Approaches to learning and teaching

Examples of possible learning and teaching activities can be found in the table below.
The content of the first column is identical to the 'Skills, knowledge and understanding for the course assessment' section in this course specification.

The second column offers suggestions for activities that could be used to enhance teaching and learning. All resources named were correct at the time of publication and may be subject to change.

1 Chemical changes and structure **Mandatory knowledge**	**Suggested activities**
(a) Rates of reaction	
To follow the progress of chemical reactions, changes in mass, volume and other quantities can be measured. Graphs can then be drawn and be interpreted in terms of: ♦ end-point of a reaction ♦ quantity of product ♦ quantity of reactant used ♦ effect of changing conditions	RSC LearnChemistry offers a range of experimental procedures that can be used to produce reaction progress graphs including: The rate of reaction of magnesium with hydrochloric acid, in which magnesium reacts with dilute hydrochloric acid in a conical flask which is connected to an inverted measuring cylinder in a trough of water. The volume of hydrogen gas produced is measured over a few minutes and the results are used to plot a graph. RSC LearnChemistry's Rate of Reaction Graphs offers an assessment for learning activity in which candidates match pre-drawn graphs to different reaction conditions for the reaction between calcium carbonate and hydrochloric acid.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Rates of reaction can be increased: ♦ by increasing the temperature ♦ by increasing the concentration of a reactant ♦ by increasing surface area/decreasing particle size ♦ through the use of a catalyst	RSC LearnChemistry website offers a wide range of practical experiments to show the effect of changing reaction conditions. For example: In The effect of concentration and temperature on reaction rate, when two colourless solutions are mixed, a dark blue colour forms. Changing the concentration or temperature of the solutions changes the time required for the blue colour to develop. Rates and Rhubarb uses rhubarb sticks to decolourise potassium permanganate. The experiment can be used to show how the rate of reaction is affected by surface area or concentration. The Burning milk powder activity shows how a pile of dried milk powder will not ignite even using a roaring Bunsen burner. However, if the powder is sprinkled onto a flame, a spectacular fireball is produced (a video of the experiment is also available). In August 2000 one of the world's most advanced submarines, the Kursk, sank to the bottom of the sea with no survivors. It is believed that rusty ironwork acted as a catalyst for the decomposition of hydrogen peroxide. In LearnChemistry's What sank the Kursk?, instructions are provided for experiments to record reaction progress graphs using different transition metals as catalysts.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
	In the simpler Hydrogen peroxide decomposition using different catalysts activity, measuring cylinders are set up containing a washing-up liquid, a catalyst and some hydrogen peroxide. The rate at which foam forms depends on the effectiveness of the catalyst (a video of the experiment is also available). Candidates can see the effect of a catalyst using experiments such as Catalysis of the reaction between zinc and sulfuric acid or in the demonstration experiment Catalysis of the reaction between sodium thiosulfate and hydrogen peroxide.
Catalysts are substances that speed up chemical reactions but can be recovered chemically unchanged at the end of the reaction.	The RSC LearnChemistry's Involvement of catalysts in reactions experiment provides visible evidence that, although a catalyst does actively participate in a reaction, it is regenerated at the end. In this reaction, a pink cobalt catalyst solution is used which changes to dark green while the catalyst is active and is seen to change back to pink once the reaction is over.
The average rate of a chemical reaction can be calculated, with appropriate units, using the equation: $rate = \frac{\Delta quantity}{\Delta t}$ The rate of a reaction can be shown to decrease over time by calculating the average rate at different stages of the reaction.	

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
(b) Atomic structure and bonding related to properties of materials	
(i) Periodic Table and atoms Elements in the Periodic Table are arranged in order of increasing atomic number. The Periodic Table can be used to determine whether an element is a metal or non-metal. Groups are columns in the Periodic Table containing elements with the same number of outer electrons, indicated by the group number. Elements within a group share the same valency and have similar chemical properties because they have the same number of electrons in their outer energy levels. The electron arrangement of the first 20 elements can be written.	The RSC's online Periodic Table is fully interactive. Filters can be used to update the table in a way that highlights: ♦ metallic or non-metallic elements ♦ individual groups ♦ individual periods ♦ the state of the elements at any temperature Clicking on the video tab gives access to a bank of videos providing profiles of all 118 elements. The RSC Periodic Table is also available as a free-of-charge app for both Android and iOS devices. RSC LearnChemistry's 'Secondary Support Pack' has been produced to support the use of Elements Top Trumps cards to help candidates become familiar with the arrangement of elements within the Periodic Table. These activities can help develop the skill of making predictions and generalisations. RSC LearnChemistry's Interactive Periodic Table game allows candidates to test their knowledge of the Periodic Table by exploring trends and patterns in elements and their position in the Table.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
An atom has a nucleus, containing protons and neutrons, and electrons that orbit the nucleus. Protons have a charge of one-positive, neutrons are neutral and electrons have a charge of one-negative. Protons and neutrons have an approximate mass of one atomic mass unit and electrons, in comparison, have virtually no mass. The number of protons in an atom is given by the atomic number. In a neutral atom the number of electrons is equal to the number of protons. The mass number of an atom is equal to the number of protons added to the number of neutrons.	The LearnChemistry Build an atom simulation activity allows candidates to build an atom from scratch, using protons, neutrons, and electrons. Nuclide notation can be explored using the 'symbol' option. This allows candidates to explore the effect of changing the numbers of protons, neutrons and electrons. The 'game' option can be used to provide a revision activity. LearnChemistry offers a selection of short video clips covering a wide range of topics. In Royal Institution Christmas Lectures® 2012: Atomic Structure, Dr Peter Wothers explores the structure of an atom and reveals that it is the number of protons that defines an element.
Isotopes are defined as atoms with the same atomic number but different mass numbers, or as atoms with the same number of protons but different numbers of neutrons. Nuclide notation is used to show the atomic number, mass number (and charge) of atoms (ions) from which the number of protons, electrons and neutrons can be determined. Most elements have two or more isotopes. The average atomic mass has been calculated for each element using the mass and proportion of each isotope present. These values are known as relative atomic masses.	

1 Chemical changes and structure (continued) **Mandatory knowledge**	**Suggested activities**
(ii) Covalent bonding Covalent bonds form between non-metal atoms. A covalent bond forms when two positive nuclei are held together by their common attraction for a shared pair of electrons. Diagrams can be drawn to show how outer electrons are shared to form the covalent bond(s) in a molecule. 7 elements exist as diatomic molecules through the formation of covalent bonds: H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2.	The formation of a covalent compound can be shown using activities from the RSC LearnChemistry website: Exploding bubbles of hydrogen and oxygen is a particularly fun way to show two non-metal elements reacting together (a video is also available). Chemistry exciting elements has an online video showing the reaction of hydrogen gas with fluorine, chlorine and bromine. The explosive reaction of hydrogen and chlorine is also shown in Fire and Flame: Part 4 (clips 43 and 44) and The Chemistry of Light: Part 3 (clip 26). Instructions on how to carry out the reaction between hydrogen and chlorine gases safely in a school or college lab is provided by SSERC (SSERC Bulletin 223, page 10, 2007).
The shape of simple covalent molecules depends on the number of bonds and the orientation of these bonds around the central atom. These molecules can be described as linear, angular, trigonal pyramidal or tetrahedral.	PhET at the University of Colorado have created Build a molecule, a simulation that lets candidates assemble molecules on screen and view their structures in 3D.
More than one bond can be formed between atoms leading to double and triple covalent bonds.	NBC Learn: Chemistry Now, available through RSC LearnChemistry, introduces the formation of double bonds, as a way of atoms acquiring a stable octet in the video Carbon, Captured: Carbon dioxide — The Chemistry of CO2: Carbon dioxide.
Covalent substances can form either discrete molecular or giant network structures.	

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Covalent molecular substances: ♦ have strong covalent bonds within the molecules and only weak attractions between the molecules ♦ have low melting and boiling points as only weak forces of attraction between the molecules are broken when a substance changes state ♦ do not conduct electricity because they do not have charged particles which are free to move. Covalent molecular substances which are insoluble in water may dissolve in other solvents.	LearnChemistry's Which substances conduct electricity? experiment enables candidates to distinguish between electrolytes and non-electrolytes and to verify that covalent substances never conduct electricity even when liquefied, whereas ionic compounds conduct in the molten state.
Covalent network structures: ♦ have a network of strong covalent bonds within one giant structure ♦ have very high melting and boiling points because the network of strong covalent bonds is not easily broken ♦ do not dissolve	The Exhibition Chemistry: Red hot carbon resource from LearnChemistry has been created to show that graphite has an exceptionally high melting point, and is a good conductor of heat in an experiment that results in the dramatic destruction of a pencil (a video is also available).
In general, covalent network substances do not conduct electricity. This is because they do not have charged particles which are free to move.	The Royal Institution Christmas Lectures 2012®: Allotropes of Carbon video, available on LearnChemistry, discusses the properties of diamond and graphite and, by burning samples of both in liquid oxygen, provides proof that they are both forms of carbon.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
(iii) Ionic compounds Ions are formed when atoms lose or gain electrons to obtain the stable electron arrangement of a noble gas. In general, metal atoms lose electrons forming positive ions and non-metal atoms gain electrons forming negative ions. Ion-electron equations can be written to show the formation of ions through loss or gain of electrons. Ionic bonds are the electrostatic attraction between positive and negative ions. Ionic compounds form lattice structures of oppositely charged ions with each positive ion surrounded by negative ions and each negative ion surrounded by positive ions. Ionic compounds have high melting and boiling points because strong ionic bonds must be broken in order to break up the lattice.	The formation of an ionic compound can be shown using experiments from the RSC LearnChemistry website that include: Reaction between aluminium and iodine, Reaction of zinc with iodine, Exhibition Chemistry: The reaction between aluminium and bromine, Reactions of chlorine, bromine and iodine with aluminium, Iron and sulfur reaction (a video is also available), Reacting elements with chlorine, Heating Group 1 metals in air and in chlorine (a video is also available), The combustion of iron wool and Halogen reactions with iron wool (a video is also available).
Many ionic compounds are soluble in water. As they dissolve the lattice structure breaks up allowing water molecules to surround the separated ions.	The PhET team at the University of Colorado have created Sugar and Salt Solutions, a simulation that lets candidates add sugar or salt to water and watch what happens at an atomic scale. They can also use a virtual conductivity tester to test the conductivity of the solutions.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Ionic compounds conduct electricity only when molten or in solution as the lattice structure breaks up allowing the ions to be free to move.	The LearnChemistry experiments Electrolysing molten lead(II) bromide and Electrolysis of molten zinc chloride (a video is also available) demonstrate that conduction is possible when ionic compounds are molten, and show the products of electrolysis. LearnChemistry's Microscale Chemistry — Using a microscale conductivity meter gives details of how to make a cheap and simple conductivity meter that can be used to test the conductivity of solids (eg metals) or solutions.
Conduction in ionic compounds can be explained by the movement of ions towards oppositely charged electrodes.	LearnChemistry offers descriptions of experiments that allow candidates to observe the movement of coloured ions. In The migration of ions: evidence for the ionic model a glass microscope slide is used to support a wet strip of filter paper on which a crystal of potassium manganate(VII) is placed. Applying a DC voltage across the filter paper causes a purple plume to move towards the positive terminal. It is relatively rare to be able to see the motion of both the positive and negative ions in the same experiment, but an example is given in Exhibition Chemistry: Migration of coloured ions by electrolysis.
(c) Formulae and reacting quantities	
(i) Chemical formulae Compound names are derived from the names of the elements from which they are formed. Most compounds with a name ending in '-ide' contain the two elements indicated. The ending '-ite' or '-ate' indicates that oxygen is also present.	

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Chemical formulae can be written for two element compounds using valency rules and a Periodic Table. Roman numerals can be used, in the name of a compound, to indicate the valency of an element. The chemical formula can also be determined from names with prefixes. The chemical formula of a covalent molecular substance gives the number of each type of atom present in a molecule. The formula of a covalent network gives the simplest ratio of each type of atom in the substance. Ions containing more than one type of atom are often referred to as group ions. Chemical formulae can be written for compounds containing group ions using valency rules and the data booklet.	
Ionic formulae give the simplest ratio of each type of ion in the substance and can show the charges on each ion, if required. In formulae, charges must be superscript and numbers of atoms/ions must be subscript.	In LearnChemistry's Writing formulae for ionic compounds, ion formulae cards are used to help candidates check, consolidate and demonstrate their ability to write correct formulae for ionic compounds.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
(ii) Calculations involving the mole and balanced equations Chemical equations, using formulae and state symbols, can be written and balanced.	LearnChemistry's Eggsplosive Chemistry provides instructions and videos to carry out spectacular demonstrations to show that getting your reactants in the right proportions can be the difference between a bang and a fizzle. The PhET team at the University of Colorado have created Balancing Chemical Equations, a simulation that lets candidates learn how to tell if a chemical equation is balanced. It also allows them explore how to balance equations with an interactive game.
The mass of a mole of any substance, in grams (g), is equal to the gram formula mass and can be calculated using relative atomic masses. Calculations can be performed using the relationship between the mass and the number of moles of a substance. A solution is formed when a solute is dissolved in a solvent.	
For solutions, the mass of solute (grams or g), the number of moles of solute (moles or mol), the volume of solution (litres or l) or the concentration of the solution (moles per litre or mol l^{-1}) can be calculated from data provided.	The Molarity Simulation from PhET is an ideal way to introduce the idea of the measurement of concentrations, allowing you to vary the volume of solvent and the amount of solute used to form solutions. The Concentration Simulation available on RSC LearnChemistry allows even more variables to be explored.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Given a balanced equation, the mass or number of moles of a substance can be calculated given the mass or number of moles of another substance in the reaction. ***(iii) Percentage composition*** The percentage composition of an element in any compound can be calculated from the formula of the compound.	Using the balanced equation, candidates can calculate the mass of magnesium oxide formed when a known mass of magnesium burns. The change in mass when magnesium burns provides a method to allow candidates to carry out an experiment to confirm their calculated value. This resource extends the procedure into the calculation of an empirical formula. National 5 candidates do not need to be able to calculate empirical formula.
(d) Acids and bases	
(i) pH The pH scale is an indication of the hydrogen ion concentration and runs from below 0 to above 14. A neutral solution has equal concentrations of H^+(aq) and OH^-(aq) ions. Water is neutral as it dissociates according to the equation $H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$ producing equal concentrations of hydrogen and hydroxide ions. At any time, only a few water molecules are dissociated into free ions. The $\rightleftharpoons$ symbol indicates that a reaction is reversible and occurs in both directions.	LearnChemistry's pH scale basics simulation can be used to explore the basics of pH. Candidates can add a variety of common solutions, modify the concentration and see the effects on pH. The pH scale advanced simulation, available from RSC LearnChemistry, provides a more sophisticated pH simulator to visualise and compare the numbers of H^+ and OH^- ions present in different solutions. Candidates can investigate the comparative conductivity of saline solution, tap water and distilled water. These measurements can be linked to ion concentration to develop an understanding of the dissociation of water molecules.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Acidic solutions have a higher concentration of $H^+(aq)$ ions than $OH^-(aq)$ and have a pH below 7. Alkaline solutions have a higher concentration of $OH^-(aq)$ ions than $H^+(aq)$ ions and have a pH above 7.	
Dilution of an acidic solution with water will decrease the concentration of $H^+(aq)$ and the pH will increase towards 7. Dilution of an alkaline solution with water will decrease the concentration of $OH^-(aq)$ and the pH will decrease towards 7.	The effect of dilution on the pH of acidic and alkaline solutions can be explored using the LearnChemistry activity The pH scale. It shows how a solution with a given pH number differs in concentration from the one with the next pH number by a factor of 10.
Soluble non-metal oxides dissolve in water forming acidic solutions.	Testing the pH of oxides from LearnChemistry offers an experiment which helps to establish the idea that the soluble oxides of metals are alkaline and the oxides of non-metals are acidic. If a supply of dry ice is available, the LearnChemistry activity Indicators and dry ice demonstration is very dramatic. Dry ice is added to pH indicator solutions. Bubbles and 'fog' are produced along with a gradual colour change. The experiment highlights that carbon dioxide dissolves to form an acidic solution.
Soluble metal oxides dissolve in water to form alkaline solutions: metal oxide + water $\rightarrow$ metal hydroxide	The video clip Free Range Chemistry: Part 3 (clip 27, 'Exploding Rock') available through LearnChemistry shows the violent reaction that occurs when water is added to calcium oxide. This is one of a series of clips produced by Peter Wothers of Cambridge University.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Metal oxides, metal hydroxides, metal carbonates and ammonia neutralise acids and are called bases. Those bases that dissolve in water form alkaline solutions.	
(ii) Neutralisation reactions A neutralisation reaction is one in which a base reacts with an acid to form water. A salt is also formed in this reaction.	In LearnChemistry's An effervescent Universal indicator rainbow experiment, sodium carbonate solution is added to a burette containing a little hydrochloric acid and Universal Indicator. The two solutions react, with effervescence, and the liquid in the burette shows a 'rainbow' of colours. A striking alternative that candidates can carry out for themselves is Neutralisation circles. Drops of dilute acid and alkali are placed a few centimetres apart on a sheet of filter paper and allowed to spread out until they meet. A few drops of Universal Indicator are then placed over the moist area of the filter paper and a band of colours showing the range of colours of the Universal Indicator is seen on the paper.
Equations can be written for the following neutralisation reactions: a metal oxide + an acid → a salt + water a metal hydroxide + an acid → a salt + water a metal carbonate + an acid → a salt + water + carbon dioxide	In Reacting copper(II) oxide with sulfuric acid black, insoluble copper(II) oxide is reacted with sulfuric acid and the product solution evaporated to form blue copper(II) sulfate crystals. A very simple example of the reaction of an acid and a carbonate not often carried out in chemistry classrooms is described in LearnChemistry's Outreach: bendy bones. Vinegar reacts with the calcium carbonate in chicken bones to release bubbles of carbon dioxide.

1 Chemical changes and structure (continued) **Mandatory knowledge**	**Suggested activities**
The name of the salt produced depends on the acid and base used. Hydrochloric acid produces chlorides, sulfuric acid produces sulfates and nitric acid produces nitrates. Spectator ions are ions that remain unchanged by the reaction. Reaction equations can be used to identify spectator ions. For neutralisation reactions, equations can be written omitting spectator ions: $2H^+(aq) + O^{2-}(s) \rightarrow H_2O(\ell)$ for metal oxides $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$ for metal hydroxides $2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(\ell) + CO_2(g)$ for aqueous metal carbonates $2H^+(aq) + CO_3^{2-}(s) \rightarrow H_2O(\ell) + CO_2(g)$ for insoluble metal carbonates	
In an acid-base titration, the concentration of the acid or base is determined by accurately measuring the volumes used in the neutralisation reaction. An indicator can be added to show the end-point of the reaction.	The interactive lab primer — titration from LearnChemistry is a suite of videos, simulations and animations created to show candidates how to use pipettes and burettes to carry out a titration. The titration animation provides, in a very clear and simple way, an overview of how a titration allows the concentration of a solution to be measured.

1 Chemical changes and structure (continued) Mandatory knowledge	Suggested activities
Given a balanced equation for the reaction occurring in any titration: ♦ the concentration of one reactant can be calculated given the concentration of the other reactant and the volumes of both solutions ♦ the volume of one reactant can be calculated given the volume of the other reactant and the concentrations of both solutions	LearnChemistry's Titration screen experiment is an interactive virtual lab resource. The activity has four levels. The first level is suitable as a resource to revise and consolidate understanding of the Acids and Bases topic at National 5 level. As this resource was created for world wide use, concentration is expressed in mol dm^{-3}. Before using this resource, it would be advisable to inform candidates that 1 dm^{3} is equivalent to 1 litre.
(iii) Neutralisation reactions can be used to prepare soluble salts Titration can be used to produce a soluble salt. Once the volumes of acid and alkali have been noted, the reaction can be repeated without the indicator to produce an uncontaminated salt solution. The solution can then be evaporated to dryness. Insoluble metal carbonates and insoluble metal oxides can be used to produce soluble salts. Excess base is added to the appropriate acid, the mixture is filtered and the filtrate evaporated to dryness.	In the Titrating sodium hydroxide with hydrochloric acid experiment from LearnChemistry, sodium hydroxide is titrated with hydrochloric acid and the product solution evaporated to produce sodium chloride crystals. LearnChemistry's Preparing salts by neutralisation of oxides and carbonates provides well-tried class experiments, which should take no more than thirty minutes to reach the point at which the product solution has been filtered.

2 Nature's chemistry Mandatory knowledge	Suggested activities
(a) Homologous series	
(i) Systematic carbon chemistry A homologous series is a family of compounds with the same general formula and similar chemical properties.	
Patterns are often seen in the physical properties of the members of a homologous series. The subsequent members of a homologous series show a general increase in their melting and boiling points. This pattern is attributed to increasing strength of the intermolecular forces as the molecular size increases. The type of intermolecular force does not need to be identified.	The SQA National 5 data booklet lists the melting and boiling points of the smaller alkanes, alkenes and cycloalkanes. Whilst the boiling points of these compounds rise steadily, there are minor anomalies in the melting points of the smaller alkanes and alkenes. Candidates are not expected to comment on these anomalies and are only expected to appreciate the overall trend of increasing melting point with increasing molecular size.
Hydrocarbons are compounds containing only hydrogen and carbon atoms. Compounds containing only single carbon–carbon bonds are described as saturated. Compounds containing at least one carbon–carbon double bond are described as unsaturated. It is possible to distinguish an unsaturated compound from a saturated compound using bromine solution. Unsaturated compounds decolourise bromine solution quickly. The structure of any molecule can be drawn as a full or a shortened structural formula.	
Isomers: ♦ are compounds with the same molecular formula but different structural formulae ♦ may belong to different homologous series ♦ usually have different physical properties	The poster 'Types Of Isomerism In Organic Chemistry', available as part of the Organic chemistry infographics resource on RSC LearnChemistry, illustrates different types of structural isomers covered in the National 5 course using examples drawn from the alkane, alkene, and cycloalkane families.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
Given a structural formula for a compound, an isomer can be drawn. Isomers can be drawn for a given molecular formula. ***(ii) Alkanes*** Alkanes: ♦ are a homologous series of saturated hydrocarbons ♦ are commonly used as fuels ♦ are insoluble in water ♦ can be represented by the general formula C_nH_{2n+2} Straight-chain and branched alkanes can be systematically named from structural formulae, containing no more than 8 carbons in the longest chain. Molecular formulae can be written and structural formulae can be drawn, from the systematic names of straight-chain and branched alkanes, containing no more than 8 carbons in the longest chain. ***(iii) Cycloalkanes*** Cycloalkanes: ♦ are a homologous series of saturated, cyclic hydrocarbons ♦ are used as fuels and solvents ♦ are insoluble in water ♦ can be represented by the general formula C_nH_{2n} Cycloalkanes (C_3–C_8) can be systematically named from structural formulae. Branched cycloalkanes are not required. Molecular formulae can be written and structural formulae can be drawn, from the systematic names of un-branched cycloalkanes.	 Twig — Oil Products: Hydrocarbons factpack, available through RSC LearnChemistry, provides a brief two-minute video with accompanying worksheets introducing alkanes and alkenes and their general formulae.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
(iv) Alkenes Alkenes: ♦ are a homologous series of unsaturated hydrocarbons ♦ are used to make polymers and alcohols ♦ are insoluble in water ♦ contain the C=C double bond functional group ♦ can be represented by the general formula C_nH_{2n} Straight-chain and branched alkenes can be systematically named indicating the position of the double bond from structural formulae containing no more than 8 carbon atoms in the longest chain. Molecular formulae can be written and structural formulae can be drawn, from the systematic names of straight-chain and branched alkenes, containing no more than 8 carbons in the longest chain. Chemical equations can be written for the addition reactions of alkenes, using molecular or structural formulae. Alkenes undergo addition reactions: ♦ with hydrogen forming alkanes, known as hydrogenation ♦ with halogens forming dihaloalkanes ♦ with water forming alcohols, known as hydration	In LearnChemistry's The hydration of alkenes activity, hex-1-ene is hydrated to produce hexan-2-ol.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
(b) Everyday consumer products	
(i) Alcohols Alcohols are used as fuels as they are highly flammable and burn with very clean flames. Alcohols are often used as solvents.	The flammability of methylated spirits in camping stoves can be demonstrated whilst methanol can be discussed as a fuel in drag racing and speedway. LearnChemistry offer a range of spectacular experiments. In the classic whoosh bottle demonstration, a mixture of alcohol and air in a large polycarbonate bottle is ignited. The resulting rapid combustion reaction, often accompanied by a dramatic 'whoosh' sound and flames, demonstrates the large amount of chemical energy released in the combustion of alcohols. The ethanol rocket is a more recent variation on this theme and comes with instructional video. The flammability of alcohols is also demonstrated in The alcohol gun experiment or the Money to burn trick (a video is also available).
Methanol, ethanol and propanol are miscible with water, thereafter the solubility decreases as size increases.	
As alcohols increase in size, their melting and boiling points increase due to the increasing strength of the intermolecular forces. The type of intermolecular force does not need to be identified.	At this level candidates are only required to have an appreciation of the general trend that as molecular size increases the strength of the intermolecular forces tends to increase. The straight-chain alcohols show increasing boiling points with increasing chain length.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
	The melting points of methanol and ethanol are anomalously high but National 5 candidates are not expected to be aware of these anomalies.

Alcohol	*Melting point* (°C)	*Boiling point* (°C)
methanol	-97.5	65
ethanol	-114	78
propan-1-ol	-124	97
butan-1-ol	-88	118
pentan-1-ol	-78	138
hexan-1-ol	-47	158
heptan-1-ol	-33	176
octan-1-ol	-15	195
nonan-1-ol	-5	213
decan-1-ol	7	231
undecan-1-ol	16	245
dodecan-1-ol	24	260
tridecan-1-ol	32	274
tetradecan-1-ol	38	287
pentadecan-1-ol	44	300
hexadecan-1-ol	49	312
heptadecan-1-ol	54	324
octadecan-1-ol	58	335
nadecan-1-ol	62	345
1-eicosanol	65	356

Please note: candidates are only required to be able to name straight-chain alcohols containing no more than 8 carbon atoms.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
An alcohol is a molecule containing a hydroxyl functional group, ─OH group. Saturated, straight-chain alcohols can be represented by the general formula $C_nH_{2n+1}OH$. Straight-chain alcohols can be systematically named indicating the position of the hydroxyl group from structural formulae containing no more than 8 carbon atoms. Molecular formulae can be written and structural formulae can be drawn, from the systematic names of straight-chain alcohols, containing no more than 8 carbons.	
(ii) Carboxylic acids Carboxylic acids are used in the preparation of preservatives, soaps and medicines. Vinegar is a solution of ethanoic acid, with molecular formula CH_3COOH. Vinegar is used in household cleaning products as it is a non-toxic acid so can be used safely in household situations.	Vinegar offers candidates an introduction to carboxylic acids using a familiar example. To obtain a rough indication of the concentration of ethanoic acid in different vinegars, marble chips are attached to the inside of the lids of a number of 35 mm film cans. Vinegar is poured into the film cans until they are one-third full. The lids are placed onto the cans and the cans are inverted. The order in which the vinegar 'rockets' take off gives a rough indication of the concentration of ethanoic acid. The concentration of ethanoic acid in vinegars can be compared by measuring the volume of carbon dioxide liberated when excess solid carbonate is added to equal volumes of different vinegars.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
	To demonstrate both the acidic nature of ethanoic acid and its use as a food preservative, pickled eggs can be produced by placing boiled eggs (still in their shells) into jars containing vinegar. The acid will remove the shell to leave a pickled egg in vinegar. Pickles (food preserved in vinegar) can be stored for a long time because the low pH prevents the growth of harmful bacteria and fungi. The Neutralisation — 'curing acidity' experiment from LearnChemistry allows candidates to follow the pH and temperature changes when an acidic solution (vinegar) is gradually neutralised by the addition of slaked lime (calcium hydroxide) and limestone (calcium carbonate).
Methanoic, ethanoic, propanoic and butanoic acid are miscible in water, thereafter the solubility decreases as size increases.	
As carboxylic acids increase in size their melting and boiling points increase due to the increasing strength of the intermolecular forces. The type of intermolecular force does not need to be identified.	At this level candidates are only required to have an appreciation of the general trend that as molecular size increases, the strength of the intermolecular forces tends to increase. The straight-chain carboxylic acids show increasing boiling points with increasing chain length. Whilst there is a general trend to increasing melting point with increasing chain length, individual acids can lie above or below the trend line.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
	Plotting a graph of the number of carbons against the boiling point allows development of graph drawing skills.

Acid	*Melting point* (^oC)	*Boiling point* (^oC)
methanoic	8	101
ethanoic	17	119
propanoic	-21	141
butanoic	-5	164
pentanoic	-34	186
hexanoic	-3	205
heptanoic	-7	222
octanoic	16	239
nonanoic	13	254
decanoic	31	269
undecanoic	29	280
dodecanoic	44	330
tridecanoic acid	45	
tetradecanoic acid	54	326
pentadecanoic acid	52	356
hexadecanoic acid	62	390
heptadecanic acid	61	321
octadecanoic acid	69	dec. 350
nonadecanoic acid	69	
eicosanoic acid	76	dec. 328

Please note: candidates are only required to be able to name straight-chain carboxylic acids containing no more than eight carbon atoms.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
Carboxylic acids can be identified by the carboxyl functional group, –COOH. Saturated, straight-chain carboxylic acids can be represented by the general formula $C_nH_{2n+1}COOH$. Straight-chain carboxylic acids can be systematically named from structural formulae, containing no more than 8 carbons. Molecular formulae can be written and structural formulae drawn, from the systematic names of straight-chain carboxylic acids, containing no more than 8 carbons.	
Solutions of carboxylic acids have a pH less than 7 and like other acids, can react with metals, metal oxides, hydroxides and carbonates forming salts. Salts formed from straight-chain carboxylic acids, containing no more than 8 carbons, can be named.	The LearnChemistry activity The acidic reactions of ethanoic acid provides instructions for simple experiments to show that carboxylic acids take part in the same reactions as hydrochloric acid. Although this resource mentions strong and weak acids, no knowledge or understanding of the concept of strong/weak acids is required at National 5.
(c) Energy from fuels	
A reaction or process that releases heat energy is described as exothermic. A reaction or process that takes in heat energy is described as endothermic.	Exothermic or endothermic? from LearnChemistry is a useful class practical to introduce energy changes in chemical reactions. Candidates measure the temperature changes in four reactions, and classify the reactions as exothermic or endothermic. The experiments can also be used to revise different types of chemical reaction and, with some classes, chemical formulae and equations.

2 Nature's chemistry (continued) Mandatory knowledge	Suggested activities
In combustion, a substance reacts with oxygen releasing energy.	Royal Institution Christmas Lectures® 2012: The Composition of Air, available from RSC LearnChemistry, presents a couple of short videos on the composition of air. The video 'Altering the Composition of the Air' shows the effect of reducing the proportion of oxygen in the air on combustion. LearnChemistry's It's a Gas: Part 1 is a series of video experiments showing the role of oxygen in supporting combustion. Clip 11, 'Oxygen and Food' shows that energy is released from food when it combines with oxygen.
Hydrocarbons and alcohols burn in a plentiful supply of oxygen to produce carbon dioxide and water. Equations can be written for the complete combustion of hydrocarbons and alcohols.	Identifying the products of combustion, from LearnChemistry, describes a procedure to collect and test the products of combustion for a solid hydrocarbon. A simpler version, that does not require the use of a pump, is given in Classic Chemistry Experiments — Combustion.
Fuels burn releasing different quantities of energy.	LearnChemistry offer several experiments to measure the release of heat. Heat energy from alcohols is an experiment comparing the amounts of heat energy produced by burning various alcohols. In Search of Solutions: Which fuel is better? is set in a camping expedition scenario and compares several types of solid fuels.

2 Nature’s chemistry (continued) Mandatory knowledge	Suggested activities
The quantity of heat energy released can be determined experimentally and calculated using, $E_h = cm\Delta T$. The quantities E_h, c, m or ΔT can be calculated, in the correct units, given relevant data. Calculations can involve heating substances other than water. It is not necessary to calculate the enthalpy per mole of substance burned.	LearnChemistry offers Heat of combustion of alcohols simulation, a virtual experiment in which candidates can investigate the factors that determine the heat produced when alcohols burn. Variables that can be adjusted include: type of alcohol, mass of water and time of heating.

3 Chemistry in society Mandatory knowledge	Suggested activities
(a) Metals	
(i) Metallic bonding Metallic bonding is the electrostatic force of attraction between positively charged ions and delocalised electrons. Metallic elements are conductors of electricity because they contain delocalised electrons. ***(ii) Reactions of metals*** Equations, involving formulae, can be written to show the reaction of metals with oxygen, water, and dilute acids: metal + oxygen → metal oxide	The combustion of iron wool from LearnChemistry is a simple but dramatic experiment showing the increase in mass occurring when metals burn. Iron wool is ignited on a simple 'see-saw' balance in a demonstration that takes no more than five minutes. An ideal accompaniment to this activity is video clip 19 'Iron Wool and Oxygen' from Free Range Chemistry: Part 2. Using the balanced equation, candidates can calculate the mass of magnesium oxide formed when a known mass of magnesium burns. The LearnChemistry resource The change in mass when magnesium burns provides a method to allow candidates to carry out an experiment to confirm their calculated value. This resource extends the procedure into the calculation of an empirical formula. National 5 candidates do not need to be able to calculate empirical formula.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
metal + water → metal hydroxide + hydrogen	For teachers and lecturers who may not have recently carried out experiments showing the reactivity of alkali metals, LearnChemisty's Alkali metals is a combined video and text CPD resource showing how to demonstrate safely the reactions of Group 1 elements with water.
metal + dilute acid → salt + hydrogen	LearnChemistry's Metals and acids experiment offers detailed instructions for two well-tried class experiments. The first shows that hydrogen is given off as metals react with an acid. In the second, the salt formed is recovered by crystallisation. A worksheet is provided. Magnesium and Hydrochloric Acid, available from the University of Oregon, shows that hydrogen is produced when magnesium reacts with hydrochloric acid.
Metals can be arranged in order of reactivity by comparing the rates at which they react.	The activity Exothermic metal-acid reactions from LearnChemistry offers a less familiar method of establishing the reactivity series. Candidates add powdered or finely-divided metals to hydrochloric acid and measure the temperature changes. The experiment reinforces ideas about energy changes during reactions, the reactivity series of the metals, and the chemical behaviour of acids. Because of the stability of its surface coating of aluminium oxide, aluminium can appear an unreactive metal. Exhibition Chemistry: Dancing flames from LearnChemistry describes an experiment to show the true reactivity of aluminium. In this demonstration eerie green flames are seen to dance over the reaction mixture (a video is also available).

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
Metals can be used to produce soluble salts. Excess metal is added to the appropriate acid, the mixture is filtered and the filtrate evaporated to dryness. ***(iii) Redox*** Reduction is a gain of electrons by a reactant in any reaction. Oxidation is a loss of electrons by a reactant in any reaction. In a redox reaction, reduction and oxidation take place at the same time.	
Ion-electron equations can be written for reduction and oxidation reactions. Ion-electron equations can be combined to produce redox equations. ***(iv) Extraction of metals*** During the extraction of metals, metal ions are reduced forming metal atoms. The method used to extract a metal from its ore depends on the position of the metal in the reactivity series. Equations can be written to show the extraction of metals.	Candidates should be familiar with page 10 of the SQA data booklet showing the electrochemical series and can practise using this resource to identify oxidation and reduction reactions.
Methods used are: ♦ heat alone (for extraction of Ag, Au and Hg)	In Decomposition of Silver Oxide, available from the University of Oregon, black silver oxide is heated in a test tube to give metallic silver and oxygen gas. The gas is captured in a balloon.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
♦ heating with carbon or carbon monoxide (for extraction of Cu, Pb, Sn, Fe and Zn)	LearnChemistry offer a wide range of activities demonstrating the extraction of a metal from its ore using carbon or carbon monoxide. Exhibition Chemistry: The extraction of iron describes a very simple experiment where iron is extracted from its ores using the charcoal formed on the tip of a used match. A variation of this experiment is given in Extraction of iron on a match head in which candidates first dip the head of an unused match in sodium carbonate powder and iron(III) oxide. When the head of the match burns it flares, resulting in the formation of iron. National 5 candidates are not required to know the details of the industrial production of iron. However, should you wish, a video showing a blast furnace in action is available as part of the resource Alchemy: Iron and Steel. Extracting metals with charcoal provides detailed instructions for the reduction of lead and copper oxides in the laboratory. Video clip 10, 'Copper from Malachite' from Free Range Chemistry: Part 1, shows Peter Wothers demonstrating the extraction of copper from its ore malachite by heating with carbon.
♦ electrolysis (for extraction of more reactive metals including aluminium)	The industrial production of aluminium is shown in a video included in LearnChemistry's resource pack Alchemy: Aluminium extraction.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
Electrolysis is the decomposition of an ionic compound into its elements using electricity. A d.c. supply must be used if the products of electrolysis are to be identified. Positive ions gain electrons at the negative electrode and negative ions lose electrons at the positive electrode.	LearnChemistry offer a number of activities to allow candidates to explore electrolysis. Electrolysing molten lead(II) bromide demonstrates that conduction is only possible where lead(II) bromide is molten, and that metallic lead and bromine are the products of electrolysis. Electrolysis of molten zinc chloride offers a safer alternative to lead bromide for demonstrating the electrolysis of molten salts (a video is also available)
(v) Electrochemical cells Electrically conducting solutions containing ions are known as electrolytes. A simple cell can be made by placing two metals in an electrolyte.	Instructions for assembling a very simple cell in which two metals are placed into salt solution are given in LearnChemistry's Electricity from chemicals. An unusual experiment in The Solar Spark: Hand Battery demonstrates that the sweat present on human skin can be used as the electrolyte in a simple cell. When candidates place one hand on an aluminium plate and the other on a copper plate, a multimeter connected between the plates shows a voltage being created.
Another type of cell can be made using two half-cells (metals in solutions of their own ions). An 'ion bridge' (salt bridge) can be used to link the half-cells. Ions can move across the bridge to complete an electrical circuit.	The University of Oregon provides instructions for the activity, Standard Zinc/Copper Cell. A zinc strip in 1·0 mol l^{-1} $ZnSO_4$ solution and a copper strip in 1·0 mol l^{-1} $CuSO_4$ solution are connected using a salt bridge.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
Electricity can be produced in cells where at least one of the half-cells does not involve metal atoms/ions. A graphite rod can be used as the electrode in such half-cells. Different pairs of metals produce different voltages. These voltages can be used to arrange the elements into an electrochemical series. The further apart elements are in the electrochemical series, the greater the voltage produced when they are used to make an electrochemical cell. Electrons flow in the external circuit from the species higher in the electrochemical series to the one lower in the electrochemical series. For an electrochemical cell, including those involving non-metals, ion-electron equations can be written for: ♦ the oxidation reaction ♦ the reduction reaction ♦ the overall redox reactions The direction of electron flow can be deduced for electrochemical cells including those involving non-metal electrodes.	
(b) Plastics	
(i) Addition polymerisation Plastics are examples of materials known as polymers.	LearnChemistry's Twig — Oil Products: Plastics and polymers provides a short introductory video on polymers/plastics.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
Polymers are long chain molecules formed by joining together a large number of small molecules called monomers. Addition polymerisation is the name given to a chemical reaction in which unsaturated monomers are joined, forming a polymer. The names of addition polymers are derived from the name of the monomer used. Note: brackets can be used in polymer names to aid identification of the monomer unit. ***(ii) Representation of the structure of monomers and polymers*** A repeating unit is the shortest section of polymer chain which, if repeated, would yield the complete polymer chain (except for the end-groups). The structure of a polymer can be drawn given either the structure of the monomer or the repeating unit. From the structure of a polymer, the monomer or repeating unit can be drawn.	Twig — Oil Products: Plastics and polymers offers a handout sheet showing the addition polymerisation of ethene. Twig — Oil Products: Plastics and polymers also provides an information sheet showing common polymers and their monomers.
(c) Fertilisers	
(i) Commercial production of fertilisers Growing plants require nutrients, including compounds containing nitrogen, phosphorus or potassium.	The activity 'Effect of nutrient solutions on plant growth (soil culture)', part of LearnChemistry's Plant science practicals — Challenging Plants uses quick growing seeds to demonstrate the effect of nutrient deficiencies on plants.

3 Chemistry in society (continued) **Mandatory knowledge**	**Suggested activities**
Fertilisers are substances which restore elements, essential for healthy plant growth, to the soil.	Challenging Plants: Fertilisers available from LearnChemistry, provides information sheets on 'Nutrients and fertilisers' and 'Fertilisers providing primary and secondary nutrients'.
Ammonia and nitric acid are important compounds used to produce soluble, nitrogen-containing salts that can be used as fertilisers.	
Ammonia is a pungent, clear, colourless gas which dissolves in water to produce an alkaline solution.	LearnChemistry provides details on experiments to introduce the properties of ammonia. In Making and testing ammonia candidates make ammonia, investigate its solubility in water and its alkaline nature. The experiment provides a useful precursor to the ammonia fountain experiment. The classic Ammonia fountain experiment illustrates the very high solubility of ammonia in water (a video is also available).
Ammonia solutions react with acids to form soluble salts. ammonia solution + an acid → an ammonium salt + water ***(ii) Haber and Ostwald processes*** The Haber process is used to produce the ammonia required for fertiliser production. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	Preparing a soluble salt by neutralisation from LearnChemistry, gives practical details for the production of ammonium sulfate crystals from ammonia solution and sulfuric acid.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
At low temperatures the forward reaction is too slow to be economical. If the temperature is increased, the rate of reaction increases but, as the temperature increases, the backward reaction becomes more dominant. An iron catalyst is used to increase reaction rate. Ammonia is the starting material for the commercial production of nitric acid. The Ostwald process uses ammonia, oxygen and water to produce nitric acid. A platinum catalyst is used in this process.	
(d) Nuclear chemistry	
(i) Radiation Radioactive decay involves changes in the nuclei of atoms. Unstable nuclei (radioisotopes) can become more stable nuclei by giving out alpha, beta or gamma radiation. Alpha particles (α) consist of two protons and two neutrons and carry a double positive charge. They have a range of only a few centimetres in air and are stopped by a piece of paper. Alpha particles will be attracted towards a negatively charged plate. Beta particles (β) are electrons ejected from the nucleus of an atom. They are able to travel over a metre in air but can be stopped by a thin sheet of aluminium. Beta particles will be attracted towards a positively charged plate. Gamma rays (γ) are electromagnetic waves emitted from within the nucleus of an atom. They are able to travel great distances in air. They can be stopped by barriers made of materials such as lead or concrete. Gamma rays are not deflected by an electric field.	LearnChemistry's The Royal Institution Christmas Lectures®: Radioactivity video clip, 'Radioactivity video' offers a simple introduction to radioactivity. PhET at the University of Colorado have created Alpha Decay which explores half-life through the decay of polonium. Beta Decay, also from PhET at the University of Colorado, shows beta decay occurring for a collection of nuclei or for an individual nucleus.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
(ii) Nuclear equations Balanced nuclear equations can be written using nuclide notation. In nuclear equations: ♦ an alpha particle can be represented as $^{4}_{2}He$ ♦ a beta particle can be represented as $^{0}_{-1}e$ ♦ a proton can be represented as $^{1}_{1}p$ ♦ a neutron can be represented as $^{1}_{0}n$ In the course of any nuclear reaction: ♦ The sum of the atomic numbers on the left of the reaction arrow is equal to the sum of the atomic numbers on the right of the reaction arrow. ♦ The sum of the mass numbers on the left of the reaction arrow is equal to the sum of the mass numbers on the right of the reaction arrow. Candidates do not need to show electrical charges when writing balanced equations representing nuclear reactions.	
(iii) Half-life Half-life is the time for half of the nuclei of a particular isotope to decay.	

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
The half-life of an isotope is a constant, unaffected by chemical or physical conditions. Radioactive isotopes can be used to date materials. The half-life of an isotope can be determined from a graph showing a decay curve. Calculations can be performed using the link between the number of half-lives, time and the proportion of a radioisotope remaining. ***(iv) Use of radioactive isotopes*** Radioisotopes have a range of uses in medicine and in industry. Candidates do not need to be able to name the isotope used in a particular application. Given information on the type of radiation emitted and/or half-lives, the suitability of an isotope for a particular application can be evaluated.	The Radioactive Dating Game from PhET at the University of Colorado matches the percentage of the dating element that remains to the age of an object.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
(e) Chemical analysis	
(i) Common chemical apparatus Candidates must be familiar with the use(s) of the following types of apparatus: ♦ conical flask ♦ beaker ♦ measuring cylinder ♦ delivery tube ♦ dropper ♦ test tubes/boiling tubes ♦ funnel ♦ filter paper ♦ evaporating basin ♦ pipette with safety filler ♦ burette ♦ thermometer	

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
(ii) General practical techniques Candidates must be familiar with the following practical techniques:	
♦ simple filtration using filter paper and a funnel to separate the residue from the filtrate	It is often necessary to obtain pure solid chemicals from impure samples. LearnChemistry's Purifying an impure solid involves the purification of alum. This experiment allows large crystals of alum to be formed.
♦ use of a balance	The interactive lab primer — weighing compounds using a balance, available through LearnChemistry, is a collection of videos and online simulation that allows candidates to become familiar with the correct use of chemical balances.
♦ methods for the collection of gases including: — collection over water (for relatively insoluble gases) — downward displacement of air (for soluble gases that are less dense than air) — upward displacement of air (for soluble gases that are more dense than air)	LearnChemistry's Generating, collecting and testing gases demonstrates the collection of gases by the three named methods.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
♦ methods of heating using Bunsen burners and electric hotplates	The interactive lab primer — heating, from LearnChemistry, provides animations showing key points in the correct operation of Bunsen burners and hotplates. The safe heating of a solution can be practised using LearnChemistry's Recovering water from copper(II) sulfate solution. A copper(II) sulfate solution is evaporated and the water condensed using simple apparatus.
♦ preparation of soluble salts by the reaction of acids with metals, metal oxides, metal hydroxides and metal carbonates	LearnChemistry offers a number of experiments in which soluble salts are prepared. Reacting copper(II) oxide with sulfuric acid describes the preparation of copper(II) sulfate crystals from copper(II) carbonate and sulfuric acid. Preparing salts by neutralisation of oxides and carbonates describes the preparation of copper(II) sulfate crystals from copper(II) oxide and the preparation of magnesium sulfate crystals from magnesium carbonate.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
♦ preparation of insoluble salts by precipitation	LearnChemistry offers a number of experiments in which insoluble salts are prepared. Making magnesium carbonate: the formation of an insoluble salt in water describes the precipitation of magnesium carbonate from magnesium sulfate and sodium carbonate. In Silver and lead halides, insoluble silver and lead halides form as precipitates when solutions of silver or lead salts are added to solutions containing halide ions. The University of Oregon's Precipitation of Lead Iodide describes an unusual way of demonstrating precipitation reactions. When a few crystals of lead nitrate and potassium iodide are added to opposite sides of a dish containing water, a line of bright yellow lead iodide forms down the middle of the dish.
♦ testing the electrical conductivity of solids and solutions	LearnChemistry offers a number of experiments to test the electrical conductivity of solids and solutions. The experiment Which substances conduct electricity? enables candidates to distinguish between non-conducting covalent substances and ionic compounds that conduct when molten or in solution (a worksheet is also provided). Electrolysis of molten zinc chloride: this demonstration shows that an ionic substance will conduct electricity when molten but not when solid (a video is also available).

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
♦ setting up an electrochemical cell using a salt bridge and either metal or carbon electrodes	
♦ electrolysis of solutions using a d.c. supply	LearnChemistry offer a number of activities exploring electrolysis. Electrolysing molten lead(II) bromide demonstrates that conduction is only possible where lead(II) bromide is molten, and that metallic lead and bromine are the products of electrolysis. Electrolysis of molten zinc chloride offers a safer alternative to lead bromide for demonstrating the electrolysis of molten salts (a video is also available). Electrolysis of copper(II) sulfate solution uses graphite rods to carry out the electrolysis of dilute copper(II) sulfate solution.
♦ determination of E_h	LearnChemistry's Heat energy from alcohols is an experiment comparing the amounts of heat energy produced by burning various alcohols.

3 Chemistry in society (continued) **Mandatory knowledge**	**Suggested activities**
(iii) Analytical methods Titration is used to determine, accurately, the volumes of solution required to reach the end-point of a chemical reaction. An indicator is normally used to show when the end-point is reached. Titre volumes within 0·2 cm^3 are considered concordant.	LearnChemistry offer a number of titration activities. The interactive lab primer — titration is a suite of videos, simulations and animations that show candidates how to use pipettes and burettes to carry out a titration. The titration animation provides a clear overview of how a titration allows the concentration of a solution to be measured. Titrations quizzes: new users guide to our practical skills quizzes is a collection of videos including another titration experiment. The ‘Colours of pH indicators’ infographic from Colourful chemistry infographics illustrates the range of indicators available. The Titration screen experiment is an interactive virtual lab resource. The activity has four levels. The first level is suitable as a resource to revise and consolidate understanding of the ‘Acids and Bases’ topic (see section 1 (d)(ii) in this table). As this resource was created for world wide use, concentration is expressed in mol dm^{-3}. Before using this resource, it would be advisable to inform candidates that 1 dm^3 is equivalent to 1 litre.
Solutions of accurately known concentration are known as standard solutions.	The Molarity Simulation from PhET is an ideal way to introduce the idea of the measurement of concentrations allowing you to vary the volume of solvent and the amount of solute used to form solutions.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
Flame tests can identify metals present in a sample.	LearnChemistry offer a number of activities related to flame testing. Assessment for Learning Chemistry: What's in a firework? uses party poppers and sparklers to set the scene for flame testing of the metallic compounds that give fireworks their colour. Flame colours — a demonstration gives straightforward instructions for a teacher demonstration of flame colours. Flame tests (the wooden splint method) gives instructions for a simple method for candidates to use. Royal Institution Christmas Lectures® 2012: group 1 flame tests is a library of short videos showing the flame colours for different ions.
Simple tests can be used to identify oxygen, hydrogen and carbon dioxide gases.	
Precipitation is the reaction of two solutions to form an insoluble salt called a precipitate. Information on the solubility of compounds can be used to predict when a precipitate will form. The formation of a precipitate can be used to identify the presence of a particular ion.	Assessment for Learning Chemistry: what happens when substances dissolve? What happens when a precipitate forms? This is a simple experimental comparison and discussion to consider the key questions 'what happens when a substance dissolves?' and 'what happens when a precipitate forms?' In Making magnesium carbonate: the formation of an insoluble salt in water a sample of magnesium carbonate is made by mixing solutions of magnesium sulfate and sodium carbonate.

3 Chemistry in society (continued) Mandatory knowledge	Suggested activities
(iv) Reporting experimental work Labelled, sectional diagrams can be drawn for common chemical apparatus. Data can be presented in tabular form with appropriate headings and units of measurement. Data can be presented as a bar, line or scatter graph with suitable scale(s) and labels. A line of best fit (straight or curved) can be used to represent the trend observed in experimental data. Average (mean) values can be calculated from data. Given a description of an experimental procedure and/or experimental results, an improvement to the experimental method can be suggested and justified.	