce whether it is a metal or a non-metal. (*Suggested practical*.) *Explaining* Show that metal foil or wire can be bent into different shapes without breaking, and that a metal conducts electricity. Use these ideas to explain metallic structure, then metallic bonding.	*Exploring* Support: Students may need help in setting up the circuit. Stretch: Students design their own tables to record the results. They write their own conclusions from their results. *Explaining* Stretch: Students write their own notes to explain the properties of metals in terms of structure and bonding.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Demonstrate the difference in melting points and electrical conductivity for one metal and one non-metal. (See *Starter*.) *Suggested practical:* Investigate the properties of a metal, such as electrical conductivity. (See *Starter* and *Exploring.*)

Lesson SC7d: Bonding (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.32: Explain why elements and compounds can be classified as: a) ionic b) simple molecular (covalent) c) giant covalent d) metallic and how the structure and bonding of these types of substances results in different physical properties, including relative melting point and boiling point, relative solubility in water and ability to conduct electricity (as solids and in solution) • C1.41: Describe the limitations of particular representations and models to include dot and cross, ball and stick models and two- and three-dimensional representations	*Starter* Ask students to classify the four bonding models (A-D) and discuss how they are useful in explaining bonding, structure and properties. A. ionic lattice model for sodium chloride B. covalent, simple molecular model of molecules of carbon dioxide C. covalent, giant molecular model of lattice of diamond D. metallic lattice drawing of lattice of ions and freely moving electrons *Exploring* Classify different types of elements and compounds using their bonding and structure through investigating their melting points, solubility in water and electrical conductivity (as solids and in solution). (*Suggested practical*.) *Explaining* Use pre-prepared models and drawings of an ionic lattice structure, e.g. sodium chloride. Students should write down what each model tells us in terms of how the bonds are formed and how the properties can be explained.	*Exploring* Support: Demonstrate a complete test for one or more of the substances before students complete the task. Stretch: Give students the names of some other substances e.g. wax, potassium nitrate, silicon carbide and tungsten and ask them to research their properties so they can decide which type of bonding and structure they contain. *Explaining* Support: Some students will need extra help in order to appreciate the limitations of space filling models in terms of relative sizes of molecules. Stretch: Ask students to research 'bonding and solubility' and produce an explanation for the properties of lattice structures in terms of solubility in water.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*Suggested practical:* Classify different types of elements and compounds by investigating their melting points and boiling points, solubility in water and electrical conductivity (as solids and in solution) including sodium chloride, magnesium sulphate, hexane, liquid paraffin, silicon(IV) oxide, copper sulphate, and sucrose (sugar).

C8 Acids				
Lesson SC8a: Acids, indicators and pH (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C0.5: Describe the use of hazard symbols on containers a) to indicate the dangers associated with the contents b) to inform people about safe-working precautions with these substances in the laboratory • C3.1: Recall that acids in solution are sources of hydrogen ions and alkalis in solution are sources of hydroxide ions • *C3.2: Recall that a neutral solution has a pH of 7 and that acidic solutions have lower pH values and alkaline solutions higher pH values. • C3.3: Recall the effect of acids and alkalis on indicators, including litmus, methyl orange and phenolphthalein • **C3.4: Recall that the higher the concentration of hydrogen ions in an acidic solution, the lower the pH; and the higher the concentration of hydroxide ions in an alkaline solution, the higher the pH**	*Starter* Ask students to write down five sentences that explain or define each of the following terms: acidic solution; alkaline solution; neutral solution; indicator; neutralisation. Ask students to compare their lists in groups and discuss any misunderstandings. Using oral questioning or a secret ballot, ask students to submit one misunderstanding that arose in their group and whether or not it has been resolved. *Exploring* Students work in groups to look at the use of indicators to test a range of common household solutions. Students can use coloured pencils to produce their own universal indicator colour chart and then look at the pH of a selection of common household solutions. Demonstrate using different indicators, or a pH probe or pH meter. *Explaining* Show the students a model of the ions present in a solution of hydrochloric acid. Briefly discuss the nature of ions and electrolysis. Then ask the students to work in groups to produce a model of what happens during the electrolysis of an acid such as hydrochloric acid.	*Exploring* Support: Some students may need help with the use of indicator colour charts. Stretch: Some students could use the link between pH and ion concentrations to organise the solutions in order of H^+ and OH^- ion concentration. *Explaining* Support: Some students will need help with the idea that positive ions will be attracted to the negative electrode. Stretch: Some students could write equations to represent the changes that occur at the electrodes during electrolysis.	• Use ratios, fractions and percentages	*Practical: Using indicators to look at the pH of common household solutions*

Lesson SC8b: Looking at acids (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C3.5: Recall that as hydrogen ion concentration in a solution increases by a factor of 10, the pH of the solution decreases by 1** • ***C3.7: Explain the terms dilute and concentrated, with respect to amount of substances in solution** • **C3.8: Explain the terms weak and strong acids, with respect to the degree of dissociation into ions**	*Starter* Demonstrate the dilution of potassium manganate(VII), roughly diluting by 50% repeatedly, until the colour cannot be seen. If there is time, this experiment can be carried out by students using copper sulfate. *Exploring* Ask students to produce two mini-posters to illustrate the difference between strong and weak acid solutions, by looking at what is happening to ions from the solute in the solution. *Explaining* Demonstrate how the pH of different acid solutions, of the same concentration, can vary. Choose examples of two strong and two weak acids. Introduce students to the idea of strong and weak acids and discuss how the different dissociations of acid molecules can help explain why their solutions have different pH values.	*Exploring* Support: Some students will need help with organising the posters to form a picture of molecules and ions in strong and weak acid solutions. Stretch: Some students could be asked to find out how the symbols '→' and '⇌' can be used in chemical equations to represent the formation of solutions by strong and weak acids. *Explaining* Support: Some students may need a word list to help them write their definitions. Stretch: Some students could try to find out how pH is calculated from H^+ ion concentrations.	• Use ratios, fractions and percentages	n/a

Lesson SC8c: Bases and salts (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C3.9: Recall that a base is any substance that reacts with an acid to form salt and water only • *C3.11: Explain the general reactions of aqueous solutions of acids with … b) metal oxides … to produce salts • *C3.13: Describe a neutralisation reaction as a reaction between an acid and a base • C3.15: Explain why, if soluble salts are prepared from an acid and an insoluble reactant: a) excess of the reactant is added b) the excess reactant is removed c) the solution remaining is only salt and water • *C3.17: Core Practical: Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide including the use of a water bath* • C0.1: Recall the formulae of elements, simple compounds and ions • C0.2: Write word equations • C0.3: Write balanced chemical equations, including the use of the state symbols (s), (l), (g) and (aq) • C0.5: Describe the use of hazard symbols on containers a) to indicate the dangers associated with the contents b) to inform people about safe-working precautions with these substances in the laboratory	*Starter* Demonstrate how the pH of an acidic solution changes when different common neutralisers are added. *Exploring* Students work in groups to investigate the preparation of a pure, dry salt (core practical). *Explaining* Revise, through class discussion, chemical reactions in general. Give students examples of simple ionic formulae to work out. Extend this by telling them the form that a compound is in and asking them to add the appropriate state symbols. Then show students how to write the formulae for more complex compounds that contain 'group ions'.	*Exploring* Support: Some students will need help with the word and symbol equations. Stretch: Ask students to find out why certain salts could *not* be prepared by this method. For example, sodium sulfate cannot be made this way as sodium oxide is soluble and the excess could not be separated. *Explaining* Support: Some students will need help and extra examples of working out ion charges (valency) and writing formulae. Stretch: Give students more challenging examples using metals with higher valencies and less familiar group ions (e.g. $AlCl_3$ and $Ca_3(PO_4)_2$).	n/a	*Core Practical: Investigate the preparation of pure, dry hydrated copper sulfate crystals starting from copper oxide including the use of a water bath*

Lesson SC8d: Alkalis and balancing equations (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C3.11: Explain the general reactions of aqueous solutions of acids with … c) metal hydroxides … to produce salts • C0.1: Recall the formulae of elements, simple compounds and ions • C0.2: Write word equations • C0.3: Write balanced chemical equations, including the use of the state symbols (s), (l), (g) and (aq) • *C3.10: Recall that alkalis are soluble bases • *C3.6: Core Practical: Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid*	*Starter* Ask students to predict the salts formed in the reaction between some named metal oxides and common acids. This can be done using a 4 × 4 grid with acid names in the first row as column headings, and metal oxide names in the first column as row headings. *Exploring* Investigation where students add successive weighed portions of calcium hydroxide powder to a fixed amount of dilute hydrochloric acid, and estimate the pH of the reaction mixture using universal indicator paper *(core practical).* *Explaining* Work with students on writing equations and using state symbols. Show students a simple balanced equation, e.g. $NaOH + HCl \rightarrow NaCl + H_2O$. Discuss why this is balanced, then show a more complex balanced equation, e.g. $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$ and discuss (including the use of OH and H to produce water when balancing; and keeping NO_3, SO_4 and PO_4 as units when balancing).	*Exploring* Support: Provide eight 0.3 g pre-weighed portions of calcium hydroxide powder to each group that needs it. Stretch: Give students narrow range indicator paper to increase the precision of their pH estimates. *Explaining* Support: Use tally charts, or coloured counters or blocks, for each element left and right. Stretch: Challenge students to evaluate how well word equations and balanced equations model chemical reactions.	• Translate information between graphical and numeric form • Plot two variables from experimental or other data	*Core Practical: Investigate the change in pH on adding powdered calcium hydroxide or calcium oxide to a fixed volume of dilute hydrochloric acid*

Lesson SC8e: Alkalis and neutralisation (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C3.14: Explain an acid-alkali neutralisation as a reaction in which hydrogen ions (H^+) from the acid react with hydroxide ions (OH^-) from the alkali to form water • C3.16: Explain why, if soluble salts are prepared from an acid and a soluble reactant: a) titration must be used b) the acid and the soluble reactant are then mixed in the correct proportions c) the solution remaining, after reaction, is only salt and water • C3.18: Describe how to carry out simple acid-alkali titrations, using burette, pipette and a suitable indicator, to prepare a pure, dry salt	*Starter* In pairs using paper or mini-whiteboards, students balance equations supplied on the board, then peer assess their answers with another pair. *Exploring* The *Explaining* task below should be done before students start this section. Students carry out a practical in which they produce sodium chloride crystals. Titration is used to neutralise dilute sodium hydroxide solution with dilute hydrochloric acid, and then repeated without the indicator. Students then use crystallisation to produce sodium chloride from the solution formed. This could be done as a demonstration with students taking notes if needed. *Explaining* Demonstration to show the correct technique for titration, could be accompanied with a cut and stick activity to ensure steps are carried out in the correct order. This should be done before the *Exploring* task above.	*Exploring* Support: Practise using the tap on a burette, and swirling a conical flask, using tap water. Stretch: Instead of the run without the indicator, activated charcoal could be used to adsorb the indicator, followed by filtration. *Explaining* Support: Cut the steps out beforehand so that the task becomes a card sort. Students could complete the task after carrying out the experiment.	n/a	*n/a*

Lesson SC8f: Reactions of acids with metals and carbonates (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C3.11: Explain the general reactions of aqueous solutions of acids with: a) metals … d) metal carbonates to produce salts • C3.12: Describe the chemical test for: a) hydrogen b) carbon dioxide (using limewater) • **C0.4: Write balanced ionic equations**	*Starter* Ask students for the typical physical properties of metals. They should suggest some from: good conductors of heat and electricity, high melting and boiling points, malleable, ductile, strong. Then discuss some chemical reactions. *Exploring* Investigating the reactions with metals and carbonates. You can also ask students to test for the presence of hydrogen and carbon dioxide. *Explaining* Summarise the two different methods of preparing soluble salts – from an insoluble reactant and an acid (using metal, base or carbonate) and from a soluble reactant and an acid. Include the general steps in the methods and the general equations.	*Exploring* Support: Give students more support or a worksheet to explain which metals and acids to use, and demonstrate how to carry out the tests for gases. Stretch: Ask students to write up the experiment, design their own results table, and write a conclusion themselves. *Explaining* Support: Students make summary notes on these different methods. They could produce a flowchart, e.g. start with asking 'Is the reactant soluble or insoluble?' Then follow the two different routes. Stretch: Ask the students to suggest as many different methods of making magnesium sulfate crystals as they can and to consider the advantages and disadvantages of each method.	• Use ratios, fractions and percentages	*Suggested practical:* Carry out simple neutralisation reactions of acids, using … metal carbonates. *Suggested practical:* Carry out tests for hydrogen and carbon dioxide.

Lesson SC8g: Solubility (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C3.19: Recall the general rules which describe the solubility of common types of substances in water: a) all common sodium, potassium and ammonium salts are soluble b) all nitrates are soluble c) common chlorides are soluble except those of silver and lead d) common sulfates are soluble except those of lead, barium and calcium e) common carbonates and hydroxides are insoluble except those of sodium, potassium and ammonium • C3.20: Predict, using solubility rules, whether or not a precipitate will be formed when named solutions are mixed together, naming the precipitate if any • C3.21: Describe the method used to prepare a pure, dry sample of an insoluble salt	*Starter* Write these anagrams on the board: busily toil (solubility), blue sol (soluble), no bullies (insoluble), Noels TV (solvent), tousle (solute), loon suit (solution), a tip receipt (precipitate). Ask the students to rearrange the letters to form words related to solubility, then to explain the meaning of each word. *Exploring* Investigate (or discuss/show a video) the preparation of insoluble salts. They could prepare a white precipitate of silver chloride using solutions of silver nitrate and sodium chloride (*suggested practical*). *Explaining* Demonstrate the formation of the same insoluble salt from different solutions, e.g. barium sulfate by adding magnesium sulfate, sodium sulfate and copper sulfate solutions to separate portions of barium chloride solution. Explain that it is always the same precipitate that forms as the barium ions are reacting with the sulfate ions. The other ions are spectator ions. Give students examples of different solutions and ask them to predict whether or not a precipitate will form.	*Exploring* Support: Provide students with a directed worksheet to take them through the method, and analysis Stretch: Give students instructions, but ask them to write up the experiment in their own words, by designing their own results tables. *Explaining* Support: Allow students access to a copy of the solubility rules. They then work out the word equation for each combination of solutions and check to see if either of the products is insoluble. Stretch: Challenge the students to do this exercise from their memory of the solubility rules. They can then write ionic equations for the formation of any precipitates.	• Use ratios, fractions and percentages	*Suggested practical:* Prepare an insoluble salt by precipitation.

C9 Calculations involving masses				
Lesson SC9a: Masses and empirical formulae (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.43: Calculate relative formula mass given relative atomic masses • C1.44: Calculate the formulae of simple compounds from reacting masses and understand that these are empirical formulae • C1.45: Deduce: a) the empirical formula of a compound from the formula of its molecule b) the molecular formula of a compound from its empirical formula and its relative molecular mass • C1.46: Describe an experiment to determine the empirical formula of a simple compound such as magnesium oxide	*Starter:* Ask students to work out the number of atoms in 5 compounds, including some with brackets, e.g. $MgCl_2$, Li_2O, $CuSO_4$, $Ca(NO_3)_2$, $(NH_4)_2CO_3$. *Exploring:* Determine the empirical formula for magnesium oxide. (*Suggested practical*.) *Explaining:* Work through examples showing how to calculate empirical and molecular formulae for compounds from reacting masses.	*Exploring:* Support: Give students a written copy of the experimental method Stretch: Students write up the experiment in their own words, design their own results tables, write a conclusion and evaluation *Explaining:* Support: You may wish to use different methods of determining empirical formulae. Stretch: Give the students an empirical formula to calculate where they are given percentages by mass of each element	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Use an appropriate number of significant figures	*Suggested practical:* Determine the empirical formula of a simple compound.

Lesson SC9b: Conservation of mass (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C1.47: Explain the law of conservation of mass applied to a) a closed system including a precipitation reaction in a closed flask b) a non-enclosed system including a reaction in an open flask that takes in or gives out a gas • C1.48: Calculate masses of reactants and products from balanced equations, given the mass of one substance • C1.49: Calculate the concentration of solutions in g dm^{-3}	*Starter:* Demonstrate the law of conservation of mass with a precipitation reaction. (*Suggested practical*.) *Exploring:* Investigate the decomposition of copper carbonate. (*Suggested practical*.) *Explaining:* Work through calculations involving masses of reactants and products using the 'reacting mass' method.	*Exploring:* Support: Give students a written copy of the experimental method. Stretch: Students write up the experiment in their own words, design their own results tables, write a conclusion and evaluation. *Explaining:* Support: Divide the students into pairs to work through the calculations. Stretch: Ask the students to make up a question using a more complex balanced equation e.g. $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Use an appropriate number of significant figures • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities	Demonstrate the law of conservation of mass with a precipitation reaction. (See *Starter*.) Investigate the decomposition of copper carbonate. (See *Exploring*.) *Suggested practical:* Investigate mass changes before and after reactions. (See *Starter* and *Exploring*.)

Lesson SC9c: Moles (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C1.52: Explain why, in a reaction, the mass of product formed is controlled by the mass of the reactant which is not in excess** • **C1.53: Deduce the stoichiometry of a reaction from the masses of the reactants and products** • **C1.50: Recall that one mole of particles of a substance is defined as:** **a) the Avogadro constant number of particles (6.02 x 10^{23} atoms, molecules, formulae or ions) of that substance** **b) a mass of 'relative particle mass' g** • **C1.51: Calculate the number of:** **a) moles of particles of a substance in a given mass of that substance and vice versa** **b) particles of a substance in a given number of moles of that substance and vice versa** **c) particles of a substance in a given mass of that substance and vice versa**	*Starter:* Try to measure the mass of 1 small item, then repeat using 20 to find the average mass of 1. Estimate how many items there are for a handful using mass. *Exploring:* Students work through calculations converting masses into moles and vice -versa, calculations involving the Avogadro constant, a calculation with a limiting reactant and determining a balanced equation from reacting masses. *Explaining:* Work through calculations finding the number of moles of each reactant, finding the simplest ratio, then deducing the balanced equation.	*Exploring:* Support: Explain each type of calculation. Stretch: Challenge students to write notes to explain the calculations to a student who has missed the lesson. *Explaining:* Support: Divide the students into pairs to work through the calculations. Stretch: Challenge students to answer a question with a more complex balanced equation e.g. 112g of iron reacts with 106.5g of chlorine to produce 218.5g of an iron chloride.	• Recognise and use expressions in decimal form • Recognise and use expressions in standard form • Use ratios, fractions and percentages • Use an appropriate number of significant figures • Understand and use the symbol: = • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Change the subject of an equation	n/a

<table>
<tr><td colspan="5">C10 Electrolytic processes</td></tr>
<tr><td colspan="5">Lesson SC10a: Electrolysis (2 hours)</td></tr>
<tr><td>Specification points</td><td>Exemplar teaching activities</td><td>Differentiation</td><td>Maths skills</td><td>Practicals</td></tr>
<tr><td>• C3.22: Recall that electrolytes are ionic compounds in the molten state or dissolved in water
• C3.23: Describe electrolysis as a process in which electrical energy, from a direct current supply, decomposes electrolytes
• C3.24: Explain the movement of ions during electrolysis, in which:
a) positively charged cations migrate to the negatively charged cathode
b) negatively charged anions migrate to the positively charged anode
• C3.27: Write half equations for reactions occurring at the anode and cathode in electrolysis
• C3.28: Explain oxidation and reduction in terms of loss or gain of electrons
• C3.29: Recall that reduction occurs at the cathode and that oxidation occurs at the anode in electrolysis reactions
• C3.31: Core Practical: Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes</td><td>Starter
Revise the formation of ions and ionic bonding by considering ionic bonding in sodium chloride and magnesium oxide. Summarise the key points.

Exploring
Investigate the electrolysis of copper sulfate solution using inert (graphite) electrodes and secondly using copper electrodes. Using the inert electrode set-up, students observe and explain the formation of copper and oxygen at the electrodes. Using the set-up with copper electrodes, students measure the mass change of the electrodes using different currents. (Core practical.)

Explaining
Demonstrate electroplating using copper sulfate solution, a strip of copper foil (positive terminal) and an object to be electroplated (negative terminal).</td><td>Exploring
Support: Provide students with a method sheet and scaffolded results tables. You may need to tell students what type of graph to draw and how to label the axes.
Stretch: Students write up the experiment in their own words, by designing their own results tables, and writing a conclusion and an evaluation.

Explaining
Support: Help the students to draw a circuit diagram and explain the reaction that happens at each electrode.
Stretch: Students draw their own circuit diagrams and write a half equation for the reaction occurring at each electrode.</td><td>• Use ratios, fractions and percentages
• Translate information between graphical and numeric form
• Understand that $y = mx + c$ represents a linear relationship
• Plot two variables from experimental or other data
• Determine the slope and intercept of a linear graph</td><td>Core Practical: Investigate the electrolysis of copper sulfate solution with inert electrodes and copper electrodes. (See Exploring.)

Demonstrate electroplating. (See Explaining.)</td></tr>
</table>

Lesson SC10b: Products from electrolysis (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C3.25: Explain the formation of the products in the electrolysis, using inert electrodes, of some electrolytes, including: a) copper chloride solution b) sodium chloride solution c) sodium sulfate solution d) water acidified with sulfuric acid e) molten lead bromide (demonstration) • C3.26: Predict the products of electrolysis of other binary, ionic compounds in the molten state • C3.30: Explain formation of the products in the electrolysis of copper sulfate solution, using copper electrodes, and how this electrolysis can be used to purify copper	*Starter* Write these anagrams on the board, and ask students to solve them: celerity loss (electrolysis), cell tree toy (electrolyte), decree lot (electrode), nae do (anode), do teach (cathode), action (cation). *Exploring* Investigate the electrolysis of: a) copper chloride solution b) sodium chloride solution c) sodium sulfate solution d) water acidified with sulfuric acid. Students test just one or two solutions and share results with another group that has tested different solutions. (*Suggested practical.*) *Explaining* Do a larger scale demonstration of the electrolysis of acidified water or aqueous sodium chloride solution using a Hofmann voltameter so that the gases can easily be collected, their volumes measured and then the gases tested to identify them. (*Suggested practical.*)	*Exploring* Support: Provide students with a method sheet and scaffolded results tables. Stretch: Students write up the experiment in their own words, by designing their own results tables, and writing a conclusion and an evaluation. *Explaining* Support: Explain what happens to the ions during the electrolysis of a molten salt, such as lead bromide or zinc chloride. Emphasise that the salt splits up to form the two elements. Once students have understood what happens during the electrolysis of molten salts, then explain the reactions for aqueous solutions. Stretch: Ask students to look for a pattern in the products formed during the electrolysis of aqueous solutions and deduce a general 'rule' for predicting the products formed during the electrolysis of other solutions.	• Use ratios, fractions and percentages	*Suggested practical:* Investigate the electrolysis of: a) copper chloride solution b) sodium chloride solution c) sodium sulfate solution d) water acidified with sulfuric acid e) molten lead bromide (demonstration). (See *Exploring* and *Explaining*.)

C11 Obtaining and using metals				
Lesson SC11a: Reactivity (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C4.1: Deduce the relative reactivity of some metals, by their reactions with water, acids and salt solutions • **C4.2: Explain displacement reactions as redox reactions, in terms of gain or loss of electrons** • *C4.3: Explain the reactivity series of metals (potassium, sodium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen), copper, silver, gold) in terms of the reactivity of the metals with water and dilute acids and that these reactions show the relative tendency of metal atoms to form cations	*Starter* Demonstrate the reactions of copper, magnesium, sodium and potassium with water. *Exploring* Give an example of a redox reactions, and ask what has been oxidised and what has been reduced. Remind the students of the alternative definitions of oxidation and reduction, in terms of electrons. Question students on formulae, balanced equations and ionic equations in relation to the reactivity series. *Explaining* Demonstrate a thermite reaction. Explain that displacement reactions can also involve reacting a more reactive metal with a less reactive metal in its metal oxide.	*Exploring* Support: Refer students back to the experiments they have carried out on salt preparations. Stretch: Students could be asked to write half equations and classify them as oxidation or reduction. *Explaining* Support: Give the students the word equation for the reaction and ask them to explain why it is a redox reaction, in terms of oxygen. Stretch: Students write the balanced equation for the reaction and explain why it is a redox reaction, in terms of oxygen. Ask them to predict which of these mixtures will react and why: magnesium and iron oxide, copper and zinc oxide, iron and copper oxide.	• Use ratios, fractions and percentages	Demonstrate the reactivity of the metals with water and dilute acids. (See *Starter* and *Explaining*.)

Lesson SC11b: Ores (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C4.4: Recall that: a) most metals are extracted from ores found in the Earth's crust b) unreactive metals are found in the Earth's crust as the uncombined elements • *C4.7: Explain why the method used to extract a metal from its ore is related to its position in the reactivity series and the cost of the extraction process, illustrated by a) heating with carbon (including iron) b) electrolysis (including aluminium) (knowledge of the blast furnace is not required) • **C4.8: Evaluate alternative biological methods of metal extraction (bacterial and phytoextraction)**	*Starter* Ask students to work in pairs to list bullet points about how metals occur in the Earth's crust and how to obtain pure metals. *Exploring* Students research the process used for the extraction of aluminium. *Explaining* Demonstrate the electrolysis of molten zinc chloride in a fume cupboard. Test for chlorine with a piece of damp blue litmus paper (which turns red then white in the presence of chlorine). (*Suggested practical.*)	*Exploring* Support: Remind students of the electrolytic processes. Stretch: Students write half equations and classify them as oxidation or reduction. *Explaining* Support: Explain that electricity splits the zinc chloride into zinc and chlorine. This happens whenever electricity passes through a molten salt. Stretch: The students write the half equations for the reaction at the two electrodes. They then explain which half equation shows oxidation and which shows reduction.	• Use ratios, fractions and percentages	*Suggested practical:* Investigate methods for extracting metals from their ores. (See *Explaining*.)

Lesson SC11c: Oxidation and reduction (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C4.2: Explain displacement reactions as redox reactions, in terms of gain or loss of electrons** • C4.5: Explain oxidation as the gain of oxygen and reduction as the loss of oxygen • *C4.6: Recall that the extraction of metals involves reduction of ores • C4.9: Explain how a metal's relative resistance to oxidation is related to its position in the reactivity series	*Starter* Revise redox reactions by writing some equations on the board and asking students what has been oxidised and what has been reduced and why. *Exploring* Work though examples of oxidation and reduction reactions. *Explaining* Demonstrate rusting of iron using ferroxyl indicator to revise corrosion and the idea of ions forming. (*Suggested practical*.)	*Exploring* Stretch: Challenge students to write half equations for the reactions and explain why they are redox reactions, in terms of electrons gained or lost. *Explaining* Support: Ask students for the essential conditions needed for rusting and any methods for preventing iron from rusting that they remember and explain how these methods work. Stretch: Tell the students that the indicator turns blue when Fe^{2+} ions are formed and ask them to write the half equation to show this ($Fe \rightarrow Fe^{2+} + 2e$). Tell the students that the indicator turns pink when oxygen and water react to form hydroxide ions and ask them to write a half equations to show this ($O_2 + 2H_2O + 4e \rightarrow 4OH^-$).	• Use ratios, fractions and percentages	*Suggested practical:* Investigate simple oxidation and reduction reactions, such as burning elements in oxygen or competition reactions between metals and metal oxides. (See *Explaining*.)

Lesson SC11d: Recycling (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C4.10: Evaluate the advantages of recycling metals, including economic implications and how recycling can preserve both the environment and the supply of valuable raw materials • C4.11: Describe that a life time assessment for a product involves consideration of the effect on the environment of obtaining the raw materials, manufacturing the product, using the product and disposing of the product when it is no longer useful • C4.12: Evaluate data from a life cycle assessment of a product	*Starter* Ask the students to discuss the advantages of recycling metals compared with throwing them away. *Exploring* Students collect data to evaluate how effective the school's recycling policy is. Ask the students to look at the recycling bins and other general rubbish bins in a particular area of the school to obtain their data. Then ask students to suggest ways in which recycling could be done more effectively. *Explaining* Present and discuss Life Cycle Assessments for different types of shopping bag.	*Exploring* Support: Students work in groups and use data that is provided. They could draw bar charts of the raw data instead of the percentages or help them to calculate the percentages. Stretch: Students should process the data before drawing bar charts, for example, by working out percentages. *Explaining* Stretch: Students conduct their own research into a different scenario involving a Life Cycle Assessment.	• Translate information between graphical and numeric form	Data collection activity to evaluate the effectiveness of the school's recycling policy. (See *Exploring*.)

C12 Reversible reactions and equilibria				
Lesson SC12a: Dynamic equilibrium (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C4.13: Recall that chemical reactions are reversible and the use of the symbol ⇌ in equations and that the direction of some reversible reactions can be altered by changing the reaction conditions • C4.14: Explain what is meant by dynamic equilibrium • C4.15: Describe the formation of ammonia as a reversible reaction between nitrogen (extracted from the air) and hydrogen (obtained from natural gas) and that it can reach a dynamic equilibrium • C4.16: Recall the conditions for the Haber process as: a) temperature 450°C b) pressure 200 atmospheres c) iron catalyst • **C4.17: Predict how the position of a dynamic equilibrium is affected by changes in:** **a) temperature** **b) pressure** **c) concentration**	*Starter* Ask students to write down 2 or 3 word, and symbol equations for reactions they can remember. Share their ideas in groups and then with the class. *Exploring* Investigate the decomposition of ammonium chloride chloride to illustrate ideas of reversible reactions in closed systems. (*Suggested practical*.) *Explaining* Show students a range of simple laboratory reactions which illustrate shifting equilibria. In each case discuss how we are able to predict the change in the equilibrium position.	*Exploring* Support: Some students will need help with writing forward and backward reaction equations. Stretch: Ask students to write a detailed explanation of what happens in the reversible reaction involving ammonium chloride. *Explaining* Support: Concentrate on the reversible nature of these reactions and how equilibrium is achieved. Stretch: Ask students to write explanations of the colour changes observed in terms of the changes in the position of equilibrium in the reactions.	n/a	*Suggested practical:* Investigate simple reversible reactions, such as the decomposition of ammonium chloride. (See *Exploring*.)

C13 Transition metals, alloys and corrosion				
Lesson SC13a: Transition metals (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.1C: Recall that most metals are transition metals and that their typical properties include: a) high melting point b) high density c) the formation of coloured compounds d) catalytic activity of the metals and their compounds as exemplified by iron	*Starter* Demonstrate a selection of common transition metals, e.g. iron, copper, zinc, silver, gold leaf. Ask students what they think these substances have in common, then show mercury and repeat the challenge. *Exploring* Investigate catalysing the reaction between iron(III) nitrate solution and sodium thiosulfate solution: a purple solution forms which turns colourless over time. Students use drops of different transition metal solutions, e.g. cobalt(II) chloride, copper(II) sulfate and iron(II) sulfate. (*Suggested practical.*) *Explaining* Demonstrate the decomposition of hydrogen peroxide using two transition metal oxides, and the use of copper(II) sulfate to catalyse the reaction between zinc and dilute sulfuric acid.	*Exploring* Support: Students may not appreciate that just one drop of catalyst solution is needed. Stretch: Students calculate 1000/time to give the relative rate of each reaction, then use the relative rate of the uncatalysed reaction to calculate the changes in rates of reaction. *Explaining* Support: Make sure that students understand that the reaction involves the production of oxygen from the hydrogen peroxide and not from the oxide, detergent or water. Stretch: Ask the students to describe how they could show that the oxides are acting as catalysts, rather than as reactants.	• Use ratios, fractions and percentages. • Use a scatter diagram to identify a correlation between two variables. • Translate information between graphical and numeric form. • Plot two variables from experimental or other data.	*Suggested practical:* Carry out an activity to show that transition metal salts have a variety of colours. (See *Exploring*.) Demonstrate the decomposition of hydrogen peroxide using two transition metal oxides. (See *Explaining*.) Demonstrate the use of copper(II) sulfate to catalyse the reaction between zinc and dilute sulfuric acid. (See *Explaining*.)

Lesson SC13b: Corrosion (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.2C: Recall that the oxidation of metals results in corrosion • C5.3C: Explain how rusting of iron can be prevented by: a) exclusion of oxygen b) exclusion of water c) sacrificial protection	*Starter* Show sodium in its container of oil, magnesium ribbon in its plastic pouch, zinc granules in their plastic bottle, and copper foil. Ask students to explain the differences in the ways the metals are stored. *Exploring* Investigate barrier rust prevention methods (nail varnish, grease and cling film) and sacrificial protection (magnesium and copper). Use Hexacyanoferrate(III) as an indicator. (*Suggested practical.*) *Explaining* Demonstrate how the tarnish on an old 1p or 2p coin can be removed using vinegar or ketchup. Discuss with the students that the ethanoic acid in these substances reacts with the compounds in the tarnish.	*Exploring* Support: Students may have difficulty coating the nails without making a mess, so consider supplying pre-prepared nails. Stretch: Ask students to suggest why a coloured substance forms in the experiment. *Explaining* Support: Make sure that students understand that the metal oxide layers form naturally, but in rusting the hydrated iron(III) oxide flakes off, exposing fresh metal to the air. Stretch: Ask students to write balanced equations for the reactions observed. Assume that the tarnish on the coin is copper oxide, CuO.	• Use ratios, fractions and percentages.	*Suggested practical:* Investigate the rusting of iron. (See *Exploring*.) Demonstrate how can be removed using vinegar or ketchup. (See *Explaining*.)

Lesson SC13c: Electroplating (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.4C: Explain how electroplating can be used to improve the appearance and/or the resistance to corrosion of metal objects	*Starter* Students examine their three rusting-experiment test tubes from the Exploring activity (Investigating rusting) in *SC13b Corrosion* and record their observations. Discuss what the results show, i.e. that air *and* water are needed for rusting to occur. *Exploring* Demonstrate electroplating metal objects (e.g. coins/metal foil) with copper using a copper anode and copper(II) sulfate solution. An orange-brown to black coating of copper should form on the metal object. Ask students to predict what will happen to the mass of the anode and the mass of the object being electroplated during the process, and to justify their answers. *Explaining* Demonstrate electroplating a piece of copper with zinc in a fume cupboard. Prepare the electrolyte by mixing 5 cm^3 of 0.1 mol dm^{-3} zinc sulfate solution with 30 cm^3 0.4 mol dm^{-3} sodium hydroxide solution. Add the electrolyte to a small plastic container. Secure a piece of zinc foil in the electrolyte and connect it to the positive terminal of a d.c. power supply. Connect a piece of copper foil to the negative terminal of the d.c. power supply and dip it in the electrolyte. Observe the copper becoming coated with zinc when the power supply is turned on. Remove the electroplated copper foil and then wash it with water.	*Exploring* Support: Make sure the students understand that the copper electrode is connected to the positive terminal, so that it is the anode. Stretch: Challenge higher tier students to write half equations for the electrode reactions *Explaining* Support: Explain that, for electroplating to work, the anode must be zinc and the electrolyte must contain zinc ions. Stretch: Challenge students to evaluate the use of zinc plating as a rust-prevention measure for iron objects and for copper objects (this is linked to sacrificial protection).	n/a	*n/a*

Lesson SC13d: Alloying (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.6C: Explain why iron is alloyed with other metals to produce alloy steels • C5.5C: Explain, using models, why converting pure metals into alloys often increases the strength of the product	*Starter* In pairs, using paper or mini whiteboards, students write down one way in which they could measure the strength of a metal, for example by squashing it, stretching it or bending it. They compare their answers with those of another pair then feed back to the class. *Exploring* They then compare the hardness of a lead-tin alloy to that of lead and tin separately. They can also scratch-test brass, copper and zinc to determine relative hardness (this could be a demonstration). *Explaining* Use a tray of identical-sized marbles to model the structure of a metal. Add a larger marble and discuss the effects this has on the structure, and the effects this change would have on the strength of a metal.	*Exploring* Support: Make sure the apparatus is stable before students begin heating. Stretch: Students could compare the melting points of the metals. They could heat small samples of their alloy, lead and tin next to each other to see which one melts first. *Explaining* Support: Make sure the students appreciate that layers of metal atoms slide over each other when metals are stretched. The metallic bonds continually break and reform as this happens. Stretch: Challenge students to evaluate this model and to explain its limitations.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*Suggested practical:* Investigate the properties of alloys.

Lesson SC13e: Uses of metals and their alloys (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *C5.7C: Explain how the uses of metals are related to their properties (and vice versa), including aluminium, copper and gold and their alloys including magnalium and brass	*Starter* Students work in groups to draw a concept map about metals, alloys and corrosion. *Exploring* Students are presented with a question in the style of a past-paper question, together with three specimen answers of varying standard. They work in groups to write an improvement to one of the specimen answers. *Explaining* Show students a Bunsen burner, a stand, boss and clamp, and a gauze mat and tripod. Ask them to suggest the properties that these items should have and whether they think one metal or alloy would be suitable for all of them.	*Exploring* Support: Give an example of what to do when a sheet arrives at a group's table. Stretch: Challenge students to devise their own answer and to write it on the back of the sheet before passing it around. *Explaining* Support: Explain that some properties are critical, for example a gauze mat should not ignite or melt in a Bunsen burner flame. Stretch: Challenge students to identify properties of the items shown that are neutral or irrelevant, for example a Bunsen burner chimney would still function even if it were not shiny.	n/a	n/a

C14 Quantitative analysis				
Lesson SC14a: Yields (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.11C: Calculate the percentage yield of a reaction from the actual yield and the theoretical yield • C5.12C: Describe that the actual yield of a reaction is usually less than the theoretical yield and that the causes of this include: a) incomplete reactions b) practical losses during the experiment c) competing, unwanted reactions (side reactions)	*Starter* Revise how to calculate percentages, e.g. calculate the percentage of students in the class who have their birthday in the current month and/or the percentage of students who have a cat. *Exploring* Provide students with data sets and work through examples to practice calculating percentage yields. *Explaining* Revise how to calculate the mass of a product from a reacting mass and explain that this is the theoretical mass.	*Exploring* Support: Divide the students into pairs to work through the calculations, with one student who has understood them helping another who finds them more challenging. Stretch: Ask students to work in pairs and write their own question, including calculating the theoretical yield, and present it to the rest of the class as a slide. *Explaining* Stretch: Calculate the maximum mass of aluminium chloride that could be produced from 6.39 g of chlorine.	• Recognise and use expressions in decimal form • Use an appropriate number of significant figures • Use ratios, fractions and percentages	n/a

Lesson SC14b: Atom economy (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.13C: Recall the atom economy of a reaction forming a desired product • C5.14C: Calculate the atom economy of a reaction forming a desired product • **C5.15C: Explain why a particular reaction pathway is chosen to produce a specified product, given appropriate data such as atom economy, yield, rate, equilibrium position and usefulness of by-products**	*Starter* Revise how to calculate relative formula masses, e.g. the relative formula mass of aluminium sulfate, $Al_2(SO_4)_3$ is 2 x A_r(Al) + 3 x A_r(S) + 12 x A_r(O) = (2 x 27) + (3 x 32) + (12 x 16) = 342. *Exploring* Students compare the manufacture of ethanol by fermentation and hydration of ethene. They research these two processes and prepare an account or presentation where they evaluate the advantages and disadvantages of each process. *Explaining* Work through examples of calculating atom economy, using the sum of the relative atomic masses of the reactants. This shows that atom economy is the proportion of reactants that are converted into useful products rather than waste products.	*Exploring* Support: Provide additional prompts to help the students with their research. Students can work in a pair or small group. *Explaining* Support: Start by revising how to calculate relative formula masses before carrying out the calculations on atom economy. Stretch: Ask students to work in pairs and write their own question and mark scheme to calculate the percentage yield and the atom economy of a reaction.	• Use an appropriate number of significant figures • Use ratios, fractions and percentages	n/a

Lesson SC14c: Concentrations (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C5.8C: Calculate the concentration of solutions in mol dm^{-3} and convert concentration in g dm^{-3} into mol dm^{-3} and vice versa**	*Starter* Revise how to carry out calculations involving quantities in moles, e.g. converting masses into moles and moles into masses. *Exploring* Work through examples of calculations of concentrations in g dm^{-3} and mol dm^{-3}. *Explaining* Demonstrate a correct procedure for making up a standard solution of sodium carbonate.	*Exploring* Support: Write the formulae needed on the board for the students to use and carry out a worked example of each type of calculation Stretch: Challenge students to complete a two-step calculation. *Explaining* Support: Show the students how to use the mass of sodium carbonate to determine the concentration of the solution in g dm^{-3} and then mol dm^{-3}. Stretch: Students work out the number of moles of solute in 10.0 cm^3 of the solution and in 24.6 cm^3 of solution and then to deduce a formula they can use to work out the number of moles of solute in a given volume of solution with a known concentration.	• Recognise and use expressions in decimal form • Recognise and use expressions in standard form • Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Use an appropriate number of significant figures • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities	Demonstrate the process for making up a standard solution. (See *Explaining*.)

Lesson SC14d: Titrations and calculations (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C5.10C: Carry out simple calculations using the results of titrations to calculate an unknown concentration of a solution or an unknown volume of solution required** • *C5.9C: Core practical: Carry out an accurate acid-alkali titration, using burette, pipette and a suitable indicator*	*Starter* Provide copies of mixed-up steps for the process of preparing a soluble salt from an acid and a soluble reactant and ask students to rearrange them into the correct order. *Exploring* Carry out an acid-alkali titration, using burette, pipette and a suitable indicator. Methyl orange or phenolphthalein could be used for this titration. Students should repeat the titration until they obtain two concordant results within 0.2 cm^3. (*Core practical.*) *Explaining* Work through examples of the different titration calculation techniques. Remind students about how to use a formula triangle to help them to re-arrange a formula, if needed.	*Exploring* Support: Provide students with a written copy of the method, and scaffolded results tables and conclusions. Stretch: Students write up the experiment in their own words, design their own results tables and calculate the concentration of the hydrochloric acid. *Explaining* Support: If students are taking Foundation Tier papers, they just need to work through the Core practical and use the results of the titration to prepare a pure, dry sample of a salt. Stretch: Ask students to make up a question of their own based on the titration of sulfuric acid and sodium hydroxide solution: $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$.	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Use an appropriate number of significant figures • Find arithmetic means • Understand and use the symbols: $=, <, \ll, \gg, >, \propto, \sim$ • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities	*Core practical: Carry out an acid-alkali titration, using burette, pipette and a suitable indicator.* (See *Exploring*.)

Lesson SC14e: Molar volume of gases (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C5.16C: Describe the molar volume, of any gas at room temperature and pressure, as the volume occupied by one mole of molecules of any gas at room temperature and pressure (The molar volume will be provided as 24 dm3 or 24000 cm3 in calculations where it is required)** • **C5.17C: Use the molar volume and balanced equations in calculations involving the masses of solids and volumes of gases** • **C5.18C: Use Avogadro's law to calculate volumes of gases involved in a gaseous reaction, given the relevant equation**	*Starter* Show students three party balloons filled to an identical size but labelled 'nitrogen', 'air' and 'carbon dioxide'. Ask students to explain what they think these balloons have in common and what is different. *Exploring* Students practise calculations involving: • molar mass, moles and mass • molar volume, moles and volume *Explaining* Demonstrate that molar volume applies to any gas. First calculate the empty mass of the syringe, using 100 cm^3 air. Then use 100 cm^3 of three readily available gases, such as carbon dioxide, oxygen and methane. Measure and record the mass of the gas syringe when filled to 100 cm^3 with each gas, and show by calculation that mass/M_r is a constant.	*Exploring* Support: Students may need help in applying the relationships in their calculations, so it may be useful to work through some questions with them. Stretch: Students could use Avogadro's constant to calculate the number of particles equivalent to each number of moles. *Explaining* Support: Explain that air is a mixture of gases, so we must use its density not an M_r value. Stretch: Challenge students to suggest different ways to determine the empty mass of the gas syringe, and to identify the possible hazards.	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Use an appropriate number of significant figures • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities	Demonstrate that molar volume applies to any gas. (See *Explaining*.)

C15 Dynamic equilibria and calculations involving volumes of gases				
Lesson SC15a: Fertilisers and the Haber process (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.22C: Recall that fertilisers may contain nitrogen, phosphorus and potassium compounds to promote plant growth • C5.24C: Describe and compare: a) the laboratory preparation of ammonium sulfate from ammonia solution and dilute sulfuric acid on a small scale b) the industrial production of ammonium sulfate in which several stages are required to produce ammonia and sulfuric acid from their raw materials and the production is carried out on a much larger scale (details of the industrial production of sulfuric acid are not required) • C5.23C: Describe how ammonia reacts with nitric acid and with sulfuric acid to produce salts that are used as fertilisers • C5.19C: Describe the Haber process as a reversible reaction between nitrogen and hydrogen to form ammonia	*Starter* Show a photograph of a farmer or gardener applying fertiliser to their plants. Ask the students to pose a question based on the photograph. *Exploring* Student carry out a simple titration to produce a pure, dry sample of ammonium sulfate. They add small portions of dilute ammonia solution to dilute sulfuric acid, and use a glass rod to remove a drop to test with universal indicator paper. Once the neutral point is reached, they add a small excess of ammonia solution to ensure that all the acid has reacted. (*Suggested practical.*) *Explaining* Demonstrate the simple titration of dilute nitric acid with dilute ammonia solution.	*Exploring* Support: Ensure students appreciate the need to have just a small excess of ammonia solution to avoid excessive fumes during crystallisation. Stretch: Students use titration with a burette and methyl orange indicator to produce their ammonium sulfate solution. *Explaining* Support: Make sure that students understand the difference between ammonia, ammonia solution, and ammonium nitrate. Stretch: Challenge students to describe and explain how they would prepare ammonium nitrate solution by titration with a burette.	• Use ratios, fractions and percentages.	*Suggested practical*: Prepare a sample of ammonium sulfate from ammonia solution and dilute sulfuric acid. (See *Exploring.*) Demonstrate the simple titration of dilute nitric acid with dilute ammonia solution. (See *Explaining*.)

Lesson SC15b: Factors affecting equilibrium (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C5.20C: Predict how the rate of attainment of equilibrium is affected by:** **a) changes in temperature** **b) changes in pressure** **c) changes in concentration** **d) use of a catalyst** • **C5.21C: Explain how, in industrial reactions, including the Haber process, conditions used are related to:** **a) the availability and cost of raw materials and energy supplies** **b) the control of temperature, pressure and catalyst used produce an acceptable yield in an acceptable time**	*Starter* Show students the balanced equation for the Haber process. Students note down as many ways to increase the equilibrium yield of ammonia as they can. *Exploring* Provide students with example data and set-ups, and ask them to predict the changes in the position of equilibrium, and the rate of attainment of equilibrium, when reaction conditions change for the Haber process and the Contact process. *Explaining* Demonstrate the reversible reaction between bismuth(III) chloride solution and a precipitate of bismuth(III) oxychloride. Show that it takes longer to reach a new position of equilibrium when adding concentrated hydrochloric acid or water, and discuss other factors.	*Exploring* Stretch: Students could explain their predictions in terms of collision theory and rates of reaction. *Explaining* Support: Discuss why the position of equilibrium changes each time, e.g. the position of equilibrium moves to the right when water is added, and to the left when hydrochloric acid is added. Stretch: Challenge the students to predict and explain what would happen if dilute sodium hydroxide solution were added to the reaction mixture.	• Use ratios, fractions and percentages.	Demonstrate a reversible reaction to show factors that affect rates of attainment of equilibrium. (See *Explaining*.)

C16 Chemical cells and fuel cells				
Lesson SC16a: Chemical cells and fuel cells (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C5.25C: Recall that a chemical cell produces a voltage until one of the reactants is used up • C5.26C: Recall that in a hydrogen–oxygen fuel cell hydrogen and oxygen are used to produce a voltage and water is the only product • C5.27C: Evaluate the strengths and weaknesses of fuel cells for given uses	*Starter* In pairs using paper or mini-whiteboards, students note down as many uses of batteries as they can, and whether mains electricity could be used instead. *Exploring* Provide students with data sets and ask them to examine the link between common metals in the reactivity series and their electrode potentials. *Explaining* Demonstrate a simple fuel cell. Dip two carbon rods into a beaker of water. Show that there is no voltage. Attach a battery so that the apparatus acts as an electrolytic cell. Allow a current to flow long enough for bubbles to form on the electrodes. Replace the battery with a voltmeter. The apparatus now acts as a fuel cell. Show that a voltage now exists.	*Exploring* Support: Work through an example calculation with the students. Stretch: Lithium has a higher electrode potential than would be expected from its position on the reactivity series. Challenge students to suggest reasons for this, given that the electrode potential is a measurable property. *Explaining* Support: Make sure that students understand that hydrogen and oxygen must be in contact with the electrodes for a voltage to exist. Stretch: Challenge the students to identify the factors that determine the voltage and current produced, and the time for which a current will flow.	• Use ratios, fractions and percentages	Demonstrate a simple fuel cell. (See *Explaining*.)

C17 Groups in the periodic table				
Lesson SC17a: Group 1 (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C6.1: Explain why some elements can be classified as alkali metals (group 1), halogens (group 7), or noble gases (group 0), based on their position in the periodic table • C6.2: Recall that alkali metals: a) are soft b) have relatively low melting points • C6.3: Describe the reactions of lithium, sodium and potassium with water • C6.4: Describe the pattern in reactivity of the alkali metals, lithium, sodium and potassium, with water; and use this pattern to predict the reactivity of other alkali metals • C6.5: Explain this pattern in reactivity in terms of electronic configurations • C0.2: Write word equations • C0.3: Write balanced chemical equations, including the use of the state symbols (s), (l), (g) and (aq)	*Starter* Give each student a blank copy of an outline periodic table. Ask students to label the main groups 1 to 0; the alkali metals, halogens and noble gases and to add the symbols of the elements in these three groups. *Exploring* Show students the metals lithium, sodium and potassium and demonstrate their main physical and chemical properties. These should include: their melting points and boiling points, their density, their conductivity, cutting them with a knife, and their reactions with water. *Explaining* Describe or show a video of the reaction between lithium and chlorine. Discuss the chemical change occurring, draw electron configurations, and agree a word and symbol equation for the reaction and write them on the board.	*Exploring* Support: Remind students of the use of indicators to identify alkaline solutions and the test for hydrogen gas. Provide an example equation for each of the reactions of the alkali metals. Stretch: Ask students to write balanced ionic equations for the reactions of alkali metals with oxygen and water. *Explaining* Support: Help students relate diagrams of electron transfer to half equations. Stretch: Ask students to write balanced ionic equations for the reactions of alkali metals with chlorine.	• Use ratios, fractions and percentages	Demonstrate the main physical and chemical properties of alkali metals. (See *Exploring*.)

Lesson SC17b: Group 7 (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C6.6: Recall the colours and physical states of chlorine, bromine and iodine at room temperature • C6.7: Describe the pattern in the physical properties of the halogens, chlorine, bromine and iodine, and use this pattern to predict the physical properties of other halogens • C6.8: Describe the chemical test for chlorine • C6.9: Describe the reactions of the halogens, chlorine, bromine and iodine, with metals to form metal halides, and use this pattern to predict the reactions of other halogens • C6.10: Recall that the halogens, chlorine, bromine and iodine, form hydrogen halides which dissolve in water to form acidic solutions, and use this pattern to predict the reactions of other halogens	*Starter* In groups ask students to list as many things about chlorine, bromine and iodine as they can think of. *Exploring* Students carry out research using text and online sources to investigate the properties of chlorine, bromine and iodine. The data can then be used to look for general trends and make predictions about the physical properties of other halogens. *Explaining* In a fume cupboard, demonstrate the reactions of different metals with halogens, e.g. heated iron/steel wool in gas jar of chlorine gas; burning magnesium in gas jar of chlorine gas; Dutch foil (copper) in warmed gas jar of chlorine. Construct word, symbol, balanced and ionic equations for the reactions.	*Exploring* Support: Help students identify suitable sources of information. Stretch: Ask students to consider the trends in all the physical property information collected. Use the trends to predict values for the properties of astatine and check predictions against recorded data. *Explaining* Support: Some students will need support with writing ionic formula for equations. Stretch: Students should try to balance the more complex ionic equations forming AlC_3, $SnCl_4$, etc.	• Make estimates of the results of simple calculations • Construct and interpret frequency tables and diagrams, bar charts and histograms	Demonstrate the reactions of different metals with halogens. (See *Explaining*.)

Lesson SC17c: Halogen reactivity (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C6.11: Describe the relative reactivity of the halogens chlorine, bromine and iodine, as shown by their displacement reactions with halide ions in aqueous solution, and use this pattern to predict the reactions of astatine • **C6.12: Explain why these displacement reactions are redox reactions in terms of gain and loss of electrons, identifying which of these are oxidised and which are reduced** • C6.13: Explain the relative reactivity of the halogens in terms of electronic configurations • **C0.4: Write balanced ionic equations**	*Starter* Ask students to draw electron shell diagrams to show the electronic configurations of fluorine (2.7), chlorine (2.8.7), bromine (2.8.18.7) and iodine (2.8.18.18.7). Discuss why these halogens react in a similar way and what will happen, in terms of electrons, when the halogens react. *Exploring* Investigate the order of reactivity of the halogens by observing the displacement reactions of halogens and halide ions. (*Suggested practical*.) *Explaining* Demonstrate the reactions of aluminium with each of three halogens, chlorine, bromine and iodine, to form the solid aluminium halides. Students should write equations and discuss how different halogens have different reactivities.	*Exploring* Support: Help students interpret their observations of colour changes as either a reaction or dilution of colours. Stretch: Students carry out a further reaction of halogens which allows them to place them in order of reactivity. *Explaining* Support: Help students identify and write formulae for the products in these reactions Stretch: Ask students to write ionic equations for the changes and identify the oxidation and reduction reactions involved.	• Use ratios, fractions and percentages	*Suggested practical:* Investigate displacement reactions of halogens reacting with halide ions in solution. (See *Exploring*.) Demonstrate the reactions of aluminium with each of three halogens, chlorine, bromine and iodine. (See *Explaining*.)

Lesson SC17d: Group 0 (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C6.14: Explain why the noble gases are chemically inert, compared with the other elements, in terms of their electronic configurations • C6.15: Explain how the uses of noble gases depend on their inertness, low density and/or non-flammability • C6.16: Describe the pattern in the physical properties of some noble gases and use this pattern to predict the physical properties of other noble gases	*Starter* Ask students to work in pairs to invent an element. The element must be a gas and not react with anything. Students design a card for the element which should include its name, the periodic table group it is in and its possible uses. *Exploring* Students organise data on the physical properties of noble gases, relating observable trends to the position of the elements in the periodic table and using the trends to predict unknown values. The properties investigated are: atomic size, relative atomic mass, boiling point and density. *Explaining* Students should draw a graph, with a best fit line, of *relative atomic mass* (horizontal axes) against the *density* (vertical axes) for the noble gases. Ask students to use their graphs to work out the densities of other common gaseous elements and compounds using their relative atomic masses.	*Exploring* Support: Give students graph paper with axes already drawn for them Stretch: Ask students to explain the trends in relative atomic mass and density by relating them to the atomic structure of the elements. *Explaining* Support: Help students with the axis and scales for their graph by giving them graph paper with axes already drawn for them. Stretch: Ask students to see if the same relationship exists for solid elements and discuss any differences in terms of the nature of the particle structure in gases and solids.	• Make estimates of the results of simple calculations • Construct and interpret frequency tables and diagrams, bar charts and histograms	n/a

C18 Rates of reaction				
Lesson SC18a: Rates of reaction (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C7.2: Suggest practical methods for determining the rate of a given reaction • C7.5: Interpret graphs of mass, volume or concentration of reactant or product against time • *C7.1: Core Practical: Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by: a) measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)* *…*	*Starter* Ask students to work in pairs to write down as many chemical reactions as they can think of, classifying them under three headings 1 - very slow reactions e.g. rusting, 2 - medium speed reactions e.g. cooking and 3 - very fast reactions e.g. explosions and precipitations. *Exploring* 1) Investigate the effect of changing the surface area of solids (the size of solid lumps) in the reaction between marble chips and hydrochloric acid. 2) Investigate the effect of changing the acid concentrations in the same reaction. (*Core practical.*) *Explaining* Discuss 'the idea of 'clock reactions' with students and how if we time a reaction to a certain point then then we can compare rates as the rate is inversely proportional to the time.	*Exploring* Support: Help students set up experiments, checking they know how to make measurements, and to measure the changes as soon as the reactions start. Stretch: Ask students to describe how the very reactive metal calcium and hydrochloric acid reaction can be carried out safely. *Explaining* Stretch: Ask students to think about how they could carry out an investigation into rates using a clock reaction with the reaction between magnesium and hydrochloric acid.	• Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Understand that $y = mx + c$ represents a linear relationship • Determine the slope and intercept of a linear graph • Draw and use the slope of a tangent to a curve as a measure of rate of change • Calculate areas of triangles and rectangles, surface areas and volumes of cubes	*Core Practical: Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:* *a) measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)* *b) observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid)* (See *Exploring*.)

Lesson SC18b: Factors affecting reaction rate (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C7.3: Explain how reactions occur when particles collide and that rates of reaction are increased when the frequency and/or energy of collisions is increased • C7.4: Explain the effects on rates of reaction of changes in temperature, concentration, surface area to volume ratio of a solid, and pressure (on reactions involving gases) in terms of frequency and/or energy of collisions between particles • *C7.1: Core Practical: Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:* *…* *b) observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid)*	*Starter* Demonstrate the idea that collisions are needed for reactions to occur using a tray of marbles with a solid block of wood in the centre. *Exploring* Investigate the effect of temperature changes on the rate of a reaction between sodium thiosulfate and hydrochloric acid. (*Core practical.*) *Explaining* Demonstrate the kinetic modelling apparatus to explain how the changes in conditions affect rates of reaction.	*Exploring* Support: Check when students make their first measurements, and give advice about how to ensure they are measuring the temperature and time correctly. Stretch: Students could graph 1/time (min^{-1}) on the vertical axis against temperature (°C) on the horizontal axis. *Explaining* Support: Students should concentrate only on changes that affect the number of collisions that take place. Stretch: Ask students to think of a way of modelling the idea that for a reaction to occur molecules must collide with a sufficient amount of energy.	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Calculate areas of triangles and rectangles, surface areas and volumes of cubes	*Core Practical: Investigate the effects of changing the conditions of a reaction on the rates of chemical reactions by:* *a) measuring the production of a gas (in the reaction between hydrochloric acid and marble chips)* *b) observing a colour change (in the reaction between sodium thiosulfate and hydrochloric acid).* (See *Exploring*.) Demonstrate the kinetic modelling apparatus to explain how the changes in conditions affect rates of reaction. (See *Explaining*.)

Lesson SC18c: Catalysts and activation energy (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C7.6: Describe a catalyst as a substance that speeds up the rate of a reaction without altering the products of the reaction, being itself unchanged chemically and in mass at the end of the reaction • C7.7: Explain how the addition of a catalyst increases the rate of a reaction in terms of activation energy • C7.8: Recall that enzymes are biological catalysts and that enzymes are used in the production of alcoholic drinks	*Starter* Ask students to draw a concept map about reaction rates. *Exploring* Students research how catalytic converters in car exhausts work, then write a brief summary including formulae for the reactions that occur. *Explaining* Demonstration of the catalytic effect of cobalt(II) ions on the reaction between hydrogen peroxide and potassium sodium tartrate (Rochelle salt).	*Exploring* Support: Help students with working out word equations to make sure the same elements appear on both sides Stretch: Ask students to write balanced equations for the reactions that remove carbon monoxide, nitrogen oxides and unburned hydrocarbons. Explain why the catalyst does not appear in the equation. *Explaining* Support: Give students a running commentary as the reaction proceeds, including an explanation of what is happening during the colour changes. Stretch: Ask students to find out about homogeneous and heterogeneous catalysts.	n/a	Demonstration of the catalytic effect of cobalt(II) ions on the reaction between hydrogen peroxide and potassium sodium tartrate (Rochelle salt). (See *Explaining*.)

C19 Heat changes in chemical reactions				
Lesson SC19a: Exothermic and endothermic reactions (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C7.9: Recall that changes in heat energy accompany the following changes: a) salts dissolving in water b) neutralisation reactions c) displacement reactions d) precipitation reactions • and that, when these reactions take place in solution, temperature changes can be measured to reflect the heat changes • C7.10: Describe an exothermic change or reaction as one in which heat energy is given out • C7.11: Describe an endothermic change or reaction as one in which heat energy is taken in	*Starter* Demonstration: Add some calcium chloride powder to some water in a boiling tube. Repeat the demonstration but with ammonium chloride powder. Ask the students to explain the temperature changes. *Exploring* Suggested practical: Students mix four different metal powders with copper(II) sulfate solution and measure the increases in temperature. They compare the order of temperature rise to the metal reactivity series. *Explaining* Demonstration: Temperature changes during neutralisation and precipitation. Discuss the factors affecting the changes observed.	*Exploring* Support: Make sure students understand the need to measure the maximum temperature obtained in each case, so they must be patient. Stretch: Challenge the students to write balanced equations for the reactions observed. *Explaining* Support: One way to remember 'exothermic' is to consider a fire exit – fires are hot, and you go out of an exit. Stretch: Ask the students to suggest and explain improvements to the experiment.	• Use ratios, fractions and percentages.	*Suggested practical: Measure temperature changes accompanying some of the following types of change:* *a) salts dissolving in water* *b) neutralisation reactions* *c) displacement reactions* *d) precipitation reactions.*

Lesson SC19b: Energy changes in reactions (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C7.12: Recall that the breaking of bonds is endothermic and the making of bonds is exothermic • C7.13: Recall that the overall heat energy change for a reaction is: a) exothermic if more heat energy is released in forming bonds in the products than is required in breaking bonds in the reactants b) endothermic if less heat energy is released in forming bonds in the products than is required in breaking bonds in the reactants • **C7.14: Calculate the energy change in a reaction given the energies of bonds (in kJ mol^{-1})** • C7.15: Explain the term activation energy • C7.16: Draw and label reaction profiles for endothermic and exothermic reactions, identifying activation energy	*Starter* Show a simple equation for the reaction between simple molecular substances, e.g. $H_2 + Cl_2 \rightarrow 2HCl$. Students work in pairs or fours to make molecular models of the reactants and then products. *Exploring* Students use molecular modelling kits and a data table of bond energies to tally the energy needed to break bonds in reactants, and the energy released when bonds are formed in the products. They then compare the two values to determine whether exothermic or endothermic. *Explaining* Ignite a hydrogen-filled balloon and demonstrate the electrolysis of acidified water. Draw energy diagrams for both and discuss the bond-breaking and bond-making processes and overall energy change.	*Exploring* Support: Use partially completed tally charts. Stretch: Students calculate energy change in the reaction and use the sign of their answer to determine whether the reaction is exothermic or endothermic. *Explaining* Support: Some students may need additional help to understand that the overall energy change is the difference between the energy needed to break bonds and the energy needed to make bonds Stretch: Challenge the students to calculate the overall energy change for both demonstrations. What do they notice? They should get the same value (243 kJ mol^{-1}, but with opposite signs).	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Translate information between graphical and numeric form	n/a

C20 Fuels				
Lesson SC20a: Hydrocarbons in crude oil and natural gas (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.1: Recall that hydrocarbons are compounds that contain carbon and hydrogen only • C8.2: Describe crude oil as: a) a complex mixture of hydrocarbons b) containing molecules in which carbon atoms are in chains or rings (names, formulae and structures of specific ring molecules not required) c) an important source of useful substances (fuels and feedstock for the petrochemical industry) d) a finite resource • C8.15: Recall that petrol, kerosene and diesel oil are non-renewable fossil fuels obtained from crude oil and methane is a non-renewable fossil fuel found in natural gas	*Starter* In pairs using paper or mini-whiteboards, students note down as many things as they can about fuels. They compare their answers with another pair, then feedback to the class. *Exploring* Students use molecular modelling kits to make models of hydrocarbons, all of which contain five carbon atoms with single C–C bonds. Students draw the structure of each one. *Explaining* Demonstrate a wooden splint burning and a candle burning. Explain why the wood is renewable but the candle wax is non-renewable, including that the wax is manufactured from crude oil. Show samples of waxes from different sources, e.g. paraffin wax (extracted from crude oil), beeswax (secreted by honey bees), lanolin (from sheep's wool), carnauba wax (from the leaves of palm plants). Discuss which of these are renewable or non-renewable.	*Exploring* Support: Show how to make a model of butane, C_4H_{10}, then convert this into 2-methylpropane. Convert this into a model of cyclobutane. Make sure the students understand the colour code for the molecular modelling kit Stretch: Challenge the students to sort the models into groups (e.g. straight chains, branched molecules, rings). *Explaining* Support: Explain the differences between 'fossil fuel' and 'non-renewable fuel'. Stretch: Challenge the students to evaluate the statement, 'all fossil fuels are non-renewable fuels, and all non-renewable fuels are fossil fuels'.	• Use ratios, fractions and percentages	n/a

Lesson SC20b: Fractional distillation of crude oil (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.3: Describe and explain the separation of crude oil into simpler, more useful mixtures by the process of fractional distillation • C8.4: Recall the names and uses of the following fractions: a) gases, used in domestic heating and cooking b) petrol, used as fuel for cars c) kerosene, used as fuel for aircraft d) diesel oil, used as fuel for some cars and trains e) fuel oil, used as fuel for large ships and in some power stations f) bitumen, used to surface roads and roofs • C8.5: Explain how hydrocarbons in different fractions differ from each other in: a) the number of carbon and hydrogen atoms their molecules contain b) boiling points c) ease of ignition d) viscosity …	*Starter* Demonstrate a sample of crude oil substitute. Ask students to describe what it is like and how it could be made useful. *Exploring* Suggested practical: Teacher demonstration involving fractional distillation of a crude oil substitute, which includes testing the viscosity and ease of ignition of fractions. *Explaining* Demonstrate the viscosities of different motor oils. Fill, then seal, long glass tubes or test tubes with different motor oils. Make sure a small air bubble remains inside each one. Measure the time taken for the bubbles to travel upwards in each sealed tube. The longer the time taken, the more viscous the motor oil.	*Exploring* Support: Ensure students are clear on the meanings of the terms 'viscosity' and 'ignition' Stretch: Challenge the students to explain how the viscosity and ease of ignition of the fractions vary with their boiling point. *Explaining* Support: Make sure students are clear that a 'thick' liquid is 'viscous' (not 'vicious'), and has a 'high viscosity'. Stretch: Challenge the students to explain, in terms of molecular size and intermolecular forces, why different liquids have different viscosities.	• Translate information between graphical and numeric form • Plot two variables from experimental or other data	*Suggested practical:* Investigate the fractional distillation of synthetic crude oil and the ease of ignition and viscosity of the fractions (see *Exploring*)

Lesson SC20c: The alkane homologous series (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.5: Explain how hydrocarbons … are mostly members of the alkane homologous series • C8.6: Explain an homologous series as a series of compounds which: a) have the same general formula b) differ by CH_2 in molecular formulae from neighbouring compounds c) show a gradual variation in physical properties, as exemplified by their boiling points d) have similar chemical properties	*Starter* In pairs using paper or mini-whiteboards, students produce a mnemonic for the fractions obtained from crude oil, either bottom to top from the fractionating column, or top to bottom from the fractionating column. They compare their answers with another pair, then feedback to the class. *Exploring* Students use molecular modelling kits to produce different members of the alkanes, alcohols and alkenes homologous series. The aim is to show some features of an homologous series, i.e. you can go from one member to the next by adding CH_2, and they have general formulae. *Explaining* Demonstrate the test-tube reactions of hexane and hexene with acidified potassium manganate(VII) solution.	*Exploring* Support: Explain the rules for using the kits. Stretch: Challenge the students to make butane C_4H_{10}, and cyclobutane, C_4H_8; pentane C_5H_{12}, and cyclopentane C_5H_{10}. Ask the students to evaluate whether these four compounds all belong to the same homologous series (they do not). *Explaining* Support: Explain that any observed change is due to a chemical reaction. Stretch: Repeat the demonstration but with ethanol.	• Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Translate information between graphical and numeric form • Plot two variables from experimental or other data	*Suggested practical:* Test-tube reactions of hexane and hexene with acidified potassium manganate(VII) solution (see *Explaining*).

Lesson SC20d: Complete and incomplete combustion (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.7: Describe the complete combustion of hydrocarbon fuels as a reaction in which: a) carbon dioxide and water are produced b) energy is given out • C8.8: Explain why the incomplete combustion of hydrocarbons can produce carbon and carbon monoxide • C8.9: Explain how carbon monoxide behaves as a toxic gas • C8.10: Describe the problems caused by incomplete combustion producing carbon monoxide and soot in appliances that use carbon compounds as fuels	*Starter* Show a carbon monoxide detector or a photo of one. Ask the students to write down, on paper or mini-whiteboards, a question based on this. *Exploring* Students carry out a practical in which they burn tea lights in different sized containers, and record the burning time. They then plot a graph of burning time against container volume. *Explaining* Demonstrate the products of combustion of candle wax. Use anhydrous copper(II) sulfate or dry cobalt chloride paper to detect water in the U-shaped tube, and limewater to detect carbon dioxide. Show the production of soot on the inverted filter funnel. Discuss the hazard of carbon monoxide, and the problems of gas and soot from appliances. For next lesson: Set up containers of cress seeds and building materials	*Exploring* Support: Measure and label the containers with their volumes before the practical activity. Provide graph paper with pre-prepared axes. Stretch: Challenge the students to explain why the flame dims before it goes out. *Explaining* Support: Make sure the students appreciate that the cold water outside the U-shaped tube does not enter the apparatus, but cools the water vapour inside. Stretch: One of the compounds in candle wax is heneicosane, $C_{21}H_{44}$. Challenge the students to write a balanced equation for the incomplete combustion of this alkane where equal amounts of carbon dioxide, carbon monoxide and carbon are produced. ($C_{21}H_{44} + 21\frac{1}{2}O_2$ $\rightarrow 22H_2O + 7CO_2 + 7CO + 7C$)	• Use ratios, fractions and percentages. • Translate information between graphical and numeric form. • Plot two variables from experimental or other data.	*Suggested practical:* Investigate the products produced from the complete combustion of a hydrocarbon.

Lesson SC20e: Combustible fuels and pollution (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.11: Explain how impurities in some hydrocarbon fuels result in the production of sulfur dioxide • C8.12: Explain some problems associated with acid rain caused when sulfur dioxide dissolves in rain water • C8.13: Explain why, when fuels are burned in engines, oxygen and nitrogen can react together at high temperatures to produce oxides of nitrogen, which are pollutants	*Starter* In pairs using paper or mini-whiteboards, students balance combustion equations supplied on the board, then peer assess their answers with another pair. *Exploring* Students investigate the effects of adding various building materials to dilute sulfuric acid, and record their observations. *Explaining* Open up the containers set up last lesson. Observe the contents and discuss the differences between the 'acid rain' contents and the 'normal rain' contents.	*Exploring* Support: Make sure students understand the need to leave each material for a few minutes rather than just recording the immediate results. Stretch: Repeat the experiment using dilute nitric acid (to mimic the effect of acid rain from NO_x). *Explaining* Support: Take out each material in turn, setting each type side by side in pairs for easy comparison to be made. Make sure that the students appreciate that this is a model for the production and effects of acid rain. Stretch: Challenge the students to evaluate the use of cress seeds to represent living organisms in this investigation.	• Use ratios, fractions and percentages. • Construct and interpret frequency tables and diagrams, bar charts and histograms.	*Suggested practical:* Investigate the effects of adding various building materials to dilute sulfuric acid, and record their observations.

Lesson SC20f: Breaking down hydrocarbons (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.14: Evaluate the advantages and disadvantages of using hydrogen, rather than petrol, as a fuel in cars • C8.16: Explain how cracking involves the breaking down of larger, saturated hydrocarbon molecules (alkanes) into smaller, more useful ones, some of which are unsaturated (alkenes) • C8.17: Explain why cracking is necessary	*Starter* In pairs using paper or mini-whiteboards, students write down the features they think a fuel for a car should have. They compare their answers with another pair, then feedback to the class. *Exploring* Students work in groups to crack paraffin oil. They observe the formation of liquid and gaseous products, with a different appearance from the original reactant. Students test each fraction with 0.002 mol dm^{-3} bromine water. *Explaining* Model a cracking reaction using a molecular modelling kit. Make a model of butane, C_4H_{10}. Break the model to make ethene, C_2H_4 and ethane, C_2H_6. Discuss the uses of this, e.g. ethene is used to make poly(ethene), and shorter alkanes make better fuels than longer ones (less viscous and ignite more easily). Break a C–H bond from each end of the ethane molecule to make a 2nd ethene molecule and H_2.	*Exploring* Support: This practical is demanding, and requires skill and care from the students. Consider swapping this activity with the Explaining activity. Stretch: Challenge the students to describe how they could separate the different substances present in the liquid paraffin, and the substances collected in the test tubes. *Explaining* Support: Make sure the students understand that many cracking reactions are possible. In general, cracking produces shorter alkanes and alkenes (and also hydrogen). Stretch: Challenge the students to explain which bond (C–H or C–C) is likely to be the stronger of the two, given what happens in cracking.	• Use ratios, fractions and percentages • Construct and interpret frequency tables and diagrams, bar charts and histograms	*Suggested practical:* Investigate the cracking of paraffin oil.

C21 Earth and atmospheric science				
Lesson SC21a: The early atmosphere (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.18: Recall that the gases produced by volcanic activity formed the Earth's early atmosphere • C8.19: Describe that the Earth's early atmosphere was thought to contain: a) little or no oxygen b) a large amount of carbon dioxide c) water vapour d) small amounts of other gases • and interpret evidence relating to this • C8.20: Explain how condensation of water vapour formed oceans	*Starter* Show students the approximate composition of the atmospheres of Venus and of Titan (Saturn's largest moon). Ask students to compare these two atmospheres. *Exploring* Students work in pairs to research the Earth's early atmosphere. One student looks for evidence that there was little oxygen, the other student looks for evidence of early carbon dioxide. Students summarise their findings in a table. *Explaining* Model a volcano to help students understand how carbon dioxide is released from volcanoes.	*Exploring* Support: Remind students of what 'evidence' is, in relation to an idea or hypothesis. Stretch: Challenge students to widen the range of gases they investigate, including water vapour. *Explaining* Support: Remind students of the limewater test for carbon dioxide before doing the demonstration. Stretch: Challenge students to research how the release of carbon dioxide from volcanoes is different from the model(s) used.	• Construct and interpret frequency tables and diagrams, bar charts and histograms • Understand and use the symbols: =, <, <<, >>, >, ∝, ~ • Translate information between graphical and numeric form	*Suggested practical:* Investigate how carbon dioxide is produced using a model volcano (see *Explaining*).

Lesson SC21b: A changing atmosphere (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.21: Explain how the amount of carbon dioxide in the atmosphere was decreased when carbon dioxide dissolved as the oceans formed • C8.22: Explain how the growth of primitive plants used carbon dioxide and released oxygen by photosynthesis and consequently the amount of oxygen in the atmosphere gradually increased • C8.23: Describe the chemical test for oxygen	*Starter* Demonstrate the tests for carbon dioxide and oxygen. *Exploring* Students are given three labelled boiling tubes containing (A) early Earth atmosphere (pre 4 billion years ago), (B) modern-day atmosphere and (C) an atmosphere that may exist on another body in the Solar System. Students then test each 'atmosphere' for water, carbon dioxide and the presence of some oxygen to distinguish between the atmospheres. *Explaining* Lead a class discussion to elicit what elements all carbonate compounds contain and where these elements come from and how. Demonstrate the presence of carbon dioxide by dripping HCl on seashells.	*Exploring* Support: Provide students with an incomplete results table to complete. Show students how to perform each test before they do their tests. Stretch: Challenge students to research the compositions of other atmospheres of bodies in the Solar System and to design a table to predict the results of the various gas tests. *Explaining* Support: Remind students that gases dissolve in water and have different solubilities. Get students to think about fish and other aquatic animals that use gills to extract oxygen from water. Stretch: Tell students that, early in the Earth's history, some carbonate rocks formed in a non-biological way. Challenge students to find out how this occurred (direct precipitation of calcium carbonate).	• Translate information between graphical and numerical form. • Plot two variables from experimental or other data.	*Suggested practical:* Investigate the proportion of oxygen in the atmosphere.

Lesson SC21c: The atmosphere (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.24: Describe how various gases in the atmosphere, including carbon dioxide, methane and water vapour, absorb heat radiated from the Earth, subsequently releasing energy which keeps the Earth warm: this is known as the greenhouse effect • C8.25: Evaluate the evidence for human activity causing climate change, considering: a) the correlation between the change in atmospheric carbon dioxide concentration, the consumption of fossil fuels and temperature change b) the uncertainties caused by the location where these measurements are taken and historical accuracy	*Starter* Groups of 3-4 students each pick a country. Each student represents their country at an international meeting and in their group discuss, for 4-5mins, how humans have changed the Earth's climate, the problems their countries may face, and possible solutions. Randomly selected groups give a 20sec summary of climate change concerns/problems and solutions. *Exploring* Students investigate the effect of carbon dioxide concentration on the temperature of air inside plastic drinks bottles. *Explaining* The *Exploring* model may be further developed by the teacher to compare different greenhouse gases, by setting up a range of bottles containing different gases, e.g. carbon dioxide, methane and nitrous oxide (N_2O).	*Exploring* Support: Provide students with a pre-drawn table to fill in for their results. Stretch: Ask students to interpret a graph of temperature against time produced by the use of a temperature probe and datalogger using the apparatus. Encourage students to use the graph to calculate rates of change at certain times by calculating the gradient of a slope between two time points or using a tangent to calculate a gradient at a certain time point. *Explaining* Support: Remind students that carbon dioxide is only one of many greenhouse gases that are produced by human activity Stretch: Challenge students to list three factors that need to be taken into account when trying to work out how much contribution to global warming a certain greenhouse gas makes (volume released, lifespan, and absorption of infrared radiation).	• Construct and interpret frequency tables and diagrams, bar charts and histograms • Make order of magnitude calculations • Translate information between graphical and numeric form	*Suggested practical:* Investigation of the effect of carbon dioxide concentration on the temperature of air inside plastic bottles (see *Exploring*).

Lesson SC21d: Climate change (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C8.26: Describe: a) the potential effects on the climate of increased levels of carbon dioxide and methane generated by human activity, including burning fossil fuels and livestock farming b) that these effects may be mitigated: consider scale, risk and environmental implications	*Starter* Present two sets of pictures: Group A = floods, drought, retreating ice caps / Group B: forest fires, burning of oil, car exhausts and farming livestock. Ask students to discuss possible links between two of the images. *Exploring* Ask students to complete a simple data analysis task looking at the impact of certain human activities on climate change. *Explaining* Use the model of a plastic drinks bottle with a carbon dioxide atmosphere (from *Exploring* in CC17c) to investigate the effect of reducing carbon dioxide concentrations (soda lime in 1 of 2 bottles) and reflecting radiation from the Sun (1 bottle in shade, another in light).	*Exploring* Support: Work through the questions with students, helping them to identify the paragraphs in which relevant information can be found. Stretch: Challenge students to find out about natural events that can cause climate change (e.g. volcanic activity). *Explaining* Support: Go through the different parts of the model, reminding students what each part represents Stretch: Ask students to list the desirable features of the material used to make the reflector.	• Recognise and use expressions in standard form. • Make order of magnitude calculations. • Translate information between graphical and numeric form.	*Suggested practical:* Investigate the presence of water vapour and carbon dioxide in the atmosphere.

C22 Hydrocarbons				
Lesson SC22a: Alkanes and alkenes (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.10C: Recall the formulae of molecules of the alkanes, methane, ethane, propane and butane, and draw the structures of these molecules, showing all covalent bonds • C9.11C: Explain why the alkanes are saturated hydrocarbons • C9.12C: Recall the formulae of molecules of the alkenes, ethene, propene, butene and draw the structures of these molecules, showing all covalent bonds (but-1-ene and but-2-ene only) • C9.13C: Explain why the alkenes are unsaturated hydrocarbons, describing that their molecules contain the functional group C=C	*Starter* On the board, write and draw the names, molecular formulae and structures of the first four alkanes. Ask students to match them up and then in pairs identify the differences and similarities between the alkanes. This revises work from topic SC20c The alkane homologous series. *Exploring* Students should compare different models of the alkanes and alkenes (molecular formula, structure, 3D model, dot and cross diagram) and give one advantage and one disadvantage of each type of model as a representation of the molecule. *Explaining* Show students molecular modelling kit molecules of the first four alkanes and the first four alkenes (including but-1-ene and but-2-ene). Ensure that students can see how the single and double bonds are modelled using the particular kit that you have.	*Exploring* Support: Go through dot and cross diagrams with students, reminding them of their work in SC6 Covalent bonding. Stretch: Challenge students to model the different possible straight chain isomers of pentene, and to name them (pent-1-ene and pent-2-ene). *Explaining* Support: Before starting, hold up the components of the molecular modelling kit that you have to show the individual items that are used to represent carbon atoms, hydrogen atoms (and covalent bonds if applicable). Stretch: Challenge students to draw the structures of hexane and hexene, including the latter's three straight chain isomers and their names.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*n/a*

Lesson SC22b: Reactions of alkanes and alkenes (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.14C: Recall the addition reaction of ethene with bromine, showing the structures of reactants and products, and extend this to other alkenes • C9.15C: Explain how bromine water is used to distinguish between alkanes and alkenes • C9.16C: Describe how the complete combustion of alkanes and alkenes involves the oxidation of the hydrocarbons to produce carbon dioxide and water	*Starter* Ask students what happens when gas in a Bunsen burner burns. Remind them, using a demonstration, of the different settings for a Bunsen and why you get yellow flames and blue flames. Ask students how they would show what gases are produced and whether the products of burning alkenes would be any different to those of alkanes. Tell students that we can test to see if a substance contains a C=C double bond and that this can be used as a test to see if an unknown substance is an alkane or an alkene. *Exploring* Suggested practical: Students use bromine water to test whether a liquid is cyclohexane or cyclohexene. *Explaining* Use a molecular modelling kit to demonstrate the addition reaction that occurs between various simple alkenes and bromine. Illustrate why the reaction does not occur with alkanes. You could encourage students to draw out the structural (displayed) formulae as you demonstrate.	*Exploring* Support: Provide students with a table to complete for their results. Stretch: Include other ‘unknown’ substances for students to test for unsaturation (e.g. limonene), after they have completed the experiment with cyclohexane and cyclohexene. *Explaining* Support: Remind students how to interpret the structural formulae of hydrocarbons, concentrating on the fact that in these (displayed) structural formulae all the covalent bonds between the atoms are shown. Stretch: Challenge students to explain why addition reactions are much better shown using (displayed) structural formulae as opposed to molecular formulae (which are empirical). Challenge them to interpret the difference between $BrCH_2CH_2Br$ and CH_3CHBr_2 (both of which have the same molecular formula – $C_2H_4Br_2$).	• Use ratios, fractions and percentages • Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*Suggested practical:* Test for unsaturation using bromine water.

C23 Alcohols and carboxylic acids				
Lesson SC23a: Ethanol production (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.33C: Describe the production of ethanol by fermentation of carbohydrates in aqueous solution, using yeast to provide enzymes • C9.34C: Explain how to obtain a concentrated solution of ethanol by fractional distillation of the fermentation mixture	*Starter* Ask students to list some common alcoholic drinks and rank them in order of alcohol content. Tell students that the yeast used to make alcohol in these drinks cannot survive in alcohol concentrations of more than about 17%. Ask them to suggest how stronger alcoholic drinks are made. Finish by asking students to work in groups to prepare a list of bullet points that describe the process of fractional distillation. *Exploring* Suggested practical: Students work in groups to investigate the effect of changing the concentration of glucose solutions on the rate of fermentation. The investigation is fairly complex and takes time to complete. Students could complete the work over a couple of lessons, or different groups could investigate different glucose concentrations and pool their results. *Explaining* Demonstrate fractional distillation using the filtered fermentation solution or a made-up solution containing 10-15% ethanol. Explain how the apparatus works at each stage of the process. Having the apparatus set up before the lesson starts will save time. The difference between the fermented solution and the distillate can be shown by testing their flammability.	*Exploring* Support: Some students will initially need help in setting up and running this investigation to make the most productive use of their time. Stretch: Ask students to complete the write-up of the investigation. Tell them they will need to choose a suitable format for recording results, drawing graphs, writing conclusions and evaluating the process. *Explaining* Support: A web search (using search terms like: condenser + fractional distillation + alcohol + how works) should produce animation and video resources that would help to explain the process Stretch: Ask students to find out about how a hydrometer can be used in wine or beer making.	• Construct and interpret frequency tables and diagrams, bar charts and histograms • Understand and use the symbols: $=$, $<$, $<<$, $>>$, $>$, $\propto$, $\sim$ • Translate information between graphical and numeric form	*Suggested practical:* Prepare a solution of ethanol by fermentation.

Lesson SC23b: Alcohols (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.26C: Recall the formulae of molecules of the alcohols, methanol, ethanol, propanol (propan-1-ol only) and butanol (butan-1-ol only), and draw the structures of these molecules, showing all covalent bonds • C9.27C: Recall that the functional group in alcohols is –OH • C9.32C: Recall members of a given homologous series have similar reactions because their molecules contain the same functional group and use this to predict the products of other members of these series • *C9.28C: Core Practical: Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols ethanol, propanol, butanol and pentanol*	*Starter* Write the names of the first four members of the alkane series on the board (from C1 to C4). Ask the students to devise a mnemonic based on the letters M, E, P, B to help them remember the relevant prefixes. E.g. Monsters Eat Pickled Beetroot, or something with more meaningful to the students to make it easier to remember. *Exploring* Core practical: Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols; methanol, ethanol, propanol, and butanol. Burn alcohols in spirit burners and heat water in a beaker or copper can. You can heat the water for a given amount of time and measure the temperature rise of the water and the mass of alcohol that was burned. *Explaining* Demonstration of the properties and reactions of alcohols: solubility, combustion and the reactions with sodium metal. • Test 1: Alcohols + water • Test 2: Universal indicator • Test 3: Igniting alcohols • Test 4: Alcohols + sodium Initiate a class discussion on the reactions and any observable trends. Students should take notes so they can write a summary of the chemical and physical properties of alcohols, including any trends in the series.	*Exploring* Support: Some students will need to be shown how to set up and use the apparatus so that heat losses are kept to a minimum. Stretch: Ask students to calculate the actual energy released during each combustion by using the equation: $\Delta Q = m \times c \times \Delta\theta$ (energy transferred = mass of water × specific heat capacity of water (4.2) × change in water temperature). If the mass of water is in grams, the energy transferred is in joules. *Explaining* Support: Some students will need help with their summary of the reactions of alcohols and could be provided with a completed summary of the chemical and physical properties of ethanol to help them. Stretch: Ask students to find out about the dehydration of alcohols and write balanced equations and descriptions of the changes involved.	• Recognise and use expressions in decimal form • Construct and interpret frequency tables and diagrams, bar charts and histograms • Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	*Core practical: Investigate the temperature rise produced in a known mass of water by the combustion of the alcohols, methanol, ethanol, propanol, butanol*

Lesson SC23c: Carboxylic acids (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.29C: Recall the formulae of molecules of the carboxylic acids, methanoic, ethanoic, propanoic and butanoic acids, and draw the structures of these molecules, showing all covalent bonds • C9.30C: Recall that the functional group in carboxylic acids is –COOH • C9.31C: Recall that ethanol can be oxidised to produce ethanoic acid and extend this to other alcohols (reagents not required) • C9.32C: Recall that members of a given homologous series have similar reactions because their molecules contain the same functional group and use this to predict the products of other members of these series	*Starter* Ask students to work in small groups to answer the question: 'How can you tell if a solution is an acid?' *Exploring* Suggested practical: Students work in groups to investigate the properties and reactions of carboxylic acids. This should involve a series of test-tube experiments using dilute methanoic, ethanoic and propanoic acid solutions, which are tested for pH and their reactions with magnesium, sodium carbonate and copper oxide. *Explaining* Discuss the meaning of oxidation reactions. Demonstrate that one way of oxidising ethanol is to burn it. This is 'destructive' oxidation as the original carbon chain has been destroyed. Then demonstrate the controlled oxidation of ethanol to ethanoic acid.	*Exploring* Support: Help students to set up the delivery tube in the water, and demonstrate how to fill a test tube with water and hold it over the delivery tube to collect the gases. Stretch: Write up the experiment in their own words, by designing their own results tables, and writing a conclusion and an evaluation. *Explaining* Support: The use of models to simply demonstrate what is happening during the oxidation of alcohols would help students who need help with ideas about oxidation. Stretch: Ask students to use the formula of ethanoic acid to write a balanced equation for the combustion reaction and the mild oxidation with copper oxide. Students could also be asked to find out about the use and advantages of reflux techniques for the oxidation of alcohols.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects • Use ratios, fractions and percentages • Recognise and use expressions in decimal form	*Suggested practical:* Investigate the properties and reactions of carboxylic acids (see *Exploring*)

C24 Polymers				
Lesson SC24a: Addition polymerisation (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.17C: Recall that a polymer is a substance of high average relative molecular mass made up of small repeating units • C9.25C: Recall that: a) DNA is a polymer made from four different monomers called nucleotides (names of nucleotides not required) b) starch is a polymer based on sugars c) proteins are polymers based on amino acids • C9.18C: Describe: a) how ethene molecules can combine together in a polymerisation reaction b) that the addition polymer formed is called poly(ethene) (conditions and mechanisms not required)	*Starter* Give each student or group of students a few paper clips. Ask them to join the paper clips together to form a short chain. Then ask each student or group to join their chain to the next one and continue this until all the chains have joined together. *Exploring* Show the students a model of ethene and ask them to make their own model. The first two groups then break one of the bonds between the two carbon atoms and join their molecules together. The third group breaks one of their bonds and joins on the chain. Continue this around the class until all the molecules have joined the chain. *Explaining* Demonstrate the polymerisation of styrene as an example of addition polymerization, or show a short video clip of the procedure.	*Exploring* Stretch: Students make their own models and join them together. *Explaining* Support: Use molecular models to show the formation of poly(phenylethene) (polystyrene). Stretch: Challenge students to write the equation for the formation of poly(phenylethene) (polystyrene).	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Demonstrate the polymerisation of styrene as an example of addition polymerisation. (See *Explaining*.)

Lesson SC24b: Polymer properties and uses (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.19C: Describe how other addition polymers can be made by combining together other monomer molecules containing C=C, to include poly(propene), poly(chloroethene) (PVC) and poly(tetrafluoroethene) (PTFE) (conditions and mechanisms not required) • C9.20C: Deduce the structure of a monomer from the structure of an addition polymer and vice versa • C9.21C: Explain how the uses of polymers are related to their properties and vice versa: including poly(ethene), poly(propene), poly(chloroethene) (PVC) and poly(tetrafluoroethene) (PTFE)	*Starter* Ask students to write down everything they know about polymers. Prompt them to include names, properties and uses of the polymers they know about. *Exploring* Students make models of propene, chloroethene and tetrafluoroethene, and join them together to form polymers. *Explaining* Put out a large display of commonly used items made from polymers and discuss the properties and uses of each of them with the students.	*Exploring* Support: Ask students to use themselves to make a model of polymerisation. Stretch: Students make their own models and join them together. They then draw the structures of the monomers and the polymers, showing the repeating unit. *Explaining* Support: Give students some paper tags and ask them to write the names of some of the polymers, their properties and uses. Stretch: Students research some other addition polymers, such as poly(ethenol) and rubber, and prepare a presentation about their structures, properties and uses.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Make models of monomers and polymers. (See *Exploring*.)

Lesson SC24c: Condensation polymerisation (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **C9.22C: Explain:** **a) why polyesters are condensation polymers** **b) how a polyester is formed when a monomer molecule containing two carboxylic acid groups is reacted with a monomer molecule containing two alcohol groups** **c) how a molecule of water is formed each time an ester link is formed**	*Starter* Demonstrate the formation of nylon. *Exploring* Students make up models of ethanol and ethanoic acid, and combine them together to form the ester, ethyl ethanoate, and water. Students then make up models of ethane-1,2-diol and ethanedioic acid and combine them together to form one ester linkage. They then join their models to those of other groups to form a polyester. *Explaining* Show students a video to illustrate the formation of esters and polyesters.	*Exploring* Support: Students draw the structure of the carboxylic acid before writing the equation for the formation of a polyester. Stretch: Students draw the structures of the monomers and the polymers, showing the repeating unit. They explain why this is condensation polymerisation. *Explaining* Support: It may be useful for them to make up molecular models of the monomers shown and join them together to form the polyester Stretch: Challenge the students to design a molecule that will react with itself to form a polyester.	• Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Demonstrate the formation of nylon. (See *Starter*.) Make models of esters and polyester. (See *Exploring*.)

Lesson SC24d: Problems with polymers (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.23C: Describe some problems associated with polymers including the: a) availability of starting materials b) persistence in landfill sites, due to non-biodegradability c) gases produced during disposal by combustion d) requirement to sort polymers so that they can be melted and reformed into a new product • C9.24C: Evaluate the advantages and disadvantages of recycling polymers, including economic implications, availability of starting materials and environmental impact	*Starter* Write words or phrases on the board related to the first two or three lessons from this topic. Ask students to think of a question that has that answer. *Exploring* Analyse the plastic recycling bins in the school. Sort them into types depending on the code stamped or printed on them. Allocate different groups a specific code and they then research that group of plastics to find out what the code means, the types of items made from that type of plastic and how that type of plastic is recycled. *Explaining* Demonstrate how quickly a biodegradable plastic bag disintegrates compared to a non-biodegradable bag.	*Exploring* Support: Students work in groups and use data that is provided. They could draw bar charts of the raw data instead of the percentages or you can help them to calculate the percentages. Stretch: Students are asked to collect their own data. They should process the data before drawing bar charts, for example, by working out percentages. *Explaining* Stretch: Challenge the students to research biodegradable polymers such as polylactic acid.	n/a	Demonstrate how quickly a biodegradable plastic bag disintegrates compared to a non-biodegradable bag. (See *Explaining*.)

C25 Qualitative analysis				
Lesson SC25a: Flame tests and photometry (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.1C: Explain why the test for any ion must be unique • C9.8C: Describe that instrumental methods of analysis are available and that these may improve sensitivity, accuracy and speed of tests • C9.9C: Evaluate data from a flame photometer: a) to determine the concentration of ions in dilute solution using a calibration curve b) to identify metal ions by comparing the data with reference data • (no knowledge of the instrument or how it works is required)	*Starter* Demonstrate lightly sprinkling table salt (sodium chloride) into a blue Bunsen burner flame. Observe the yellow flame colour produced and ask the students to explain the observation. *Exploring* Students carry out flame tests on compounds containing Li^+, Na^+, K^+, or Ca^{2+} ions. Note that Cu^{2+} is deliberately left out but is covered in the teacher demonstration in *Explaining*. This is because its salts are coloured, which gives its identity away before testing. Students then use flame tests to identify the metal ion present in 'unknown' samples. *Explaining* Demonstrate how to carry out a flame test using copper chloride. Show that the same colour is obtained whether the sample is solid, in solution, or introduced to the flame in different ways, and discuss how the colour arises.	*Exploring* Support: Student could be given damp wooden splints instead of flame test loops. Stretch: Challenge the students to order the flame colours observed in order of increasing frequency of observed flame colour (i.e. red → blue: Li^+, Ca^{2+}, Na^+, K^+). *Explaining* Support: Explain the importance of avoiding contamination during flame tests. In particular, sodium ions produce a very persistent yellow flame which frequently hides other colours. Stretch: Challenge the students to suggest how the coloured light could be analysed, e.g. by its intensity and/or by its spectrum of colours.	• Translate information between graphical and numeric form.	*Suggested practical:* Students carry out flame tests on compounds containing Li^+, Na^+, K^+, or Ca^{2+} ions (see *Exploring*).

Lesson SC25b: Tests for positive ions (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.1C: Explain why the test for any ion must be unique • C9.2C: Describe flame tests to identify the following ions in solids: a) lithium ion, Li^+ (red) b) sodium ion, Na^+ (yellow) c) potassium ion, K^+ (lilac) d) calcium ion, Ca^{2+} (orange-red) e) copper ion, Cu^{2+} (blue-green) • C9.3C: Describe tests to identify the following ions in solids or solutions as appropriate: a) aluminium ion, Al^{3+} b) calcium ion, Ca^{2+} c) copper ion, Cu^{2+} d) iron(II) ion, Fe^{2+} e) iron(III) ion, Fe^{3+} … • using sodium hydroxide solution • C9.4C: Describe the chemical test for ammonia • C9.7C: Identify the ions in unknown salts, using results of the tests above	*Starter* Ask the students to define the terms 'precipitate' and 'excess'. Take feedback on their answers then demonstrate the reaction between copper sulfate solution and dilute ammonia solution. *Exploring* Students carry out hydroxide precipitate tests on solutions containing Al^{3+}, Ca^{2+}, Cu^{2+}, Fe^{2+} or Fe^{3+}. If a white precipitate forms, the students add excess sodium hydroxide solution and record any changes. Students use sodium hydroxide solution to identify the metal ion present in 'unknown' samples. *Explaining* Demonstrate the chemical test for ammonium ions in solution. Discuss the correct method for heating solutions safely, and what the results of the litmus show about ammonia (it dissolves to form an alkaline solution). Demonstrate the reaction between cobalt(II) chloride solution and dilute sodium hydroxide solution. Discuss the formation of the precipitate, how it might be useful to identify metal ions, why the precipitate is coloured (a transition metal is involved), and the importance of being patient with observations (i.e. the students would miss a change if they were not patient).	*Exploring* Support: Check that the students are keeping the volumes of solution small, as it becomes difficult to mix the contents of the test tube if the excess occupies a large part of the test tube. Stretch: Challenge the students to write a balanced ionic equation for the formation of each precipitate. *Explaining* Support: Make sure that the students understand that ammonium ions, NH_4^+, are not the same as ammonia, NH_3. Stretch: Challenge students to write a balanced equation and/or ionic equation for the formation of ammonia in the ammonium ion test, and the formation of the $Co(OH)_2$ precipitate: $NH_4^+(aq) + OH^-(aq) \rightarrow H_2O(l) + NH_3(g)$ $Co^{2+}(aq) + 2OH^-(aq) \rightarrow Co(OH)_2(s)$	• Use ratios, fractions and percentages	*Suggested practical:* Students carry out hydroxide precipitate tests on solutions containing Al3+, Ca2+, Cu2+, Fe2+ or Fe3+ (see *Exploring*).

Lesson SC25c: Tests for negative ions (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.5C: Describe tests to identify the following ions in solids or solutions as appropriate: a) carbonate ion, CO_3^{2-} using dilute acid and identifying the carbon dioxide evolved b) sulfate ion, SO_4^{2-} using dilute hydrochloric acid and barium chloride solution c) chloride ion, Cl^-, bromide ion, Br^-, iodide ion, I^-, using dilute nitric acid and silver nitrate solution • C9.7C: Identify the ions in unknown salts, using results of the tests above • *C9.6C: Core practical: Identify the ions in unknown salts, using the tests for the specified cations and anions in 9.2C, 9.3C, 9.4C, 9.5C*	*Starter* Demonstrate the reaction between lead nitrate solution and potassium bromide solution. Repeat the demonstration but using potassium iodide solution (a yellow precipitate forms). Discuss how these precipitates may be useful in a chemical test to identify bromide ions and iodide ions in substances, and whether this could be extended to chloride ions. *Exploring* Core practical: Students use silver nitrate solution to identify Cl^-, Br^- and I^- ions; barium chloride solution to detect sulfate ions; and dilute acid to detect carbonate ions in sodium carbonate solution via effervescence. They then identify the negatively charged ions present in 'unknown' samples. *Explaining* Demonstrate the reaction of calcium carbonate with dilute hydrochloric acid to form bubbles of carbon dioxide gas. Repeat the first demonstration but with the addition of a delivery tube to lead off the gas formed so it can be tested using limewater in a boiling tube.	*Exploring* Support: Check that the students appreciate that they can use either acid for their carbonate test, but they must use dilute nitric acid with silver nitrate and dilute hydrochloric acid with barium chloride solution. Stretch: Challenge the students to investigate why they must use dilute nitric acid with silver nitrate and dilute hydrochloric acid with barium chloride solution. *Explaining* Support: Explain that the limewater test is particularly important when a solid is being tested, since it could contain a reactive metal that produces hydrogen instead of carbon dioxide. Stretch: Challenge the students to explain why carbon dioxide forms a white precipitate with limewater.	• Use ratios, fractions and percentages	*Core practical: Identify the ions in unknown salts, using the tests for the specified cations and anions in 9.2C, 9.3C, 9.4C, 9.5C* (see *Exploring*)

C26 Bulk and surface properties of matter including nanoparticles				
Lesson SC26a: Comparing properties of materials (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.38C: Compare, using data, the physical properties of glass and clay ceramics, polymers, composites and metals • C9.39C: Explain why the properties of a material make it suitable for a given use and use data to select materials appropriate for specific uses	*Starter* Show students (photos of) a range of materials (glass, ceramics, polymers, metals) and ask the students to group them. Take feedback on how the groups were decided. *Exploring* Students investigate the strength of different shopping bag polymers. They hang increasing masses from strips of plastic and measure the extension. They then plot graphs of extension against load, and determine the best polymer for use as a shopping bag. *Explaining* Demonstrate producing plastic sulfur. Show how the plastic sulfur that is formed can be bent and twisted. Discuss how the sulfur rings broke into chains by heating, then were randomly tangled in the plastic state. Over some time the crystalline form returns. Link these observations to glass ceramics and to polymers.	*Exploring* Support: Provide students with blank results tables to fill in. Stretch: Challenge students to cut their own strips at right angles to the original strips provided, then see if that makes a difference to the properties. *Explaining* Support: Use molecular modelling kit to show S_8 rings which can be opened by breaking S–S covalent bonds. Stretch: Challenge students to explain what the experiment shows about energy transfers when covalent bonds are broken, and when they are formed.	• Plot two variables from experimental or other data.	*Suggested practical:* Investigate the strength of different shopping bag polymers (see *Exploring*)

Lesson SC26b: Comparing uses of materials (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.38C: Compare, using data, the physical properties of glass and clay ceramics, polymers, composites and metals • C9.39C: Explain why the properties of a material make it suitable for a given use and use data to select materials appropriate for specific uses	*Starter* In pairs using paper or mini-whiteboards, students write down as many properties of glass ceramics, clay ceramics, polymers and metals they can think of. They compare their answers with another pair, then feedback to the class. *Exploring* Students investigate the properties of plasterboard. They measure the load needed to break a strip of plasterboard, and a similar strip with the paper peeled away from one face. They drop-test a ball bearing in a plastic tube to investigate the surface impact depth, with and without the paper. *Explaining* Demonstrate a simple model for a reinforced beam: roll modelling clay into three long cylinders then flatten them embed a length of dry spaghetti into each length of modelling clay, then cover them by folding over the modelling clay mould the three lengths side-by-side to form one cylinder. Test the breaking strength of a beam by suspending it between two tripods, then use string to hang slotted masses from the middle. Add masses until failure. Try this with three pieces of spaghetti together, then with a length of modelling clay alone, then with the reinforced modelling clay. Compare their breaking strengths, and discuss the reasons for any differences observed.	*Exploring* Support: Provide students with plasterboard strips with the paper already removed from one face. Stretch: Challenge the students to investigate the effect on the breaking strength of removing paper from both faces of the plasterboard. *Explaining* Support: Show that the spaghetti is still identifiable inside the modelling clay. Stretch: Challenge the students to explain the advantages of this composite material, other than strength (e.g. waterproof).	• Substitute numerical values into algebraic equations using appropriate units for physical quantities • Translate information between graphical and numeric form	*Suggested practical:* Investigate the properties of plasterboard (see *Exploring*).

Lesson SC26c: Nanoparticles (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• C9.35C: Compare the size of nanoparticles with the sizes of atoms and molecules • C9.36C: Describe how the properties of nanoparticulate materials are related to their uses including surface area to volume ratio of the particles they contain, including sunscreens • C9.37C: Explain the possible risks associated with some nanoparticulate materials	*Starter* Show some consumer products (or photos of some consumer products) that contain nanoparticles. Ask the students to suggest a link between these products. Make a distinction between polymer microbeads (10 μm – 5 mm diameter) and nanoparticles (1 nm – 100 nm diameter). *Exploring* Students carry out a guided Web search. They research the use of nanoparticles in sunscreens or self-cleaning windows. They work in pairs or small groups to produce a summary of their findings as a leaflet, poster or PowerPoint presentation. The bottom part of the sheet has some stimulus material about these two uses. This can be cut from the worksheet prior to printing/photocopying for most students. *Explaining* Demonstrate potassium iodide powder catalysing the decomposition of hydrogen peroxide solution. Demonstrate that laser light is scattered by colloidal silver (a consumer product), but not by silver nitrate solution or deionised water. Discuss why the laser beam is only visible from the side when it passes through the colloidal silver (which contains nanoparticulate silver, large enough to scatter the light).	*Exploring* Support: Provide stimulus material Stretch: Challenge students to compare and contrast the two uses for nanoparticulate materials. *Explaining* Support: Demonstrate scattering when a few drops of milk are added to the beaker of deionised water. This is to emphasise that the scattering is due to small (but not dissolved) particles. Stretch: Challenge the students to predict the effect on light scattering of diluting the colloidal silver (less scattering) or changing particle size (smaller particles scatter red light better).	• Recognise and use expressions in standard form • Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Make order of magnitude calculations • Calculate areas of triangles and rectangles, surface areas and volumes of cubes	*n/a*

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