3.4 Module C1: Carbon Chemistry

Module C1: Carbon Chemistry

Item C1: Fundamental Chemical Concepts

Summary: Throughout the study of chemistry in GCSE science there are a number of ideas and concepts that are fundamental. These ideas and concepts have not been put into a particular item but should permeate through all the GCSE Chemistry Modules C1 to C6.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
These learning outcomes are intended to be taught throughout this specification.	Understand that in a chemical reaction reactants are changed into products. Recognise the reactants and products in a word equation. Construct word equations given the reactants and products.
These learning outcomes are intended to be taught throughout this specification.	Recognise the reactants and the products in a symbol equation.
These learning outcomes are intended to be taught throughout this specification.	Deduce the number of elements in a compound given its formula. Deduce the number of atoms in a formula with no brackets. Deduce the number of each different type of atom in a formula with no brackets.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a substance is an element or a compound from its formula. Deduce the names of the different elements in a compound given its formula.
These learning outcomes are intended to be taught throughout this specification.	Understand that a molecule is made up of more than one atom joined together. Understand that a molecular formula shows the numbers and types of atom in a molecule. Deduce the number of atoms in a displayed formula. Deduce the names of the different elements in a compound given its displayed formula. Deduce the number of each different type of atom in a displayed formula.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a particle is an atom, molecule or ion given its formula. Understand that atoms contain smaller particles one of which is a negative electron.
These learning outcomes are intended to be taught throughout this specification.	Recall that two types of chemical bond holding atoms together are: • ionic bonds • covalent bonds.

Module C1: Carbon Chemistry

Item C1: Fundamental Chemical Concepts

Links to other modules: C1 to C6

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct word equations (not all reactants and products given).	
Construct balanced symbol equations given the formulae (no brackets) of the reactants and products. Explain why a symbol equation is balanced.	Construct balanced symbol equations given the formulae (some or all with brackets) of the reactants and products. Construct balanced symbol equations given the names of the reactants and products (limited to the learning outcomes in C1).
Deduce the number of atoms in a formula with brackets. Deduce the number of each type of different atom in a formula with brackets. Recall the formula of the following substances: • carbon dioxide and carbon monoxide • oxygen and water.	Recall the formula of the following substances: • sulfuric acid • sulfur dioxide • sodium hydrogencarbonate and sodium carbonate.
Understand that a displayed formula shows both the atoms and the bonds in a molecule. Write the molecular formula of a compound given its displayed formula.	Construct balanced equations using displayed formulae.
Understand that positive ions are formed when electrons are lost from atoms. Understand that negative ions are formed when electrons are gained by atoms.	
Understand that an ionic bond is the attraction between a positive ion and a negative ion. Understand that a covalent bond is a shared pair of electrons.	Explain how an ionic bond is formed. Explain how a covalent bond is formed.

Module C1: Carbon Chemistry

Item C1a: Making crude oil useful

Summary: Articles on television and in newspapers show the unacceptable side of oil exploitation in terms of oil pollution at sea or on beaches. This item develops ideas about oil exploitation and how crude oil is changed into useful products such as fuels. It also demonstrates the importance of timescale with reference to non-renewable fuels. This item provides the opportunity to illustrate the use of ICT in science and technology when researching oil exploitation and the industrial production of products from crude oil. The discussion about exploitation of oil raises ethical issues and allows consideration of some questions that science cannot currently answer.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research different fossil fuels with groups of candidates preparing a presentation on each fuel.	Recall that crude oil, coal and gas are fossil fuels. Describe non-renewable fuels as ones which take a very long time to make and are used up faster than they are formed.
Demonstrate the fractional distillation of crude oil using synthetic crude oil mixture. Research the different products that can be made from crude oil.	Recognise that fractional distillation separates crude oil into useful products called fractions. Understand that fractional distillation works because of differences in boiling points. Recognise that LPG, petrol, diesel, paraffin, heating oil, fuel oils and bitumen are fractions obtained from crude oil. Recall that LPG contains propane and butane gases.
Research the problems of oil exploitation and possible solutions.	Describe some of the environmental problems involved in the exploitation of crude oil: • oil slicks as a result of accidents • damage to wildlife and beaches.
Demonstrate the cracking of liquid paraffin.	Label the laboratory apparatus used for cracking liquid paraffin. Describe cracking as a process that: • needs a catalyst and a high temperature • converts large hydrocarbon molecules into smaller ones that are more useful • makes more petrol.

Module C1: Carbon Chemistry

Item C1a: Making crude oil useful

Links to other items: C1b: Using carbon fuels, C1d: Making polymers, C1e: Designer polymers, C3f: Energy, C6d: Alcohols, C6g: Natural fats and oils

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain why fossil fuels are finite resources and are non-renewable: • finite resources are no longer being made or being made extremely slowly • non-renewable resources are used up faster than they are formed. Describe crude oil as a mixture of many hydrocarbons.	Discuss the problems associated with the finite nature of crude oil: • all the readily extractable resources will be used up in the future • finding replacements • conflict between making petrochemicals and fuels.
Label a diagram of a crude oil fractional distillation column to show the main fractions and the temperature gradient. Describe how fractional distillation separates crude oil into fractions: • crude oil is heated • use of a fractionating column which has a temperature gradient (cold at the top and hot at the bottom) • fractions containing mixtures of hydrocarbons are obtained • fractions contain many substances with similar boiling points • fractions with low boiling points 'exit' from the top of the fractionating column • fractions with high boiling points 'exit' at the bottom of the fractionating column.	Explain in terms of molecular size, intermolecular forces and boiling point why crude oil can be separated by fractional distillation. Understand that during boiling the intermolecular forces between molecules break but covalent bonds within the molecule do not.
Explain some of the potential environmental problems involved in the transportation of crude oil: • damage to birds' feathers causing death • use of detergents to clean up oil slicks and consequent damage to wildlife.	Explain in simple terms the political problems associated with the exploitation of crude oil: • UK dependent on oil and gas from politically unstable countries • future supply issues.
Describe cracking as a process that: • converts large alkane molecules into smaller alkane and alkene molecules • makes useful alkene molecules that can be used to make polymers. Interpret data about the supply and demand of crude oil fractions (no recall expected).	Explain how cracking helps an oil refinery match its supply of useful products such as petrol with the demand for them.

Module C1: Carbon Chemistry

Item C1b: Using carbon fuels

Summary: This item develops ideas about fuels and the factors that need to be considered when choosing a fuel that is fit for purpose. It also considers the process of combustion and how and why decisions about science and technology are made.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Discuss fuels for a purpose (e.g. choosing the right fuel for heating/lighting a remote house in Scotland, powering a car, use in an electricity generating station).	Interpret simple data about fuels in order to choose the best fuel for a particular purpose (no recall expected). List the factors about fuels in order to choose the best fuel for a particular purpose: • energy value • availability • storage • cost • toxicity • pollution e.g. acid rain, greenhouse effect • ease of use.
Carry out an experiment to show that combustion of a hydrocarbon in a plentiful supply of air produces carbon dioxide and water.	Recall that the combustion of a fuel releases useful heat energy. Understand why complete combustion needs a plentiful supply of oxygen (air). Recall that complete combustion of a hydrocarbon fuel makes only carbon dioxide and water. Construct word equations to show the complete combustion of a hydrocarbon fuel given the reactants and products.
Design a poster warning about the dangers of carbon monoxide poisoning e.g. using appropriate ICT software. Investigate the products of complete and incomplete combustion by experiment.	Understand why incomplete combustion takes place. Explain why a blue Bunsen flame releases more energy than a yellow flame. Identify that a yellow flame produces lots of soot. Recall that incomplete combustion of a hydrocarbon fuel makes carbon monoxide, carbon (soot) and water. Recall that carbon monoxide is a poisonous gas. Construct word equations to show the incomplete combustion of a hydrocarbon fuel given the reactants and products.

Module C1: Carbon Chemistry

Item C1b: Using carbon fuels

Links to other items: C1a: Making crude oil useful, C1c: Clean air, C1d: Making polymers, C3c: Rate of reaction (3), C6b: Energy transfers – fuel cells, C6d: Alcohols

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Interpret data about fuels in order to choose the best fuel for a particular purpose (no recall expected). Suggest the key factors that need to be considered when choosing a fuel for a particular purpose.	Evaluate the use (no recall expected) of different fuels. Explain why the amount of fossil fuels being burnt is increasing: • increasing world population • growth of use in developing countries e.g. India and China.
Describe an experiment to show that combustion of a hydrocarbon in a plentiful supply of air produces carbon dioxide and water. Construct word equations to show the complete combustion of a hydrocarbon fuel (not all reactants and products given).	Construct the balanced symbol equation for the complete combustion of a simple hydrocarbon fuel given its molecular formula.
Explain the advantages of complete combustion over incomplete combustion of hydrocarbon fuels. Construct word equations to show the incomplete combustion of a hydrocarbon fuel (not all reactants and products given).	Construct the balanced symbol equation for the incomplete combustion of a simple hydrocarbon fuel given its molecular formula and the product (carbon or carbon monoxide).

Module C1: Carbon Chemistry

Item C1c: Clean air

Summary: The increase in respiratory illnesses such as asthma in young people may be caused by an increase in air pollution. This item develops ideas about air pollution and how it can be prevented. The use of catalytic converters to reduce atmospheric pollution is also considered. The evolution of the atmosphere including the timescales involved and the ethical issues around human influences on the atmosphere are also introduced.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Experimental determination of the composition of clean air. Produce some research or a poster to show the main processes in the carbon cycle. Produce a time line showing the sequence of events in the evolution of the atmosphere.	Recall that air contains oxygen, nitrogen, water vapour and carbon dioxide. Understand how photosynthesis, respiration and combustion affect the level of carbon dioxide and the level of oxygen in the air. Understand that oxygen, nitrogen and carbon dioxide levels in the present day atmosphere are approximately constant.
Research the increase in occurrences of asthma in the UK and possible links with air pollution e.g. from the internet. Write a leaflet describing the main forms of atmospheric pollution, their effects and origins.	Relate the common pollutants found in air to the environmental problem the pollutant causes and/or to the source of the pollutant: • carbon monoxide – a poisonous gas formed by the incomplete combustion of petrol or diesel in car engines • oxides of nitrogen – causes photochemical smog and acid rain and are formed in the internal combustion engine • sulfur dioxide – causes acid rain that will kill plants, kill aquatic life, erode stonework and corrode metals and is formed when sulfur impurities in fossil fuels burn.
Research the methods of preventing atmospheric pollution.	Recall that a catalytic converter removes carbon monoxide from the exhaust gases of a car.

Module C1: Carbon Chemistry

Item C1c: Clean air

Links to other items: C1b: Using carbon fuels, C6e: Depletion of the ozone layer

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall the percentage composition by volume of clean air: • 21% oxygen • 78% nitrogen • 0.035% carbon dioxide. Describe a simple carbon cycle involving photosynthesis, respiration and combustion. Describe how the present day atmosphere evolved: • original atmosphere came from gases escaping from the interior of the Earth • photosynthesis by plants increased the percentage of oxygen until it reached today's level.	Evaluate the effects of human influences on the composition of air, for example: • deforestation • population. Describe one possible theory for how the present day atmosphere evolved over millions of years (based on the composition of gases vented by present day volcanic activity): • degassing of early volcanoes producing an atmosphere rich in water and carbon dioxide • condensing of water vapour to form oceans • dissolving of carbon dioxide in ocean waters • relative increase of nitrogen due to its lack of reactivity • development of photosynthetic organisms • increase in oxygen levels due to photosynthesis.
Interpret data about the effects of atmospheric pollutants.	Explain why the high temperature inside an internal combustion engine allows nitrogen from the air to react with oxygen to make oxides of nitrogen.
Explain why it is important that atmospheric pollution is controlled. Understand that a catalytic converter changes carbon monoxide into carbon dioxide.	Explain how use of a catalytic converter removes carbon monoxide from exhaust fumes using the balanced symbol equation: $2CO + 2NO \rightarrow N_2 + 2CO_2$

Module C1: Carbon Chemistry

Item C1d: Making polymers

Summary: Candidates will be familiar with the idea that virtually all materials are made through chemical reactions. They will also be able to represent compounds by formulae and chemical reactions by word equations. This item applies these ideas to the formation of a group of substances vital for life in the 21st century.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Use of molecular models. Use of ICT to show shapes of molecules.	Recall the two elements chemically combined in a hydrocarbon: • carbon • hydrogen. Recognise a hydrocarbon from its molecular or displayed formula.
Use of molecular models. Use of ICT to show shapes of molecules.	Recognise that alkanes are hydrocarbons.
Test for unsaturation using bromine water.	Recognise that alkenes are hydrocarbons.
Card game: matching monomers and polymers. Use of molecular models. Making 'polypaperclips'.	Deduce the name of an addition polymer given the name of the monomer and vice versa.
Demonstration of preparation of nylon as an example of how monomers can form chains (but understanding that this is not an example of addition polymerisation). Demonstration – making poly(phenylethene) – details from RSC website www.practicalchemistry.org. PVA polymer slime details from RSC website www.practicalchemistry.org.	Recall that large molecules, called polymers, are made when many small molecules, called monomers, join together in a polymerisation reaction.

Module C1: Carbon Chemistry

Item C1d: Making polymers

Links to other items: C1a: Making crude oil useful, C1b: Using carbon fuels, C1e: Designer polymers

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that a hydrocarbon is a compound formed between carbon atoms and hydrogen atoms only. Given the molecular or displayed formula of a compound, explain why it is a hydrocarbon.	Describe a saturated compound as one which contains only single covalent bonds between carbon atoms. Describe an unsaturated compound as one which contains at least one double covalent bond between carbon atoms.
Recall that alkanes are hydrocarbons which contain single covalent bonds only. Interpret information on displayed formulae of alkanes.	Interpret information from the displayed formula of a saturated hydrocarbon.
Recall that alkenes are hydrocarbons which contain a double covalent bond(s) between carbon atoms. Understand that double bonds involve two shared pairs of electrons. Interpret information on displayed formulae of alkenes. Describe how the reaction with bromine can be used to test for an alkene: • bromine water is orange • bromine water is decolourised.	Interpret information from the displayed formula of an unsaturated hydrocarbon. Explain the reaction between bromine and alkenes: • addition reaction • formation of a colourless dibromo compound.
Recognise the displayed formula for a polymer.	Draw the displayed formula of an addition polymer given the displayed formula of its monomer. Draw the displayed formula of a monomer given the displayed formula of its addition polymer.
Describe addition polymerisation as a process in which many alkene monomer molecules react together to give a polymer which requires high pressure and a catalyst.	Explain addition polymerisation in terms of addition of unsaturated molecules.

Module C1: Carbon Chemistry

Item C1e: Designer polymers

Summary: Candidates may be familiar with the idea that everyday items such as supermarket bags are made from polymers. This item explores why technology moves forward with the development of materials focusing on the very wide range of uses that polymers have in the 21st century, including health care. Issues of disposal of polymers are also considered.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Activity interpreting information and researching personal interests in the context of why technology moves forward with the development of materials precisely matched to need using a variety of contexts to capture different interests (CDs, sports equipment, health contexts etc).	Interpret simple information about properties of polymers (plastics) and their uses given appropriate information (no recall expected).
Data-search about waterproof clothing e.g. using appropriate ICT. Identification of polymers (plastics).	Recall that nylon is used in clothing.
Research how local councils dispose of public waste.	Understand that many polymers are non-biodegradable and so will not decay or decompose by bacterial action. Recall some of the ways that waste polymers can be disposed of: • use of land-fill sites • burning of waste polymers • recycling.

Module C1: Carbon Chemistry

Item C1e: Designer polymers

Links to other items: C1a: Making crude oil useful, C1d: Making polymers

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Suggest the properties a polymer (plastic) should have in order to be used for a particular purpose. Explain why a polymer (plastic) is suitable for a particular use given the properties of the polymer.	Understand that the atoms in plastics are held together by strong covalent bonds. Relate the properties of plastics to simple models of their structure: • plastics that have weak intermolecular forces between polymer molecules have low melting points and can be stretched easily as the polymer molecules can slide over one another • plastics that have strong forces between the polymer molecules (covalent bonds or cross-linking bridges) have high melting points, cannot be stretched and are rigid.
Compare the properties of nylon and GORE-TEX® fabric: • nylon is tough, lightweight, keeps water out and keeps UV light out but does not let water vapour through it which means that sweat condenses • GORE-TEX® fabric has all of the properties of nylon but is also breathable. Explain why the discovery of GORE-TEX® type materials has been of great help to active outdoor people to cope with perspiration wetness.	Explain why GORE-TEX® type materials are waterproof and yet breathable: • nylon laminated with PTFE / polyurethane membrane • holes in membrane are too small for water to pass through but are big enough for water vapour to pass through • membrane is too fragile on its own and so is combined with nylon.
Explain why chemists are developing new types of polymers: • polymers that dissolve • biodegradable polymers. Explain environmental and economic issues related to the use and disposal of polymers.	

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Module C1: Carbon Chemistry

Item C1f: Cooking and food additives

Summary: Cooking involves chemical reactions in food to develop a different texture and taste. This item considers the chemical changes that happen to some foods when they are cooked. Much of the food eaten today contains food additives to colour food, enhance the flavour, add vitamins, stabilise the food, or stop it decaying. This item considers different types of food additive and some of the issues concerned with their use. This item provides the opportunity to collect and analyse secondary data using ICT tools when researching food additives and provides opportunities for interpreting and applying science ideas.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Investigate the effect of heating on proteins such as those in eggs or meat. Investigate the effect of heat on potatoes. RSC material at www.practicalchemistry.org/experiments/structure-and-bonding.	Recognise that a chemical change takes place if: • there is a new substance made • the process is irreversible • an energy change takes place. Explain why cooking food is a chemical change: • a new substance is formed • the process cannot be reversed.
Data search into the types of food additive e.g. using suitable web sites. Look at food labels for additives. Discuss the advantages and disadvantages of using food additives. Investigate emulsifiers by mixing oil and water. Test a range of common substances to see which act as emulsifiers.	Relate types of food additive to their function: • antioxidants stop foods from reacting with oxygen • food colours give food an improved colour • flavour enhancers improve the flavour of a food • emulsifiers help oil and water to mix and not separate.
Investigate the action of heat on baking powder.	Explain how baking powder helps make cakes rise. Recall that the chemical test for carbon dioxide is that it turns lime water cloudy.

Module C1: Carbon Chemistry

Item C1f: Cooking and food additives

Links to other items: C5c: Quantitative analysis, C6g: Natural fats and oils

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that protein molecules in eggs and meat change shape when eggs and meat are cooked: this is called denaturing.	Explain why the texture of egg or meat changes when it is cooked: • shape of protein molecules permanently changes. Explain why potato is easier to digest if it is cooked: • cell walls rupture resulting in loss of rigid structure and a softer texture • starch grains swell up and spread out.
Describe emulsifiers as molecules that have a water loving (hydrophilic) part and an oil or fat loving (hydrophobic) part.	Explain why an emulsifier helps to keep oil and water from separating: • hydrophilic end bonds to water molecules • hydrophobic end bonds with oil or fat molecules.
Recall the word equation for the decomposition of sodium hydrogencarbonate (not all products given) sodium hydrogencarbonate → sodium carbonate + carbon dioxide + water Construct the balanced symbol equation for the decomposition of sodium hydrogencarbonate (some or all formulae given): $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$	Construct the balanced symbol equation for the decomposition of sodium hydrogencarbonate (formulae not given): $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Module C1: Carbon Chemistry

Item C1g: Smells

Summary: Cosmetics play an important part in the life of teenagers. This item considers some cosmetic products: perfumes and nail varnish remover. The properties of these products and the need for testing new cosmetic products are considered. This item provides the opportunity to explore how and why decisions about science and technology are made, including ethical issues on the testing of cosmetics on animals. The investigation on nail varnish removal provides the opportunity to collect and analyse primary scientific data, working accurately and safely.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Preparation of an ester e.g. butyl ethanoate. Microscale preparation of a range of esters and identification of the smells. Research the uses of esters.	Understand that cosmetics are either synthetic or natural depending on their source. Recall that esters are perfumes that can be made synthetically.
Research and display the properties of perfumes.	Recall the necessary physical properties of perfumes: • evaporates easily • non-toxic • does not react with water • does not irritate the skin • insoluble in water.
Investigate the removal of coloured nail varnish with different solvents.	Understand that nail-varnish remover dissolves nail varnish colours. Understand the terms solvent, solute, solution, soluble and insoluble.
Debate: "Is testing of cosmetics on animals ever justified?"	Recall that testing of cosmetics on animals is banned in the EU. Explain why new cosmetic products need to be thoroughly tested before they are permitted to be used.

Module C1: Carbon Chemistry

Item C1g: Smells

Links to other items: C6g: Natural fats and oils

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that alcohols react with acids to make an ester and water. Describe how to carry out a simple experiment to make an ester.	
Explain why a perfume needs certain properties: • easily evaporates so that the perfume particles can easily reach the nose • non-toxic so it does not poison you • does not react with water because otherwise the perfume would react with perspiration • does not irritate the skin otherwise the perfume could not be put directly on the skin • insoluble in water so it cannot be washed off easily.	Explain the volatility (ease of evaporation) of perfumes in terms of kinetic theory: • in order to evaporate particles need sufficient energy to overcome the attraction to other molecules in the liquid • only weak attraction exists between particles in the liquid perfume so it is easy to overcome this attraction.
Recall that esters can be used as solvents. Describe a solution as a mixture of solvent and solute that does not separate out. Interpret information on the effectiveness of solvents (no recall expected).	Explain why water will not dissolve nail varnish colours: • attraction between water molecules is stronger than attraction between water molecules and particles in nail varnish • attraction between particles in nail varnish is stronger than attraction between water molecules and particles in nail varnish.
Explain why testing of cosmetics on animals has been banned in the EU.	Explain why people have different opinions about whether the testing of cosmetics on animals is ever justified.

Module C1: Carbon Chemistry

Item C1h: Paints and pigments

Summary: Pigments and paints play an important part in our modern lives. Our clothes, houses and our local environment are all made much more interesting and pleasing to the eye by the use of colour.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Making coloured substances by mixing together solutions. Data-search via internet about paints and the ingredients in paints. Make a simple paint.	Relate the ingredients of a paint to their function: • solvent thins the paint and makes it easier to spread • binding medium sticks the pigment in the paint to the surface • pigment is the substance that gives the paint its colour. Recall that oil paints: • have the pigment dispersed in an oil • and often a solvent that dissolves oil.
Survey some advertisement leaflets about different types of paints.	Explain why paint is used (in a given context).
Investigate thermochromic pigments using materials e.g. material from Middlesex University Teaching Resources. Demonstrate some objects that contain thermochromic pigments.	Recall that thermochromic pigments change colour when heated or cooled. Recall uses of thermochromic pigments.
Investigate phosphorescent pigments using material e.g. material from Middlesex University Teaching Resources.	Recall that phosphorescent pigments can glow in the dark.

Module C1: Carbon Chemistry

Item C1h: Paints and pigments

Links to other items: C6c: Redox reactions

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe paint as a colloid where the particles are mixed and dispersed with particles of a liquid but are not dissolved.	Explain why the components of a colloid will not separate.
Describe how most paints dry: • paints are applied as a thin layer • the solvent evaporates. Describe emulsion paints as water based paints that dry when the solvent evaporates.	Explain how oil paints dry: • the solvent evaporates • the oil is oxidised by atmospheric oxygen.
Explain why thermochromic pigments are suited to a given use.	Explain how acrylic paints can be added to thermochromic pigments to make even more colour changes.
Explain why phosphorescent pigments glow in the dark: • they absorb and store energy • then release it as light over a period of time.	Recall that phosphorescent pigments are much safer than the alternative radioactive substances.

3.5 Module C2: Chemical Resources

Module C2: Chemical Resources

Item C2: Fundamental Chemical Concepts

Summary: Throughout the study of chemistry in GCSE science there are a number of ideas and concepts that are fundamental. These ideas and concepts have not been put into a particular item but should permeate through all the GCSE Chemistry Modules C1 to C6.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
These learning outcomes are intended to be taught throughout this specification.	Understand that in a chemical reaction reactants are changed into products. Recognise the reactants and products in a word equation. Construct word equations given the reactants and products.
These learning outcomes are intended to be taught throughout this specification.	Recognise the reactants and the products in a symbol equation.
These learning outcomes are intended to be taught throughout this specification.	Deduce the number of elements in a compound given its formula. Deduce the number of atoms in a formula with no brackets. Deduce the number of each different type of atom in a formula with no brackets.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a substance is an element or a compound from its formula. Deduce the names of the different elements in a compound given its formula.
These learning outcomes are intended to be taught throughout this specification.	Understand that a molecule is made up of more than one atom joined together. Understand that a molecular formula shows the numbers and types of atom in a molecule. Deduce the number of atoms in a displayed formula. Deduce the names of the different elements in a compound given its displayed formula. Deduce the number of each different type of atom in a displayed formula.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a particle is an atom, molecule or ion given its formula. Understand that atoms contain smaller particles one of which is a negative electron.
These learning outcomes are intended to be taught throughout this specification.	Recall that two types of chemical bond holding atoms together are: • ionic bonds • covalent bonds.

Module C2: Chemical Resources

Item C2: Fundamental Chemical Concepts

Links to other modules: C1 to C6

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct word equations (not all reactants and products given).	
Construct balanced symbol equations given the formulae (no brackets) of the reactants and products. Explain why a symbol equation is balanced.	Construct balanced symbol equations given the formulae (some or all with brackets) of the reactants and products. Construct balanced symbol equations given the names of the reactants and products (limited to the learning outcomes in C2).
Deduce the number of atoms in a formula with brackets. Deduce the number of each type of different atom in a formula with brackets. Recall the formula of the following substances: • calcium carbonate and calcium oxide • carbon dioxide, hydrogen and water • sodium chloride and potassium chloride • ammonia and nitrogen • hydrochloric acid.	Recall the formula of the following substances: • nitric acid and sulfuric acid • copper oxide, sodium hydroxide, potassium hydroxide and sodium carbonate • potassium sulfate, sodium sulfate and ammonium sulfate • calcium chloride, magnesium chloride magnesium sulfate and copper(II) sulfate.
Understand that a displayed formula shows both the atoms and the bonds in a molecule. Write the molecular formula of a compound given its displayed formula.	Construct balanced equations using displayed formulae.
Understand that positive ions are formed when electrons are lost from atoms. Understand that negative ions are formed when electrons are gained by atoms.	
Understand that an ionic bond is the attraction between a positive ion and a negative ion. Understand that a covalent bond is a shared pair of electrons.	Explain how an ionic bond is formed. Explain how a covalent bond is formed.

Module C2: Chemical Resources

Item C2a: The structure of the Earth

Summary: We often read or hear news items on earthquakes and volcanoes. This item builds on the interest young people show towards these events. Models are used to help explain volcanic eruptions. The development of the theory of plate tectonics illustrates science as an evidence based discipline, the collaborative nature of science and how scientific theories develop and are validated. It also covers how the Earth's surface has changed over time.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Create a scale model of the Earth's structure. Use ICT and/or other material to construct a map of where volcanoes and earthquakes occur on the Earth's surface. 'Wegener and continental drift' example taken from the Collins Ideas and Evidence CD.	Describe the structure of the Earth as a sphere with a thin rocky crust, a mantle and an iron core. Understand how the movement of tectonic plates results in volcanic activity and earthquakes. Recall that the movement of tectonic plates is very slow (about 2.5cm per year). Understand the timescales involved in the movement of continents. Recognise that: • many theories have been put forward to explain the nature of the Earth's surface • Earth scientists accept the theory of plate tectonics.
Model a volcano using the candle wax experiment. Look for clues contained in volcanic rocks that show how they formed. Video clips of volcano types. Treacle investigation.	Explain how the size of crystals in an igneous rock is related to the rate of cooling of molten rock. Describe magma as molten rock beneath the surface of the Earth and lava as molten rock at the Earth's surface. Recall that some volcanoes erupt runny lava, while some erupt thick lava violently and catastrophically.
Research examples of people who live near volcanoes and the reasons why.	Explain why some people choose to live near volcanoes.

Module C2: Chemical Resources

Item C2a: The structure of the Earth

Links to other items: C2b: Construction materials

<table>
<tr><th>Assessable learning outcomes
both tiers: standard demand</th><th>Assessable learning outcomes
Higher Tier only: high demand</th></tr>
<tr><td>Describe the lithosphere as the (relatively) cold rigid outer part of the Earth that includes the crust and part of the mantle.
Describe the lithosphere as made of tectonic plates that are less dense than the mantle below.
Explain the problems associated with studying the structure of the Earth:
• crust is too thick to drill through
• the need to use seismic waves produced by earthquakes or man-made explosions.

Explain why the theory of plate tectonics is now widely accepted:
• it explains a wide range of evidence
• it has been discussed and tested by a wide range of scientists.</td><td>Describe the mantle as the zone between the crust and the core which is:
• cold and rigid just below the crust
• hot and non-rigid at greater depths and therefore able to move.
Describe the theory of plate tectonics:
• energy transfer involving convection currents in the semi-rigid mantle causing the plates to move slowly
• oceanic crust more dense than continental crust
• collision between oceanic plate and continental plate leads to subduction and partial melting
• plates cooler at ocean margins so sink and pull plates down.
Describe in simple terms the development of the theory of plate tectonics:
• Wegener's continental drift theory (1914)
• continental drift theory not accepted by scientists at the time
• new evidence in 1960s – sea floor spreading
• theory of plate tectonics slowly accepted by the scientific community as subsequent research has supported the theory.</td></tr>
<tr><td>Understand that the type of volcanic eruption depends on the composition of the magma.</td><td>Describe different types of igneous rocks that are formed from lava:
• iron-rich basalt is formed from runny lava from a fairly safe volcanic eruption
• silica-rich rhyolite is formed from thick lava from an explosive eruption.</td></tr>
<tr><td>Explain why geologists study volcanoes:
• to be able to forecast future eruptions
• to reveal information about the structure of the Earth.</td><td>Explain why geologists are now able to better forecast volcanic eruptions but not with 100% certainty.</td></tr>
</table>

Module C2: Chemical Resources

Item C2b: Construction materials

Summary: Most landscapes include buildings such as houses, factories, flats or skyscrapers. Many of these buildings are made from raw materials found in the Earth or on the Earth's surface. The removal of the raw materials and their use has an enormous impact on the environment.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Data-search about construction materials and their sources.	Recall that some rocks are used in construction of buildings and roads: • granite, limestone, marble and aggregates.
Look at samples of marble, limestone and granite. Video clips of mining and quarrying.	Explain why there are environmental problems when rocks are quarried or mined from the ground: • landscape destroyed and has to be reconstructed when the mining or quarrying has finished • increased noise, traffic and dust.
Experimental investigation of the decomposition of calcium carbonate.	Recall that limestone and marble are both forms of calcium carbonate. Recall that limestone thermally decomposes to make calcium oxide and carbon dioxide.
Making a sample of concrete.	Describe how concrete is made: • cement, sand, aggregate and water are mixed together • mixture then allowed to set.
Investigating the strength of concrete beams.	Describe how concrete can be reinforced using a steel support.

Module C2: Chemical Resources

Item C2b: Construction materials

Links to other items: C2a: The structure of the Earth, C2d: Making cars

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Relate some construction materials to the substances found in the Earth's crust from which they are manufactured: • aluminium and iron from ores • brick from clay • glass from sand.	
Compare the hardness of limestone, marble and granite.	Explain why granite, marble and limestone have different hardness: • limestone is a sedimentary rock • marble is a metamorphic rock made by the action of high pressures and temperatures on limestone • granite is an igneous rock.
Construct the word equation for the decomposition of limestone (products not given) calcium carbonate → calcium oxide + carbon dioxide Construct the balanced symbol equation for the decomposition of limestone (given some formulae): $CaCO_3 \rightarrow CaO + CO_2$ Describe thermal decomposition as a reaction in which, when heated, one substance is chemically changed into at least two new substances.	Construct the balanced symbol equation for the decomposition of limestone (formulae not given): $CaCO_3 \rightarrow CaO + CO_2$
Recall that cement is made when limestone and clay are heated together.	
Recall that reinforced concrete is a composite material.	Explain why reinforced concrete is a better construction material than non-reinforced concrete in terms of: • hardness of the concrete • flexibility and strength of the steel.

Module C2: Chemical Resources

Item C2c: Metals and alloys

Summary: Metallic elements and alloys have many uses in our society. This item examines how metals are extracted from their ores. It also describes some of the uses of some important alloys including smart alloys.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Extraction of copper by heating malachite and carbon. Experimental purification of copper by electrolysis.	Understand how copper can be extracted by heating its ore with carbon. Describe reduction as the removal of oxygen from a substance. Recall that copper can be purified by electrolysis. Explain why recycling copper is cheaper than extracting copper from its ore: • saves resources • uses less energy.
Research about alloys – their uses and composition. Data search or experimental investigation into the properties of alloys. Modelling alloys with plasticine – see RSC website www.practicalchemistry.org. Making solder and comparing its properties with lead and tin – see RSC website www.practicalchemistry.org.	Recall that alloys are mixtures containing one or more metal elements. Recognise that brass, bronze, solder, steel, and amalgam are alloys. Recall one important large scale use for each of the following alloys: • amalgam used in tooth fillings • brass used in musical instruments, coins and door decorations e.g. door knockers • solder used to join electrical wires.
Internet research about smart alloys and their uses. Investigate nitinol (Middlesex University Teaching Resources).	Recognise that the properties of an alloy are different from the properties of the metals from which it is made. Interpret data about the properties of metals, including alloys e.g. hardness, density, boiling point and strength. Suggest properties needed by a metal or alloy for a particular given use.

Module C2: Chemical Resources

Item C2c: Metals and alloys

Links to other items: C2d: Making cars, C4f: Transition elements, C4g: Metal structure and properties, C6a: Electrolysis, C6c: Redox reactions

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Label the apparatus needed to purify copper by electrolysis. Explain some of the advantages and disadvantages of recycling copper.	Describe the use of electrolysis in the purification of copper: • impure copper as anode • pure copper as cathode • copper(II) sulfate solution as electrolyte • cathode gains mass because copper is deposited • anode loses mass as copper dissolves. Explain why the electrolytic purification of copper involves both oxidation and reduction: • $Cu^{2+} + 2e^- \rightarrow Cu$ as an example of reduction because electrons are gained • $Cu - 2e^- \rightarrow Cu^{2+}$ as an example of oxidation because electrons are lost.
Recall the main metals in each of the following alloys: • amalgam – mercury • brass – copper and zinc • solder – lead and tin.	
Explain why metals, including alloys are suited to a given use given appropriate data (no recall expected).	Evaluate the suitability of metals for a given use given appropriate data. Explain how the use of 'smart alloys' such as those with a shape memory property have increased the number of applications of alloys: • nitinol (nickel and titanium) used to make spectacle frames as the frames will return to their original shape after bending.

Module C2: Chemical Resources

Item C2d: Making cars

Summary: Young people take the use of cars for granted. This item develops ideas about the problem of disposing of cars and the recycling of metals. Rusting and corrosion are also considered.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Investigate the corrosion of aluminium and iron using different conditions (e.g. salt water, acid rain, moist air). Comparing rate of corrosion of cars in the UK with that of Mediterranean countries.	Recall that rusting needs iron, water and oxygen. Recall that aluminium does not corrode in moist conditions. Describe oxidation as the addition of oxygen or the reaction of a substance with oxygen. Interpret simple data about the rate of corrosion of different metals in different conditions (no recall is expected).
Compare the physical properties of iron and aluminium and their alloys both by data search and by experiment (density, magnetic property, electrical conductivity, flexibility, hardness and strength). Write a promotional leaflet for a car made from aluminium illustrating the advantages of such a car over one made from iron or steel.	Compare the properties of iron and aluminium: • iron is more dense than aluminium • iron is magnetic and aluminium is not • iron corrodes (rusts) easily and aluminium does not • iron and aluminium are both malleable • iron and aluminium are both good electrical conductors.
Research all the materials that are used to manufacture cars (e.g. plastics, fibres, glass, copper, iron, aluminium).	Recall the major materials needed to build a car: • steel, copper and aluminium • glass, plastics and fibres.
Discuss the problems of disposing of cars. Visit a car scrap yard.	Describe the advantages of recycling materials: • saves natural resources • reduces disposal problems.

Module C2: Chemical Resources

Item C2d: Making cars

Links to other items: C2b: Construction materials, C2c: Metals and alloys, C4g: Metal structure and properties, C6c: Redox reactions

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand how salt water and acid rain affect rusting. Understand that rusting is an oxidation reaction (iron reacts with oxygen forming an oxide). Construct the word equation for rusting: iron + oxygen + water → hydrated iron(III) oxide Explain why aluminium does not corrode in moist conditions. Interpret data about the rate of corrosion of different metals in different conditions (no recall is expected).	
Understand that alloys often have properties that are different from the metals they are made from and that these properties may make the alloy more useful than the pure metal, to include: • steel is harder and stronger than iron • steel is less likely to corrode than iron. Describe advantages and disadvantages of building car bodies from aluminium or from steel: • car body of the same car will be lighter with aluminium • car body with aluminium will corrode less • car body of the same car will be more expensive made from aluminium.	Explain advantages and disadvantages of building car bodies from aluminium or from steel: • get better fuel economy because the car body of the same car will be lighter with aluminium • longer lifetime because the car body with aluminium will corrode less.
Suggest properties needed by a material for a particular use in a car. Explain why a material used in a car is suited to a particular use given appropriate data (no recall expected).	
Explain the advantages and disadvantages of recycling the materials used to make cars. Explain why new laws specify that a minimum percentage of all materials used to manufacture cars must be recyclable.	Evaluate information on materials used to manufacture cars (no recall expected).

Module C2: Chemical Resources

Item C2e: Manufacturing chemicals: making ammonia

Summary: This item is introduced using the context of the industrial preparation of ammonia using chemicals from the air and its link with the fertiliser industry. The concept of reversible reactions is introduced with reference being made to the production of ammonia. In reversible reactions the fact that a balance has to be struck between rate and percentage conversion is explored more generally. Industrial case studies provide the opportunity to examine how scientific knowledge and ideas change over time. The factors affecting the cost of making a new substance provide opportunities to present information using technical, scientific and mathematical language.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Examine historical, social, moral or economic reasons leading to the need to produce ammonia as a starting point for fertiliser production. Produce a poster on ammonia manufacture. Computer animation to illustrate how temperature and pressure affect yield in the Haber process e.g. Multimedia Science School 11-16 or Boardworks. Industrial case study. Watch video of Haber process with pre-prepared questions.	Recall that in the Haber process ammonia is made from nitrogen from the air and hydrogen that comes from the cracking of oil fractions or from natural gas.
Research manufacturing costs (via internet) and class discussion.	Describe that the cost of making a new substance depends on: • price of energy (gas and electricity) • cost of starting materials • wages (labour costs) • equipment (plant) • how quickly the new substance can be made (cost of catalyst).
Industrial case studies.	Recognise that $\rightleftharpoons$ is used to represent a reversible reaction. Understand that a reversible reaction proceeds in both directions.
Survey of household chemicals containing ammonia and their uses.	Recall some of the uses of ammonia: • manufacture of fertilisers • manufacture of nitric acid.

Module C2: Chemical Resources

Item C2e: Manufacturing chemicals: making ammonia

Links to other items: C2g: Fertilisers and crop yields, C3a: Rate of reaction (1), C3b: Rate of reaction (2), C3c: Rate of reaction (3), C5f: Equilibria

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe how ammonia is made in the Haber process: • nitrogen + hydrogen ⇌ ammonia • iron catalyst • high pressure • temperature in the region of 450°C • unreacted nitrogen and hydrogen are recycled. Construct the balanced symbol equation for the manufacture of ammonia in the Haber process (given some or all of the formulae): $N_2 + 3H_2 \rightleftharpoons 2NH_3$	Explain the conditions used in the Haber process: • high pressure increases the percentage yield of ammonia • high temperature decreases the percentage yield of ammonia • high temperature gives a high rate of reaction • 450°C is an optimum temperature to give a fast reaction with a sufficiently high percentage yield • catalyst increases the rate of reaction but does not change the percentage yield. Construct the balanced symbol equation for the manufacture of ammonia in the Haber process (formulae not given): $N_2 + 3H_2 \rightleftharpoons 2NH_3$
Describe how different factors affect the cost of making a new substance: • the higher the pressure the higher the plant cost • the higher the temperature the higher the energy cost • catalysts reduce costs by increasing the rate of reaction • when unreacted starting materials are recycled costs are reduced • automation reduces the wages bill.	Explain how economic considerations determine the conditions used in the manufacture of chemicals: • rate must be high enough to give a sufficient daily yield of product • percentage yield must be high enough to give a sufficient daily yield of product • a low percentage yield can be accepted if the reaction can be repeated many times with recycled starting materials • optimum conditions used that give the lowest cost rather than the fastest reaction or highest percentage yield.
Interpret data in tabular and graphical form relating to percentage yield in reversible reactions and changes in conditions (no recall required).	Interpret data about rate, percentage yield and costs for alternative industrial processes (no recall required).
Recognise the importance of ammonia in relation to world food production.	

Module C2: Chemical Resources

Item C2f: Acids and bases

Summary: Young people are familiar with acids and alkalis. They are excited by the opportunity to use these 'dangerous' chemicals. This item revises previous knowledge and understanding and gives them the opportunity to practice word and symbolic equations in relation to neutralisation reactions. The testing of pH provides the opportunity to use ICT as part of teaching and learning.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Carry out an experiment to test a variety of solutions to find pH: • reactions between acids and alkalis • reactions between acids and bases. (Opportunity to use data logger.) Test everyday household substances.	Describe how universal indicator can be used to estimate the pH of a solution. Recall the colour changes with litmus.
Simple investigation into the change in pH during neutralisation (not pH titration curves).	Recall that an alkali is a soluble base.
Investigate the reactions of acids with bases and carbonates e.g. hydrochloric acid with metal oxides, hydroxides and carbonates.	Understand that an acid can be neutralised by a base or alkali, or vice versa.

Module C2: Chemical Resources

Item C2f: Acids and bases

Links to other items: C2g: Fertilisers and crop yields, C3a: Rate of reaction (1), C3b: Rate of reaction (2), C3c: Rate of reaction (3), C5d: Titrations, C5g: Strong and weak acids

Assessable learning outcomes both tiers: standard demand	**Assessable learning outcomes Higher Tier only: high demand**
Understand that indicators use colour change to show changes in pH, including: • sudden or gradual changes • colour changes over different pH ranges.	
Recall that in neutralisation: acid + base → salt + water. Recall that in solution all acids contain H^+ ions. Understand that the pH of an acid is determined by the concentration of H^+ ions.	Explain why an acid is neutralised by an alkali in terms of the ions present: • acids contain H^+ • alkalis contain OH^- • neutralisation involves the reaction $H^+ + OH^- \rightleftharpoons H_2O$
Explain why metal oxides and metal hydroxides neutralise acids. Recall that carbonates neutralise acids to give water, a salt and carbon dioxide. Construct word equations to show the neutralisation of acids by bases and carbonates (names of the products not given). Predict the name of the salt produced when a named base or carbonate is neutralised by a laboratory acid limited to: • sulfuric acid • nitric acid • hydrochloric acid • phosphoric acid.	Construct balanced symbol equations for the neutralisation of acids by bases and carbonates limited to: • sulfuric acid, nitric acid and hydrochloric acid • ammonia, potassium hydroxide, sodium hydroxide and copper oxide • sodium carbonate and calcium carbonate.

Module C2: Chemical Resources

Item C2g: Fertilisers and crop yields

Summary: News items regularly feature stories of famine in various parts of the world. In this item we explore the role of fertilisers in increasing plant growth and crop yield. This item looks at the use of contemporary scientific and technological developments and their benefits, risks and drawbacks.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Survey of fertilisers available at garden centres and commercially (via internet searches). Research the main processes involved in eutrophication. Eutrophication animation or case study.	Recall that fertilisers increase crop yield. Recall that plants absorb minerals through their roots. Describe fertilisers as chemicals that provide plants with essential chemical elements. Recall that nitrogen, phosphorus and potassium are three essential elements needed for plant growth. Recognise the essential elements given the formula of a fertiliser. Understand that the use of fertilisers can be beneficial (increasing food supply) and also cause problems e.g. death of aquatic organisms (eutrophication).
Preparation of a fertiliser by the neutralisation of an acid by an alkali using a burette (e.g. potassium nitrate or ammonium sulfate).	Identify the apparatus needed to prepare a fertiliser by the neutralisation of an acid with an alkali: • burette and measuring cylinder • filter funnel. Recall the names of two nitrogenous fertilisers manufactured from ammonia e.g.: • ammonium nitrate • ammonium phosphate • ammonium sulfate • urea.

Module C2: Chemical Resources

Item C2g: Fertilisers and crop yields

Links to other items: C2e: Manufacturing chemicals: making ammonia, C2f: Acids and bases

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain why fertilisers must be dissolved in water before they can be absorbed by plants. Identify arguments for and against the use of fertilisers: • world population is rising so need to produce more food • eutrophication and pollution of water supplies can result from excessive use of fertilisers.	Explain how the use of fertilisers increases crop yield: • replaces essential elements used by a previous crop or provides extra essential elements • more nitrogen gets incorporated into plant protein so increased growth. Explain the process of eutrophication: • run-off of fertiliser • increase of nitrate or phosphate in river water • algal bloom • blocks off sunlight to other plants which die • aerobic bacteria use up oxygen • most living organisms die.
Predict the name of the acid and the alkali needed to make a named fertiliser for example: • ammonium nitrate.	Describe the preparation of a named synthetic fertiliser by the reaction of an acid and an alkali: • names of reactants • experimental method • how a neutral solution is obtained • how solid fertiliser is obtained.

Module C2: Chemical Resources

Item C2h: Chemicals from the sea: the chemistry of sodium chloride

Summary: The sea is a major source of salt. Producing chemicals from salt on a large scale in the UK has been carried out for hundreds of years. Salt is still an important raw material in the production of bulk chemicals today.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research salt mining.	Recall that sodium chloride (salt) can be obtained from the sea or from salt deposits.
Carry out an experiment to electrolyse sodium chloride solution, test the products hydrogen and chlorine and show, using Universal Indicator, that the solution becomes alkaline.	Recall that the electrolysis of concentrated sodium chloride gives chlorine and hydrogen. Recall that the chemical test for chlorine is that it bleaches moist litmus paper.
Survey the range of products formed from salt.	Recall that sodium chloride is used: • as a preservative • as a flavouring. Understand that sodium chloride is an important raw material in the chemical industry, including use as a source of chlorine and sodium hydroxide. Recall that household bleach, PVC and solvents are made from substances derived from salt. Recall that chlorine is used to sterilise water and to make solvents, household bleach and plastics. Recall that hydrogen is used in the manufacture of margarine. Recall that sodium hydroxide is used to make soap.

Module C2: Chemical Resources

Item C2h: Chemicals from the sea: the chemistry of sodium chloride

Links to other items: C4b: Ionic bonding, C4e: The Group 7 elements, C4h: Purifying and testing water

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe how salt can also be mined as rock salt and by solution mining in Cheshire. Explain how mining for salt can lead to subsidence.	
Recall the products of the electrolysis of concentrated sodium chloride solution (brine): • hydrogen made at the cathode • chlorine made at the anode • sodium hydroxide is also made. Explain why it is important to use inert electrodes in the electrolysis of sodium chloride solution.	Explain how the electrolysis of sodium chloride solution (brine) produces sodium hydroxide, hydrogen and chlorine: • $NaCl(aq)$ contains Na^+, OH^-, Cl^-, H^+ • cathode $2H^+ + 2e^- \rightarrow H_2$ • anode $2Cl^- - 2e^- \rightarrow Cl_2$ • ions not discharged make sodium hydroxide. Explain why the electrolysis of sodium chloride involves both reduction and oxidation.
Describe how sodium hydroxide and chlorine are used to make household bleach.	Explain the economic importance of the chlor-alkali industry.

3.6 Module C3: Chemical Economics

Module C3: Chemical Economics

Item C3: Fundamental Chemical Concepts

Summary: Throughout the study of chemistry in GCSE science there are a number of ideas and concepts that are fundamental. These ideas and concepts have not been put into a particular item but should permeate through all the GCSE Chemistry Modules C1 to C6.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
These learning outcomes are intended to be taught throughout this specification.	Understand that in a chemical reaction reactants are changed into products. Recognise the reactants and products in a word equation. Construct word equations given the reactants and products.
These learning outcomes are intended to be taught throughout this specification.	Recognise the reactants and the products in a symbol equation.
These learning outcomes are intended to be taught throughout this specification.	Deduce the number of elements in a compound given its formula. Deduce the number of atoms in a formula with no brackets. Deduce the number of each different type of atom in a formula with no brackets.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a substance is an element or a compound from its formula. Deduce the names of the different elements in a compound given its formula.
These learning outcomes are intended to be taught throughout this specification.	Understand that a molecule is made up of more than one atom joined together. Understand that a molecular formula shows the numbers and types of atom in a molecule. Deduce the number of atoms in a displayed formula. Deduce the names of the different elements in a compound given its displayed formula. Deduce the number of each different type of atom in a displayed formula.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a particle is an atom, molecule or ion given its formula. Understand that atoms contain smaller particles one of which is a negative electron.
These learning outcomes are intended to be taught throughout this specification.	Recall that two types of chemical bond holding atoms together are: • ionic bonds • covalent bonds.

Module C3: Chemical Economics

Item C3: Fundamental Chemical Concepts

Links to other modules: C1 to C6

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct word equations (not all reactants and products given).	
Construct balanced symbol equations given the formulae (no brackets) of the reactants and products. Explain why a symbol equation is balanced.	Construct balanced symbol equations given the formulae (some or all with brackets) of the reactants and products. Construct balanced symbol equations given the names of the reactants and products (limited to the learning outcomes in C3).
Deduce the number of atoms in a formula with brackets. Deduce the number of each type of different atom in a formula with brackets. Recall the formula of the following substances: • calcium carbonate • carbon dioxide, hydrogen and water. • hydrochloric acid.	Recall the formula of the following substances: • sulfuric acid • calcium chloride, magnesium chloride and magnesium sulfate.
Understand that a displayed formula shows both the atoms and the bonds in a molecule. Write the molecular formula of a compound given its displayed formula.	Construct balanced equations using displayed formulae.
Understand that positive ions are formed when electrons are lost from atoms. Understand that negative ions are formed when electrons are gained by atoms.	
Understand that an ionic bond is the attraction between a positive ion and a negative ion. Understand that a covalent bond is a shared pair of electrons.	Explain how an ionic bond is formed. Explain how a covalent bond is formed.

Module C3: Chemical Economics

Item C3a: Rate of reaction (1)

Summary: Explosions are impressive examples of very fast reactions. This item develops ideas about how the rate of a reaction can be determined through practical work.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Video clips of fires, rusting and explosions to illustrate different rates of reaction.	Recognise that some reactions can be fast and others very slow: • rusting is a slow reaction • burning and explosions are very fast reactions.
Investigate the rate of reaction of magnesium ribbon and dilute hydrochloric acid by measuring reaction time. Investigate the rate of the reaction of sodium thiosulfate and dilute hydrochloric acid by measuring reaction time. Investigate the rate of reaction of magnesium ribbon or calcium carbonate and dilute hydrochloric acid using a gas syringe to collect gas. Investigate the rate of reaction of calcium carbonate and dilute hydrochloric acid using mass loss.	Label the laboratory apparatus needed to measure the rate of reaction producing a gas: • gas syringe • flask. Plot experimental results involving gas volumes or mass loss on a graph. Plot experimental results involving reaction times on a graph. Interpret data in tabular, graphical and written form about the rate of reaction or reaction time for example: • reading off values from a graph • comparing rates of reaction by comparing gradients of graphs • comparing rates of reaction using reaction times.
	Explain why a reaction stops.

Module C3: Chemical Economics

Item C3a: Rate of reaction (1)

Links to other items: C2e: Manufacturing chemicals: making ammonia, C2f: Acids and bases, C3b: Rate of reaction (2), C3c: Rate of reaction (3), C4d: The Group 1 elements, C5e: Gas volumes, C5f: Equilibria, C5g: Strong and weak acids

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that the rate of a reaction measures how much product is formed in a fixed time period. Understand common units for the rate of reaction: • g/s or g/min • cm^3/s or cm^3/min.	
Interpret data in tabular, graphical and written form about the rate of reaction or reaction time for example: • comparing the rate of reaction during a reaction.	Interpret data from tabular, graphical and written form about the rate of reaction or reaction time for example: • calculating the rate of reaction from the slope of an appropriate graph including determining units • extrapolation • interpolation.
Recognise and use the idea that the amount of product formed is directly proportional to the amount of limiting reactant used. Recall that the limiting reactant is the reactant not in excess that is all used up at the end of the reaction.	Explain, in terms of reacting particles, why the amount of product formed is directly proportional to the amount of limiting reactant used.

Module C3: Chemical Economics

Item C3b: Rate of reaction (2)

Summary: This item develops the ideas of rate of reaction including the collision theory model. The effect of changing temperature, concentration and pressure on the rate of reaction are considered by means of practical work.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
ICT simulations involving collisions between particles.	Recognise that chemical reactions take place when particles collide.
Investigate the rate of reaction using magnesium ribbon or calcium carbonate and different temperatures of dilute hydrochloric acid.	Describe the effect of changing temperature on the rate of a chemical reaction.
Investigate the rate of reaction using magnesium ribbon or calcium carbonate and with different concentrations of hydrochloric acid. Investigate the rate of reaction of sodium thiosulfate with dilute hydrochloric acid (disappearing cross experiment).	Describe the effect of changing the concentration on the rate of a chemical reaction.
Look at the application of rate of reaction in everyday life (e.g. speed of cooking with pressure cooker, the rusting of metals, rate of dissolving tablets for medicinal use).	Describe the effect of changing the pressure on the rate of a chemical reaction of gases.
Investigate the rate of reaction using magnesium ribbon or calcium carbonate and dilute hydrochloric acid using a gas syringe to collect gas.	Interpret data in tabular, graphical and written form about the effect of temperature, concentration and pressure on the rate of reaction for example: • reading off values from a graph • comparing rates of reaction by comparing gradients of graphs • comparing rates of reaction using reaction times.

Module C3: Chemical Economics

Item C3b: Rate of reaction (2)

Links to other items: C2e: Manufacturing chemicals: making ammonia, C2f: Acids and bases, C3a: Rate of reaction (1), C3c: Rate of reaction (3), C4d: The Group 1 elements, C5e: Gas volumes, C5f: Equilibria, C5g: Strong and weak acids

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that the rate of reaction depends on the number of collisions between reacting particles.	Understand that the rate of reaction depends on the: • collision frequency of reacting particles • energy transferred during the collision (whether the collision is successful or effective).
Explain, in terms of the reacting particle model, why changes in temperature change the rate of reaction.	Explain, using the reacting particle model, why changes in temperature change the rate of reaction in terms of successful collisions between particles.
Explain, in terms of the reacting particle model, why changes in concentration change the rate of reaction.	Explain, using the reacting particle model, why changes in concentration change the rate of reaction in terms of successful collisions between particles.
Explain, in terms of the reacting particle model, why changes in pressure change the rate of reaction.	Explain, using the reacting particle model, why changes in pressure change the rate of reaction in terms of successful collisions between particles.
Interpret data in tabular, graphical and written form about the effect of temperature and concentration on the rate of reaction for example: • deciding when a reaction has finished • comparing the rate of reaction during a reaction. Draw sketch graphs to show the effect of changing temperature, concentration or pressure on: • rate of reaction • amount of product formed in a reaction.	Interpret data from tabular, graphical and written form about the effect of temperature and concentration on the rate of reaction for example: • calculating the rate of reaction from the slope of an appropriate graph • extrapolation • interpolation.

Module C3: Chemical Economics

Item C3c: Rate of reaction (3)

Summary: Explosions are impressive examples of very fast reactions. This item develops the ideas of rate of reaction including collision frequency. The effect of changing surface area and catalysts on the rate of reaction are considered by means of practical work.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Class practical to investigate catalysis using hydrogen peroxide and metal oxide catalysts or zinc and dilute hydrochloric acid with a variety of possible catalysts including copper and copper compounds.	Recall that the rate of a reaction can be increased by the addition of a catalyst.
Investigate surface area using magnesium powder and ribbon with acid, or marble chips and powder with acid.	Recall that the rate of a reaction can be increased by using powdered reactant rather than a lump (or vice versa).
Watch a video on flour/lycopodium explosions. Video clips of other explosions e.g. knocking down a building, explosion in a quarry. Demonstrate explosive reactions (cornflour or custard powder).	Describe an explosion as a very fast reaction which releases a large volume of gaseous products.
Look at the application of rate of reaction in everyday life (e.g. resin and hardener in car body filler, catalytic converters).	Interpret data in tabular, graphical and written form about the effect of surface area and the addition of a catalyst on the rate of reaction, for example: • reading off values from a graph • comparing rates of reaction by comparing gradients of graphs • comparing rates of reaction using reaction times.

Module C3: Chemical Economics

Item C3c: Rate of reaction (3)

Links to other items: C2e: Manufacturing chemicals: making ammonia, C2f: Acids and bases, C3a: Rate of reaction (1), C3b: Rate of reaction (2), C4d: The Group 1 elements, C5e: Gas volumes, C5f: Equilibria, C5g: Strong and weak acids

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe a catalyst as a substance which changes the rate of reaction and is unchanged at the end of the reaction. Understand why only a small amount of a catalyst is needed to catalyse large amounts of reactants and that a catalyst is specific to a particular reaction.	
Explain, in terms of reacting particles and surface area, the difference in rate of reaction between a lump and powdered reactant.	Explain, in terms of collisions between reacting particles, the difference in rate of reaction between a lump and powdered reactant.
Explain the dangers of fine combustible powders in factories (e.g. custard powder, flour or sulfur).	
Interpret data in tabular, graphical and written form about the effect of surface area and the addition of a catalyst on the rate of reaction: • deciding when a reaction has finished • comparing the rate of reaction during a reaction. Draw sketch graphs to show the effect of changing surface area and the addition of a catalyst on the: • rate of reaction • amount of product formed in a reaction.	Interpret data from tabular, graphical and written form about the effect of surface area and the addition of a catalyst on the rate of reaction: • calculating the rate of reaction from the slope of an appropriate graph • extrapolation • interpolation.

Module C3: Chemical Economics

Item C3d: Reacting masses

Summary: Quantitative aspects of chemistry involving relative atomic mass are introduced. Relative atomic masses are used to calculate relative formula masses. Balanced symbol equations are used quantitatively to calculate reacting masses and to predict the mass of product that should be formed in a reaction.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Looking at the periodic table to find relative atomic masses. Relative formula mass (M_r) calculations.	Calculate the relative formula mass of a substance from its formula (no brackets) given the appropriate relative atomic masses.
Class experiment to confirm the principle of conservation of mass using precipitation reactions such as sodium hydroxide solution with copper(II) sulfate solution.	Understand that the total mass of reactants at the start of a reaction is equal to the total mass of products made and that this is called the principle of conservation of mass. Use the principle of conservation of mass to calculate mass of reactant or product for example: • mass of gaseous product formed during decomposition • mass of oxygen that reacts with a known mass of magnesium to make magnesium oxide.
Class experiment to find out the relationship between mass of malachite and mass of copper oxide that can be obtained from it – opportunity to use spreadsheets for analysis of results.	Use simple ratios to calculate reacting masses and product masses given the mass of a reactant and a product.

Module C3: Chemical Economics

Item C3d: Reacting masses

Links to other items: C3e: Percentage yield and atom economy, C5a: Moles and molar mass, C5b: Percentage composition and empirical formula

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Calculate the relative formula mass of a substance from its formula (with brackets) given appropriate relative atomic masses.	
Use provided relative formula masses and a symbol equation (1:1 molar ratio) to show that mass is conserved during a reaction. Explain why mass is conserved in chemical reactions.	Use relative formula masses and a provided symbol equation to show that mass is conserved during a reaction.
Recognise and use the idea that the mass of product formed is directly proportional to the mass of limiting reactant used.	Interpret chemical equations quantitatively. Calculate masses of products or reactants from balanced symbol equations using relative formula masses.

Module C3: Chemical Economics

Item C3e: Percentage yield and atom economy

Summary: Percentage yield and atom economy are two important concepts that help the chemical industry make their processes more sustainable and green. This item shows how to calculate these two quantities and shows their importance to the chemical industry.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Preparation of ammonium sulfate or other salts.	Understand percentage yield as a way of comparing amount of product made (actual yield) to amount expected (predicted yield): • 100% yield means that no product has been lost • 0% yield means that no product has been made. Recognise possible reasons (given experimental details) why the percentage yield of a product is less than 100% for example: • loss in filtration • loss in evaporation • loss in transferring liquids • not all reactants react to make product.
Class practical involving the preparation of magnesium sulfate from a variety of starting materials (magnesium, magnesium oxide, magnesium hydroxide or magnesium carbonate) – comparison of percentage yield and atom economy.	Understand atom economy as a way of measuring the amount of atoms that are wasted when manufacturing a chemical: • 100% atom economy means that all atoms in the reactant have been converted to the desired product • the higher the atom economy the 'greener' the process.
	Interpretation of simple percentage yield and atom economy data.

Module C3: Chemical Economics

Item C3e: Percentage yield and atom economy

Links to other items: C3d: Reacting masses, C5b: Percentage composition and empirical formula

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall and use the formula: $$\text{percentage yield} = \frac{\text{actual yield}}{\text{predicted yield}} \times 100$$	Explain why an industrial process wants as high a percentage yield as possible, to include: • reducing the reactants wasted • reducing cost.
Recall and use the formula: $$\text{atom economy} = \frac{M_r \text{ of desired products}}{\text{sum of } M_r \text{ of all products}} \times 100$$ Calculate atom economy when given balanced symbol equation (1:1 molar ratio) and appropriate relative formula masses.	Calculate atom economy when given balanced symbol equation and appropriate relative formula masses. Explain why an industrial process wants as high an atom economy as possible: • to reduce the production of unwanted products • to make the process more sustainable.
Interpretation of complex percentage yield and atom economy data.	

Module C3: Chemical Economics

Item C3f: Energy

Summary: This item develops ideas about how the amount of energy released during chemical reactions such as combustion can be measured. Ideas about bond forming and bond breaking are used to explain why reactions are exothermic or endothermic.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Carry out experiments to find out about exothermic and endothermic reactions (with the option of using data loggers).	Recall that an exothermic reaction is one in which energy is transferred into the surroundings (releases energy). Recall that an endothermic reaction is one in which energy is taken from the surroundings (absorbs energy). Recognise exothermic and endothermic reactions using temperature changes.
Compare the energy output from a blue and from a yellow Bunsen flame. Measure the energy released per gram during the combustion of butane and the combustion of some liquid fuels – possible use of spreadsheets to analyse results.	Describe, using a diagram, a simple calorimetric method for comparing the energy transferred in combustion reactions: • use of spirit burner or a bottled gas burner • heating water in a copper calorimeter • measuring the temperature change • fair tests. Interpret and use data from simple calorimetric experiments related to the combustion of fuels to compare which fuel releases the most energy.

Module C3: Chemical Economics

Item C3f: Energy

Links to other items: C1a: Making crude oil useful, C1b: Using carbon fuels, C6b: Energy transfers – fuel cells

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall bond making as an exothermic process and bond breaking as an endothermic process.	Explain why a reaction is exothermic or endothermic using the energy changes that occur during bond breaking and bond making.
Describe a simple calorimetric method for comparing the energy transferred per gram of fuel combusted: • use of spirit burner or a bottled gas burner • heating water in a copper calorimeter • measuring mass of fuel burnt • measuring temperature change • fair and valid tests. Calculate the energy transferred by using the formula (no recall needed): • energy transferred (in J) = m × c × ΔT • where m = mass of water heated • c = specific heat capacity (4.2 J/g °C) • ΔT = temperature change.	Use the formula energy transferred (in J) = m × c × ΔT to calculate: • m = mass of water heated • ΔT = temperature change. Calculate the energy output of a fuel in J/g by recalling and using the formula: $\text{energy per gram} = \dfrac{\text{energy released (in J)}}{\text{mass of fuel burnt (in g)}}$

Module C3: Chemical Economics

Item C3g: Batch or continuous?

Summary: Speciality chemicals such as pharmaceutical drugs are widely used in our society. This item looks at how speciality chemicals are developed, tested and marketed. It also describes the differences between batch manufacture used for speciality chemicals and continuous manufacture used for making substances such as ammonia.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Industrial case studies. See www.atworkwithscience.com.	Describe the differences between a batch and a continuous process.
Industrial case studies.	List the factors that affect the cost of making and developing a pharmaceutical drug: • research and testing • labour costs • energy costs • raw materials • time taken for development • marketing. Explain why pharmaceutical drugs need to be thoroughly tested before they can be licensed for use.
Practical extraction of a natural oil from a plant. Research plants and animals used as sources of drugs.	Recall that the raw materials for speciality chemicals such as pharmaceuticals can be either made synthetically or extracted from plants.
	Explain why it is important to manufacture pharmaceutical drugs to be as pure as possible. Describe how melting point, boiling point and thin layer chromatography can be used to establish the purity of a compound.

Module C3: Chemical Economics

Item C3g: Batch or continuous?

Links to other items: C2e: Manufacturing chemicals: making ammonia, C6d: Alcohols

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain why batch processes are often used for the production of pharmaceutical drugs but continuous processes are used to produce chemicals such as ammonia.	Evaluate the advantages and disadvantages of batch and continuous manufacturing processes given relevant data and information.
Explain why it is often expensive to make and develop new pharmaceutical drugs.	Explain why it is difficult to test and develop new pharmaceutical drugs that are safe to use.
Describe how chemicals are extracted from plant sources: • crushing • boiling and dissolving in suitable solvent • chromatography.	
Interpret melting point, boiling point and chromatographic data relating to the purity of a substance.	

Module C3: Chemical Economics

Item C3h: Allotropes of carbon and nanochemistry

Summary: Electronic devices are becoming smaller each year due to the introduction of nanotechnology. Nanotubes can be made from Fullerenes which are allotropes of carbon. This item describes the structure, properties and uses of three allotropes of carbon and some of the new applications of nanotubes.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Examine and compare the structures of diamond, graphite and Buckminster fullerene. Research the discovery of Buckminster fullerene.	Explain why diamond, graphite and Buckminster fullerene are all forms of carbon. Recognise the structures of diamond, graphite and Buckminster fullerene.
	List the physical properties of diamond: • lustrous, colourless and clear (transparent) • hard and has a high melting point • insoluble in water • does not conduct electricity.
Examine samples of graphite.	List the physical properties of graphite: • black, lustrous and opaque • slippery • insoluble in water • conducts electricity.
Build models of fullerenes and nanotubes. (RSC – contemporary chemistry for schools and colleges has useful worksheets etc). Survey of uses of fullerenes (via internet).	Recall that nanotubes are used to reinforce graphite in tennis rackets because nanotubes are very strong. Recall that nanotubes are used as semiconductors in electrical circuits.

Module C3: Chemical Economics

Item C3h: Allotropes of carbon and nanochemistry

Links to other items: C4c: The Periodic Table and covalent bonding

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain why diamond, graphite and fullerenes are allotropes of carbon.	
Explain, in terms of properties, why diamond is used in cutting tools and jewellery.	Explain, in terms of structure and bonding, why diamond: • does not conduct electricity • is hard and has a high melting point.
Explain, in terms of properties, why graphite is used: • in pencil leads • in lubricants.	Explain, in terms of structure and bonding, why graphite: • conducts electricity • is slippery • has a high melting point.
Explain why diamond and graphite have a giant molecular structure.	Predict and explain the properties of substances that have a giant molecular structure.
Explain why fullerenes can be used in new drug delivery systems.	Explain how the structure of nanotubes enables them to be used as catalysts.

3.7 Module C4: The Periodic Table

Module C4: The Periodic Table

Item C4: Fundamental Chemical Concepts

Summary: Throughout the study of chemistry in GCSE science there are a number of ideas and concepts that are fundamental. These ideas and concepts have not been put into a particular item but should permeate through all the GCSE Chemistry Modules C1 to C6.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
These learning outcomes are intended to be taught throughout this specification.	Understand that in a chemical reaction reactants are changed into products. Recognise the reactants and products in a word equation. Construct word equations given the reactants and products.
These learning outcomes are intended to be taught throughout this specification.	Recognise the reactants and the products in a symbol equation.
These learning outcomes are intended to be taught throughout this specification.	Deduce the number of elements in a compound given its formula. Deduce the number of atoms in a formula with no brackets. Deduce the number of each different type of atom in a formula with no brackets.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a substance is an element or a compound from its formula. Deduce the names of the different elements in a compound given its formula.
These learning outcomes are intended to be taught throughout this specification.	Understand that a molecule is made up of more than one atom joined together. Understand that a molecular formula shows the numbers and types of atom in a molecule. Deduce the number of atoms in a displayed formula. Deduce the names of the different elements in a compound given its displayed formula. Deduce the number of each different type of atom in a displayed formula.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a particle is an atom, molecule or ion given its formula. Understand that atoms contain smaller particles one of which is a negative electron.
These learning outcomes are intended to be taught throughout this specification.	Recall that two types of chemical bond holding atoms together are: • ionic bonds • covalent bonds.

Module C4: The Periodic Table

Item C4: Fundamental Chemical Concepts

Links to other modules: C1 to C6

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct word equations (not all reactants and products given).	
Construct balanced symbol equations given the formulae (no brackets) of the reactants and products. Explain why a symbol equation is balanced.	Construct balanced symbol equations given the formulae (some or all with brackets) of the reactants and products. Construct balanced symbol equations given the names of the reactants and products (limited to the learning outcomes in C4).
Deduce the number of atoms in a formula with brackets. Deduce the number of each type of different atom in a formula with brackets. Recall the formula of the following substances: • sodium chloride and potassium chloride • chlorine, bromine and iodine • water, carbon dioxide and hydrogen.	Recall the formula of the following substances: • the oxides of sodium, magnesium, zinc, copper(II), iron(II) and manganese • magnesium chloride and barium chloride • the carbonates of copper(II), iron(II), zinc and manganese • the hydroxides of sodium, potassium, lithium, copper(II), iron(II) and iron(III) • silver nitrate.
Understand that a displayed formula shows both the atoms and the bonds in a molecule. Write the molecular formula of a compound given its displayed formula.	Construct balanced equations using displayed formulae.
Understand that positive ions are formed when electrons are lost from atoms. Understand that negative ions are formed when electrons are gained by atoms.	
Understand that an ionic bond is the attraction between a positive ion and a negative ion. Understand that a covalent bond is a shared pair of electrons.	Explain how an ionic bond is formed. Explain how a covalent bond is formed.

Module C4: The Periodic Table

Item C4a: Atomic structure

Summary: Atomic structure is fundamental to the study of chemistry. This item considers the sub-atomic particles and electronic structures. This item provides the opportunity to develop and use scientific theories, models and ideas. The item also includes how a scientific theory has developed.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research the models developed for the structure of an atom.	Recall that an atom has a nucleus surrounded by electrons. Recall that a nucleus is positively charged, an electron is negatively charged and an atom is neutral. Understand that atoms have a very small mass and a very small size.
Deduce the numbers of protons, electrons and neutrons from atomic numbers and mass numbers.	Identify the atomic number of an element or vice versa by using a Periodic Table. Recall that atomic number is the number of protons in an atom. Recall that mass number is the total number of protons and neutrons in an atom.
Identify elements and numbers of atoms of each element from formulae.	Explain why a substance is an element or a compound given its formula.
Draw electronic structures given atomic numbers.	Deduce the number of occupied shells or the number of electrons from the electronic structure of an element.
Research or produce a poster of the work of Dalton, J.J. Thomson, Rutherford and/or Bohr. Produce a timeline of events for the development of the theory of atomic structure.	Describe the main stages in the development of atomic structure illustrating the provisional nature of evidence: • Dalton's atomic theory (detail not required) • J.J. Thomson (discovery of the electron) • Rutherford (nuclear atom) • Bohr (electron orbits).

Module C4: The Periodic Table

Item C4a: Atomic structure

Links to other items: C4b: Ionic bonding, C4c: The Periodic Table and covalent bonding

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that the nucleus is made up of protons and neutrons. Recall the relative charge and relative mass of an electron, a proton and a neutron: • electron charge –1 and mass 0.0005 (zero) • proton charge +1 and mass 1 • neutron charge 0 and mass 1.	Explain why an atom is neutral in terms of its sub-atomic particles. Understand that atoms have a radius of about 10^{-10}m and a mass of about 10^{-23}g.
Describe isotopes as varieties of an element that have the same atomic number but different mass numbers. Deduce the number of protons, electrons and neutrons in a particle given its atomic number and mass number: • using data in a table • using the conventional symbolism e.g. carbon-12 or ${}^{12}_{6}C$.	Deduce the number of protons, electrons and neutrons in a charged particle given its atomic number, mass number and the charge on the particle: • using data in a table • using the conventional symbolism e.g. carbon-12 or ${}^{12}_{6}C$. Identify isotopes from data about the number of electrons, protons and neutrons in particles.
Describe the arrangement of elements in the Periodic Table.	
Explain how the identity of an element can be deduced from its electronic structure.	Deduce the electronic structure of the first 20 elements in the periodic table e.g. calcium is 2.8.8.2.
Describe Dalton's atomic theory and how the work of J.J. Thomson, Rutherford and Bohr contributed to the development of the theory of atomic structure: • the theory changed as new evidence was found • science explanations are provisional but more convincing when predictions are later confirmed.	Explain the significance of the work of Dalton, J.J. Thomson, Rutherford and Bohr in the development of the theory of atomic structure: • unexpected results (e.g. Geiger and Marsden's experiment) led to the theory of a nuclear atom.

Module C4: The Periodic Table

Item C4b: Ionic bonding

Summary: This item extends the ideas about atomic structure into ionic bonding and the properties of ionic compounds. The experimental investigation of solubility and electrical conductivity allows the opportunity to collect primary data safely and accurately, and to analyse it using quantitative and qualitative methods.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Draw “dot and cross” diagrams to model ionic bonding.	Recall that an ion is a charged atom or group of atoms. Recognise an ion, an atom and a molecule from given formulae.
Research melting points and boiling points of sodium chloride and magnesium oxide. Experimental investigation of solubility and electrical conductivity of solids and solutions.	Compare the electrical conductivity of sodium chloride in solid, molten liquid and solution. Compare the melting points of sodium chloride and magnesium oxide.

Module C4: The Periodic Table

Item C4b: Ionic bonding

Links to other items: C2h: Chemicals from the sea: the chemistry of sodium chloride, C4a: Atomic structure, C4d: The Group 1 elements, C4e: The Group 7 elements, C4f: Transition elements

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that atoms with an outer shell of 8 electrons have a stable electronic structure. Explain how and why metal atoms form positive ions. Explain how and why non-metal atoms form negative ions. Understand that, in ionic bonding, a metal and non-metal combine by transferring electrons to form positive ions and negative ions which then attract one another. Deduce the formula of an ionic compound from the formula of the positive and negative ions.	Explain, using the “dot and cross” model, the ionic bonding in simple binary compounds.
Recall that sodium chloride solution conducts electricity. Recall that magnesium oxide and sodium chloride conduct electricity when molten. Describe the structure of sodium chloride or magnesium oxide as a giant ionic lattice in which positive ions are strongly attracted to negative ions.	Explain, in terms of structure and bonding, some of the physical properties of sodium chloride: • high melting points • electrical conductivity of solid, molten liquid and solution. Explain, in terms of structure and bonding, why the melting point of sodium chloride is lower than that of magnesium oxide. Predict and explain the properties of substances that have a giant ionic structure.

Module C4: The Periodic Table

Item C4c: The Periodic Table and covalent bonding

Summary: This item introduces covalent bonding. It also provides an introduction to the Periodic Table. This item provides the opportunity to develop and use scientific theories, models and ideas.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Draw electronic structures of covalent molecules. Construct molecular models of covalent compounds.	Recall that there are two types of bonding: • ionic bonding between metals and non-metals • covalent bonding between non-metals.
Research melting point, boiling point and electrical conductivity of carbon dioxide and water.	Recall that carbon dioxide and water do not conduct electricity.
Quiz to identify different elements, symbols, groups, periods etc.	Deduce, using a Periodic Table, elements that are in the same group. Describe a group of elements as all the elements in a vertical column of the Periodic Table and that the elements have similar chemical properties.
Quiz to identify different elements, symbols, groups, periods etc.	Deduce, using a periodic table, elements that are in the same period. Describe a period of elements as all the elements in a horizontal row of the Periodic Table.
Research or produce a poster of the work of Dobereiner, Newlands and/or Mendeleev. Produce a timeline of events for the development of the Periodic Table and its later confirmation.	Describe the main stages in the development of the classification of elements: • Dobereiner • Newlands • Mendeleev. Understand that classification of elements was provisional, based on evidence gathered at the time.

Module C4: The Periodic Table

Item C4c: The Periodic Table and covalent bonding

Links to other items: C3h: Allotropes of carbon and nanochemistry, C4a: Atomic structure

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that non-metals combine together by sharing electron pairs and this is called covalent bonding.	Explain, using the “dot and cross” model, the covalent bonding in simple binary compounds or molecules containing single and double covalent bonds.
Describe carbon dioxide and water as simple molecules with weak intermolecular forces between molecules.	Explain, in terms of structure and bonding, some of the physical properties of carbon dioxide and water: • low melting points • do not conduct electricity. Predict and explain the properties of substances that have a simple molecular structure.
Recognise that the group number is the same as the number of electrons in the outer shell. Deduce the group to which an element belongs from its electronic structure (limited to the s and p blocks).	
Recognise that the period to which the element belongs corresponds to the number of occupied shells in the electronic structure. Deduce the period to which the element belongs from its electronic structure.	
Describe the evidence or observations that caused Newlands and Mendeleev to develop new models of periodic classification of elements.	Explain how further evidence confirmed Mendeleev’s ideas about the Periodic Table: • confirmation of his predictions about unknown elements • how investigations on atomic structure (mass number and electronic structure) agreed with his ideas.

Module C4: The Periodic Table

Item C4d: The Group 1 elements

Summary: This item studies the properties of the Group 1 elements. The item links the similarity of their properties to the position of the elements in the Periodic Table.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research properties of alkali metals e.g. using the internet. Demonstrate reactions of sodium, lithium and potassium with water. Show video of reactions of rubidium and caesium with water.	Explain why the Group 1 elements are known as the alkali metals. Explain why Group 1 elements are stored under oil. Describe the reaction of lithium, sodium and potassium with water: • hydrogen is formed • an alkali is formed which is the hydroxide of the metal • the reactivity with water increases down Group 1 • potassium gives a lilac flame. Construct the word equation for the reaction of a Group 1 element with water.
	Recognise sodium, lithium and potassium as Group 1 elements.
Candidates carry out flame tests on alkali metal chlorides.	Recall the flame test colours for lithium, sodium and potassium compounds. Interpret information about flame tests e.g. deduce the alkali metal present from flame colours.

Module C4: The Periodic Table

Item C4d: The Group 1 elements

Links to other items: C3a: Rate of reaction (1), C3b: Rate of reaction (2), C3c: Rate of reaction (3), C4b: Ionic bonding, C4e: The Group 7 elements, C6c: Redox reactions

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Predict the properties of Group 1 elements rubidium and/or caesium with water. Construct the balanced symbol equation for the reaction of a Group 1 element with water (given all or some formulae) e.g.: $2Na + 2H_2O \rightarrow 2NaOH + H_2$	Construct the balanced symbol equation for the reaction of a Group 1 element with water (formulae not given) e.g.: $2Na + 2H_2O \rightarrow 2NaOH + H_2$ Predict the physical properties of rubidium and/or caesium given information about the other Group 1 elements.
Explain why Group 1 elements have similar properties.	Explain why Group 1 elements have similar properties, in terms of forming positive ions with stable electronic structures. Construct a balanced symbol equation to show the formation of an ion of a Group 1 element from its atom. Explain, in terms of electron loss, the trend in reactivity of the Group 1 elements with water. Recall the loss of electrons as oxidation. Explain why a process is oxidation from its ionic equation.
Describe how to use a flame test to identify the presence of lithium, sodium and potassium compounds: • use of moistened flame test wire • flame test wire dipped into solid sample • flame test wire put into blue Bunsen flame • colours of the flames.	

Module C4: The Periodic Table

Item C4e: The Group 7 elements

Summary: This item studies the properties of the Group 7 elements. The item links the similarity of their properties to the position of the elements in the Periodic Table. Researching the properties of the halogens allows the use of ICT as a teaching and learning tool.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research the physical properties and uses of the halogens.	Recall that the Group 7 elements are known as the halogens. Recognise fluorine, chlorine, bromine and iodine as Group 7 elements. Describe the uses of some Group 7 elements: • chlorine is used to sterilise water • chlorine is used to make pesticides and plastics • iodine is used to sterilise wounds.
Demonstrate or show video of reaction of sodium with chlorine. Also see RSC website: www.practicalchemistry.org.	Recognise that Group 7 elements react vigorously with Group 1 elements. Construct the word equation for the reaction between a Group 1 element and a Group 7 element (product given).
Investigation of displacement reactions of the halogens (good opportunity for predicting/ hypothesising).	Recall that the reactivity of the Group 7 elements decreases down the group. Construct the word equation for the reaction between a Group 7 element and a metal halide (reactants and products given).

Module C4: The Periodic Table

Item C4e: The Group 7 elements

Links to other items: C2h: Chemicals from the sea: the chemistry of sodium chloride, C4b: Ionic bonding, C4d: The Group 1 elements, C4h: Purifying and testing water, C5h: Ionic equations and precipitation, C6c: Redox reactions, C6e: Depletion of the ozone layer

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe the physical appearance of the Group 7 elements at room temperature: • chlorine is a green gas • bromine is an orange liquid • iodine is a grey solid.	Predict the properties of fluorine or astatine given the properties of the other Group 7 elements e.g.: • physical properties • melting point • boiling point • displacement reactions.
Identify the metal halide formed when a Group 1 element reacts with a Group 7 element. Construct the word equation for the reaction between a Group 1 element and a Group 7 element (product not given). Construct the balanced symbol equation for the reaction of a Group 1 element with a Group 7 element (some or all formulae given).	Construct the balanced symbol equation for the reaction of a Group 1 element with a Group 7 element (formulae not given).
Describe the displacement reactions of Group 7 elements with solutions of metal halides: • chlorine displaces bromides and iodides • bromine displaces iodides. Construct the word equation for the reaction between a Group 7 element and a metal halide (not all reactants and products given). Construct balanced symbol equations for the reactions between Group 7 elements and metal halides (some or all formulae given).	Construct balanced symbol equations for the reactions between Group 7 elements and metal halides (formulae not given). Predict the feasibility of displacement reactions e.g. will bromine react with sodium astitide solution.
Explain why Group 7 elements have similar properties.	Explain why Group 7 elements have similar properties, in terms of forming negative ions with stable electronic structures. Construct an equation to show the formation of a halide ion from a halogen molecule. Explain, in terms of electron gain, the trend in reactivity of the Group 7 elements. Recall the gain of electrons as reduction. Explain why a process is reduction from its ionic equation.

Module C4: The Periodic Table

Item C4f: Transition elements

Summary: This item covers some properties and chemistry of the transition elements and introduces thermal decomposition and precipitation. The experiments on thermal decomposition allow opportunities to collect and analyse science data, working as an individual or in a group, to analyse results and present the information using scientific conventions and symbols.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Show a large number of transition elements and ask pupils to deduce or research their properties.	Identify whether an element is a transition element from its position in the Periodic Table. Recognise that all transition elements are metals and have typical metallic properties. Deduce the name or symbol of a transition element using the Periodic Table. Recall that copper and iron are transition elements.
Investigation of thermal decomposition of transition metal carbonates including test for carbon dioxide.	Describe thermal decomposition as a reaction in which a substance is broken down into at least two other substances by heat. Construct word equations for thermal decomposition reactions (all reactants and products given). Recall that the test for carbon dioxide is that it turns limewater milky.
Investigation of precipitation reactions of transition metal ions with sodium hydroxide.	Describe precipitation as a reaction between solutions that makes an insoluble solid.

Module C4: The Periodic Table

Item C4f: Transition elements

Links to other items: C2c: Metals and alloys, C4b: Ionic bonding, C4g: Metal structure and properties, C5h: Ionic equations and precipitation, C6c: Redox reactions

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that compounds of transition elements are often coloured: • copper compounds are often blue • iron(II) compounds are often light green • iron(III) compounds are often orange/brown. Recall that transition elements and their compounds are often used as catalysts: • iron in the Haber process • nickel in the manufacture of margarine.	
Describe the thermal decomposition of carbonates of transition elements including $FeCO_3$, $CuCO_3$, $MnCO_3$ and $ZnCO_3$: • metal oxide and carbon dioxide formed • word equations (not all products given) • colour change occurs (colours not needed).	Construct the balanced symbol equations for the thermal decomposition of: • $FeCO_3$ • $CuCO_3$ • $MnCO_3$ • $ZnCO_3$
Describe the use of sodium hydroxide solution to identify the presence of transition metal ions in solution: • Cu^{2+} gives a blue solid • Fe^{2+} gives a grey/green solid • Fe^{3+} gives an orange/brown solid • the solids are called precipitates.	Construct balanced symbol equations for the reactions between Cu^{2+}, Fe^{2+} and Fe^{3+} with OH^- (without state symbols) given the formulae of the ions.

Module C4: The Periodic Table

Item C4g: Metal structure and properties

Summary: Metals are a very important class of materials. This item relates the properties of metals to their structure. The item also includes information on superconductors. The research and data interpretation activities allow the analysing and interpretation of scientific information and the collection of secondary data using ICT.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research uses of some metals and relate to properties – a poster could be produced.	Explain why iron is used to make cars and bridges. Explain why copper is used to make electrical wiring.
Data search or experimental comparison of different metal properties. Data interpretation activity.	List the physical properties of metals: • lustrous, hard and high density • high tensile strength • high melting and boiling points • good conductors of heat and electricity. Interpret data about the properties of metals e.g. hardness, density and electrical conductivity. Explain why metals are suited to a given use (data will be provided). Suggest properties needed by a metal for a particular given use e.g. saucepan bases need to be good conductors of heat.
	Recognise that the particles in a metal are held together by metallic bonds.
Internet research into superconductors. Displacement reactions to show metal crystals e.g. copper in aqueous silver nitrate. Produce a poster on superconductors. Bubble raft demonstration.	Recall that at low temperatures some metals can be superconductors.

Module C4: The Periodic Table

Item C4g: Metal structure and properties

Links to other items: C2c: Metals and alloys, C2d: Making cars, C4f: Transition elements

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain why metals are suited to a given use (data will be provided).	
Understand that metals have high melting points and boiling points due to strong metallic bonds. Describe how metals conduct electricity.	Describe metallic bonding as the strong attraction between a sea of delocalised electrons and close packed positive metal ions. Explain, in terms of structure, why metals have: • high melting points and boiling points • conduct electricity.
Describe what is meant by the term superconductor. Describe the potential benefits of superconductors: • loss free power transmission • super-fast electronic circuits • powerful electromagnets.	Explain some of the drawbacks of superconductors.

Module C4: The Periodic Table

Item C4h: Purifying and testing water

Summary: Young people see many examples of famine and disaster in the world. Often a lack of pure water is associated with the disaster. This item develops ideas about the importance of clean water both in the United Kingdom and in the developing nations of the world. The purification of water is considered as well as simple ways to test for dissolved substances in water.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Use text-books, video and/or internet and information from local water companies to find out about the water resources in the United Kingdom and the need to conserve water.	Interpret simple data about water resources in the United Kingdom (no recall is expected). Recall different types of water resources found in the United Kingdom: • lakes • rivers • aquifers • reservoirs. Explain why water is an important resource for many important industrial chemical processes.
Research the pollutants found in water.	List some of the pollutants that may be found in domestic water supplies: • nitrate residues • lead compounds • pesticide residues.
Visit a water purification plant. Design a poster to describe the purification of domestic water.	List the types of substances present in water before it is purified: • dissolved salts and minerals • microbes • pollutants • insoluble materials. Recall that chlorination kills microbes in water.
Investigate the solution chemistry of some dissolved ions. Preparation of an insoluble salt e.g. barium sulfate, by precipitation, filtration, washing and drying.	Recall that barium chloride solution is used to test for sulfate ions: • gives a white precipitate. Recall that silver nitrate solution is used to test for halide ions: • chloride ions give a white precipitate • bromide ions give a cream precipitate • iodide ions give a pale yellow precipitate. Construct word equations for the reactions of barium chloride with sulfates and silver nitrate with halides (all reactants and products given).

Module C4: The Periodic Table

Item C4h: Purifying and testing water

Links to other items: C2h: Chemicals from the sea: the chemistry of sodium chloride, C4e: The Group 7 elements, C5h: Ionic equations and precipitation, C6f: Hardness of water

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Interpret data about water resources in the United Kingdom (no recall is expected). Explain why it is important to conserve water.	
Explain why drinking water may contain some of the pollutants listed below: • nitrate • lead compounds • pesticide.	
Describe the water purification process to include filtration, sedimentation and chlorination.	Explain why some soluble substances are not removed from water during purification. Explain the disadvantages of using distillation of sea water to make large quantities of fresh water.
Interpret data about the testing of water with aqueous silver nitrate and barium chloride solutions. Construct word equations for the reactions of barium chloride with sulfates and silver nitrate with halides (not all reactants and products given). Understand that the reactions of barium chloride with sulfates and silver nitrate with halides are examples of precipitation reactions.	Construct balanced symbol equations for the reactions of barium chloride with sulfates and silver nitrate with halides given the appropriate formulae.

3.8 Module C5: How Much? (Quantitative Analysis)

Module C5: How Much? (Quantitative Analysis)

Item C5: Fundamental Chemical Concepts

Summary: Throughout the study of chemistry in GCSE science there are a number of ideas and concepts that are fundamental. These ideas and concepts have not been put into a particular item but should permeate through all the GCSE Chemistry Modules C1 to C6.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
These learning outcomes are intended to be taught throughout this specification.	Understand that in a chemical reaction reactants are changed into products. Recognise the reactants and products in a word equation. Construct word equations given the reactants and products.
These learning outcomes are intended to be taught throughout this specification.	Recognise the reactants and the products in a symbol equation.
These learning outcomes are intended to be taught throughout this specification.	Deduce the number of elements in a compound given its formula. Deduce the number of atoms in a formula with no brackets. Deduce the number of each different type of atom in a formula with no brackets.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a substance is an element or a compound from its formula. Deduce the names of the different elements in a compound given its formula.
These learning outcomes are intended to be taught throughout this specification.	Understand that a molecule is made up of more than one atom joined together. Understand that a molecular formula shows the numbers and types of atom in a molecule. Deduce the number of atoms in a displayed formula. Deduce the names of the different elements in a compound given its displayed formula. Deduce the number of each different type of atom in a displayed formula.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a particle is an atom, molecule or ion given its formula. Understand that atoms contain smaller particles one of which is a negative electron.
These learning outcomes are intended to be taught throughout this specification.	Recall that two types of chemical bond holding atoms together are: • ionic bonds • covalent bonds.

Module C5: How Much? (Quantitative Analysis)

Item C5: Fundamental Chemical Concepts

Links to other modules: C1 to C6

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct word equations (not all reactants and products given).	
Construct balanced symbol equations given the formulae (no brackets) of the reactants and products. Explain why a symbol equation is balanced.	Construct balanced symbol equations given the formulae (some or all with brackets) of the reactants and products. Construct balanced symbol equations given the names of the reactants and products (limited to the learning outcomes in C5).
Deduce the number of atoms in a formula with brackets. Deduce the number of each type of different atom in a formula with brackets. Recall the formula of the following substances: • hydrochloric acid and ethanoic acid • carbon dioxide, hydrogen and water • sodium chloride and potassium chloride • ammonia and calcium carbonate.	Recall the formula of the following substances: • sulfuric acid and nitric acid • sodium hydroxide, potassium hydroxide and magnesium carbonate • sodium sulfate, potassium sulfate, magnesium sulfate and barium sulfate • lead(II) nitrate and lead iodide • potassium iodide and potassium nitrate.
Understand that a displayed formula shows both the atoms and the bonds in a molecule. Write the molecular formula of a compound given its displayed formula.	Construct balanced equations using displayed formulae.
Understand that positive ions are formed when electrons are lost from atoms. Understand that negative ions are formed when electrons are gained by atoms.	
Understand that an ionic bond is the attraction between a positive ion and a negative ion. Understand that a covalent bond is a shared pair of electrons.	Explain how an ionic bond is formed. Explain how a covalent bond is formed.

Module C5: How Much? (Quantitative Analysis)

Item C5a: Moles and molar mass

Summary: This item develops the concept of relative formula mass into the scientific measure for the amount of a substance, moles. The mole concept will be used as an alternative way to calculate reacting masses.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Review relative formula mass calculations. Molar mass calculations.	Recall that the unit for the amount of a substance is the mole. Recall that the unit for molar mass is g/mol. Understand that the term molar mass of a substance refers to its relative formula mass in grams. Calculate the molar mass of a substance from its formula (without brackets) using the appropriate relative atomic masses.
Carry out an experiment to measure the increase in mass on complete oxidation of magnesium ribbon in a crucible. Class practical involving the mass changes when carbonates are heated.	Understand that mass is conserved during a chemical reaction. Interpret experimental results involving mass changes during chemical reactions. Use understanding of conservation of mass to carry out very simple calculations: • mass of gas or water lost during thermal decomposition • mass of gas gained during reaction • determine a reacting amount for a simple reaction given all the other reacting amounts.

Module C5: How Much? (Quantitative Analysis)

Item C5a: Moles and molar mass

Links to other items: C3d: Reacting masses, C5c: Quantitative analysis, C5e: Gas volumes

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Calculate the molar mass of a substance from its formula (with brackets) using the appropriate relative atomic masses.	Recall and use the relationship between molar mass, number of moles and mass: • number of moles = mass ÷ molar mass • determine the number of moles of an element from the mass of that element • determine the number of moles of a compound from the mass of that compound • determine the masses of the different elements present in a given number of moles of a compound. Recall that the relative atomic mass of an element is the average mass of an atom of the element compared to the mass of 1/12th of an atom of carbon-12.
Given a set of reacting masses, calculate further reacting amounts by simple ratio.	Calculate mass of products and/or reactants using the mole concept from a given balanced equation and the appropriate relative atomic masses.

Module C5: How Much? (Quantitative Analysis)

Item C5b: Percentage composition and empirical formula

Summary: Every compound has a fixed percentage composition by mass and this composition can be used to identify an unknown sample. This item shows how the mole concept and percentage composition can be used to determine the empirical formula of a compound.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Carry out an experiment to measure the increase in mass on complete oxidation of magnesium ribbon in a crucible. Also see www.practicalchemistry.org. Carry out an experiment to measure the decrease in mass on reduction of copper oxide e.g. reduction with methane gas. Also see www.practicalchemistry.org.	Determine the mass of an element in a known mass of compound given the masses of the other elements present.
Carry out an experiment to determine the percentage of water of crystallisation in a sample of hydrated salt. Research the percentage by mass of essential elements in fertilisers.	Calculate the molar mass of a substance from its formula (without brackets) using the appropriate relative atomic masses.

Module C5: How Much? (Quantitative Analysis)

Item C5b: Percentage composition and empirical formula

Links to other items: C3d: Reacting masses, C3e: Percentage yield and atom economy, C5c: Quantitative analysis

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that an empirical formula gives the simplest whole number ratio of each type of atom in a compound. Deduce the empirical formula of a compound given its chemical formula. Calculate the percentage by mass of an element in a compound given appropriate experimental data about the mass of the element and the mass of the compound.	Recall and use the relationship between molar mass, number of moles and mass: • number of moles = mass ÷ molar mass. Determine the number of moles of an element from the mass of that element. Calculate empirical formula of a compound from the: • percentage composition by mass • mass of each element in a sample of the compound.
Calculate the molar mass of a substance from its formula (with brackets) using the appropriate relative atomic masses.	Calculate the percentage by mass of an element in a compound given its formula and the appropriate atomic masses.

Module C5: How Much? (Quantitative Analysis)

Item C5c: Quantitative analysis

Summary: An understanding of quantities and concentrations is important for everyday tasks in the home as well as being vital for medical and other technological applications. Performing calculations involving concentration develops the skill of analysing scientific information quantitatively.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
ICT simulations about concentration.	Recall that concentration of solutions may be measured in g/dm^3 (g per dm^3). Recall that concentration of solutions may be measured in mol/dm^3 (mol per dm^3). Recall that volume is measured in dm^3 or cm^3. Recall that 1000 cm^3 equals 1 dm^3.
Follow simple instruction to dilute solutions by specified amounts.	Describe how to dilute a concentrated solution.
Survey everyday examples of dilution e.g.: • dilution of concentrated orange juice • dilution of windscreen wash fluid for different temperatures • dilution of liquid medicines.	Explain the need for dilution in areas such as food preparation, medicine and baby milk: • concentrated orange cordial needs to be diluted to make sure the taste is not too strong • medicines may need to be diluted to avoid giving overdoses • baby milk must be of the correct concentration so as not to harm the baby.
Survey information on food packaging with particular regard to guideline daily amounts (GDA) values.	Interpret information on food packaging about guideline daily amounts (GDA) for example: • the smallest or largest amount of a particular substance.

Module C5: How Much? (Quantitative Analysis)

Item C5c: Quantitative analysis

Links to other items: C1f: Cooking and food additives, C5a: Moles and molar mass, C5b: Percentage composition and empirical formula

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that the more concentrated a solution the more solute particles there are in a given volume (the more crowded the solute particles). Convert volume in cm^3 into dm^3 or vice versa.	Recall and use the relationship between the amount in moles, concentration in mol/dm^3 and volume in dm^3: • amount in moles = concentration × volume • concentration = amount in moles ÷ volume • volume = amount in moles ÷ concentration.
Perform calculations involving concentration for simple dilutions of solutions e.g. how to dilute a 1.0 mol/dm^3 solution into a 0.1 mol/dm^3 solution or how to perform a 1 in 10 dilution.	
Interpret information on food packaging about guideline daily amounts (GDA) for example: • percentage of GDA in a portion.	Interpret more complex food packaging information and its limitations for example: • convert amounts of sodium to amounts of salt. Explain why the above conversion may be inaccurate, to include sodium ions coming from other sources.

Module C5: How Much? (Quantitative Analysis)

Item C5d: Titrations

Summary: Titrations are the historical backbone of so many analytical procedures. Whilst instrumental techniques have now removed much of the need for repetitive titrations, it is the technique that chemists often fall back on for 'one off' analysis. This item will enable students to perform acid-base titrations and use the results for volumetric analysis.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Demonstrate or carry out an investigation to find out how pH changes during the neutralisation of an alkali with an acid (pH titration curve) using a strong acid and using a pH meter.	Interpret a simple pH curve to include: • determine the pH at a particular volume added or vice versa (major grid lines). Explain how universal indicator can be used to estimate the pH value of a solution.
Carry out a simple acid-alkali titration using an indicator such as litmus or phenolphthalein. Microscale titrations details from RSC website www.practicalchemistry.org.	Identify the apparatus used in an acid-base titration: • burette and conical flask • pipette and pipette filler. Describe the procedure for carrying out a simple acid-base titration: • acid in burette, alkali in conical flask (or vice versa) • acid slowly added to alkali (or vice versa) until end point is reached • end point detected by the sudden change in colour of an indicator. Explain why it is important to use a pipette filler when using a pipette in an acid-base titration. Calculate the titre given appropriate information from tables or diagrams. Understand that the titre depends on the concentration of the acid or alkali.
Simple investigation of the colour changes of indicators limited to universal indicator, phenolphthalein and litmus during neutralisation. Universal indicator rainbow see details from RSC website www.practicalchemistry.org.	Describe the colours of the following indicators in acids and alkalis: • universal indicator, litmus and phenolphthalein.

Module C5: How Much? (Quantitative Analysis)

Item C5d: Titrations

Links to other items: C2f: Acids and bases, C5c: Quantitative analysis, C5g: Strong and weak acids

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Interpret a simple pH curve to include: • determine the volume of acid or alkali at neutralisation • determine the pH at a particular volume added or vice versa (not major grid lines).	Sketch a pH titration curve for the titration of an acid or an alkali.
Explain the need for several consistent titre readings in titrations.	Calculate the concentration of an acid or alkali from titration results, limited to examples involving a one to one molar ratio (acid:alkali). Recall and use the relationship between the amount in moles, concentration in mol/dm^3 and volume in dm^3: • amount in moles = concentration × volume • concentration = amount in moles ÷ volume • volume = amount in moles ÷ concentration.
Describe the difference in colour change during a titration using a single indicator, such as litmus or phenolphthalein, compared to a mixed indicator, such as universal.	Explain why an acid-base titration should use a single indicator rather than a mixed indicator.

Module C5: How Much? (Quantitative Analysis)

Item C5e: Gas volumes

Summary: Many reactions involve gases either as reactants or as products. It is often easier to measure the volume of a gas rather than the mass. The course of a reaction can be monitored by measuring how the volume of gas collected changes with time. This item describes a few ways in which the volume of a gas can be measured and how this can be used to follow the course of a reaction. The item also describes how the volume of gas produced can be predicted by calculation.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Carry out simple experiments to show how the volume of a gas produced in a reaction can be measured e.g. displacement of water in a burette or measuring cylinder, use of a gas syringe.	Identify apparatus used to collect the volume of a gas produced in a reaction: • gas syringe • upturned measuring cylinder • upturned burette.
Carry out experiments to measure the mass of a gas being produced during a reaction e.g. marble and acid and/or thermal decomposition of zinc carbonate.	Recall that measurement of change of mass may be used to monitor the amount of gas made in a reaction.
Carry out simple experiments to measure the volume of gas evolved as the amounts of reactants are changed e.g. magnesium and dilute hydrochloric acid, marble chips and acid.	Explain why a reaction stops.
ICT simulation of the progress of a reaction showing how the amount of reactant and/or amount of product present changes with time.	Interpret data in table, graphical and written form about the volume of gas produced during the course of a reaction (limited to major grid lines on graphs) for example: • deduce total volume of gas produced • deduce when the reaction has stopped • deduce volume of gas at a particular time and vice versa • compare rates of reaction using gradients of graphs.

Module C5: How Much? (Quantitative Analysis)

Item C5e: Gas volumes

Links to other items: C3a: Rate of reaction (1), C3b: Rate of reaction (2), C3c: Rate of reaction (3), C5a: Moles and molar mass, C5c: Quantitative analysis

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe an experimental method to measure the volume of gas produced in a reaction given appropriate details about the reaction.	
Describe an experimental method to measure the mass of gas produced in a reaction given appropriate details about the reaction.	
Understand how the amount of product formed varies with the amount of limiting reactant used. Recall that the limiting reactant is the reactant not in excess that is all used up at the end of the reaction. Explain why a reaction stops in terms of the limiting reactant present given appropriate qualitative information about the reaction.	Explain in terms of reacting particles why the amount of product formed is directly proportional to the amount of limiting reactant used. Calculate the volume of a known number of moles of gas given the molar gas volume of 24 dm^3 at room temperature and pressure (rtp). Calculate the amount in moles of a volume of gas at rtp given the molar gas volume at rtp.
Interpret data in table, graphical and written form about the volume of gas produced during the course of a reaction (not major grid lines) for example: • deduce total volume of gas produced • deduce when the reaction has stopped • deduce volume of gas at a particular time and vice versa • deduce the volume of gas produced with different amounts of limiting reactant.	Sketch a graph to show how the volume of gas produced during the course of a reaction changes, given appropriate details about the reaction.

Module C5: How Much? (Quantitative Analysis)

Item C5f: Equilibria

Summary: Many important industrial chemical processes rely on reversible reactions that can reach a chemical equilibrium. This item focuses on the equilibrium between the two directions of a reversible reaction and on the nature of the equilibrium position.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Reversible reactions between acids and alkalis using an indicator. Reversible reactions between chromate and dichromate. Demonstration of the reaction of $BiCl_3$ in concentrated HCl with water.	Understand that a reversible reaction can proceed in both directions, both forwards and backwards. Recall that the symbol $\rightleftharpoons$ is used to show that a reaction is reversible. Recognise, given the word or balanced symbol equations, reactions that are reversible.
	Interpret data in the form of tables or graphs (using major grid-lines) about the equilibrium composition, for example: • composition at particular temperatures • composition at particular pressures • effect of temperature and pressure on composition.
Show a video about Contact Process.	Recall the raw materials used to make sulfuric acid by the Contact Process: • sulfur • air • water. Describe the manufacture of sulfuric acid: • sulfur is burnt to produce sulfur dioxide • sulfur dioxide reacts with oxygen to produce sulfur trioxide • sulfur trioxide reacts with water to produce sulfuric acid.

Module C5: How Much? (Quantitative Analysis)

Item C5f: Equilibria

Links to other items: C2e: Manufacturing chemicals: making ammonia, C3a: Rate of reaction (1), C3b: Rate of reaction (2), C3c: Rate of reaction (3)

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that in a reversible reaction at equilibrium: • the rate of the forward reaction equals the rate of the backward reaction • the concentrations of the reactants and the products do not change. Understand how the position of equilibrium is related to the ratio of the concentration of the products to the concentration of the reactants.	Explain why a reversible reaction may reach an equilibrium: • importance of a closed system • initially rate of forward reaction decreases • initially rate of backward reaction increases • eventually rate of forward equals rate of backward reaction.
Recall that a change in temperature, pressure or concentration of reactant or product may change the position of equilibrium. Interpret data in the form of tables or graphs about the equilibrium composition, for example: • composition at particular temperatures • composition at particular pressures • effect of temperature and pressure on composition.	Understand in simple qualitative terms factors that affect the position of equilibrium: • removing a product moves the position of equilibrium to the right or vice versa • adding extra reactant moves the position of equilibrium to the right or vice versa • increasing the temperature moves the position of equilibrium in the direction of the endothermic reaction or vice versa • increasing the pressure moves the position of equilibrium to the side with the least number of moles of gas molecules or vice versa. Explain the effect of changing product concentration, reactant concentration, temperature or pressure on the position of equilibrium given appropriate details about a reaction.
Understand that the reaction between sulfur dioxide and oxygen is reversible: • sulfur dioxide + oxygen $\rightleftharpoons$ sulfur trioxide • $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ Describe the conditions used in the Contact Process: • V_2O_5 catalyst • around 450°C • atmospheric pressure.	Explain the conditions used in the Contact Process: • increasing the temperature moves the position of equilibrium to the left and increases rate of reaction so a compromise temperature is used • addition of catalyst increases rate but does not change position of equilibrium • even at low pressure, the position of equilibrium is already on right so expensive high pressure is not needed.

Module C5: How Much? (Quantitative Analysis)

Item C5g: Strong and weak acids

Summary: Weak acids are of enormous importance in situations where we want an acid reaction without the aggressive effects of a very low pH. This item compares the reactions and properties of ethanoic acid; a weak acid with hydrochloric acid a strong acid.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Measure the pH values of strong and weak acids of the same concentrations.	Recall that ethanoic acid is a weak acid. Recall that hydrochloric, nitric and sulfuric acids are strong acids. Understand that strong acids have a lower pH than weak acids of the same concentration.
Compare the rate of reaction of 1.0 mol/dm^3 hydrochloric acid and 1.0 mol/dm^3 ethanoic acid with calcium carbonate and magnesium.	Recall that both ethanoic acid and hydrochloric acid react with magnesium to give hydrogen and with calcium carbonate to give carbon dioxide. Recall that magnesium and calcium carbonate react slower with ethanoic acid than with hydrochloric acid of the same concentration because ethanoic acid is a weak acid.
Investigate the volumes of gas produced when equal amounts of strong and weak acids react with a substance such as magnesium or with marble chips.	Understand that the same amount of hydrochloric and of ethanoic acid produce the same volume of gaseous products in their reaction with magnesium and calcium carbonate.
Comparison of the electrical conductivities and electrolysis of strong and weak acids.	Understand that ethanoic acid has a lower electrical conductivity than hydrochloric acid of the same concentration. Recall that electrolysis of both ethanoic acid and hydrochloric acid makes hydrogen at the negative electrode.

Module C5: How Much? (Quantitative Analysis)

Item C5g: Strong and weak acids

Links to other items: C2f: Acids and bases, C3a: Rate of reaction (1), C3b: Rate of reaction (2), C3c: Rate of reaction (3)

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that an acid ionises in water to produce H^+ ions. Understand that a strong acid completely ionises in water and a weak acid does not fully ionise and forms an equilibrium mixture.	Explain why the pH of a weak acid is much higher than the pH of a strong acid of the same concentration. Explain the difference between acid strength and acid concentration: • acid strength (strong or weak) is a measure of the degree of ionisation of the acid • acid concentration is a measure of the number of moles of acid in one dm^3. Construct equations for the ionisation of weak and strong acids given the formula of the mono-basic acid.
Explain why ethanoic acid reacts slower than hydrochloric acid of the same concentration: • there are fewer hydrogen ions in ethanoic acid • in ethanoic acid there are fewer collisions between hydrogen ions and reactant particles.	Explain why ethanoic acid reacts slower than hydrochloric acid of the same concentration: • ethanoic acid has a lower concentration of hydrogen ions • in ethanoic acid the hydrogen ions have a lower collision frequency with reactant particles.
Explain why the volume of gaseous products of the reactions of acids is determined by the amounts of reactants present not the acid strength.	
Explain why ethanoic acid is less conductive than hydrochloric acid of the same concentration: • there are fewer hydrogen ions available to move. Explain why hydrogen is produced during the electrolysis of ethanoic acid and of hydrochloric acid.	Explain why ethanoic acid is less conductive than hydrochloric acid of the same concentration: • lower concentration of hydrogen ions to carry the charge in ethanoic acid.

Module C5: How Much? (Quantitative Analysis)

Item C5h: Ionic equations and precipitation

Summary: Precipitation is a process used to test for ions in solutions. In this item we explore several precipitation reactions and the associated concept of ionic equations. This provides the opportunity to apply scientific information using quantitative approaches.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Carry out simple precipitation reactions: • Cl^-, Br^- and I^- with $Pb(NO_3)_2(aq)$ • SO_4^{2-} with $BaCl_2(aq)$.	Describe a precipitation reaction. Understand that most precipitation reactions involve ions from one solution reacting with ions from another solution.
	Describe how lead nitrate solution can be used to test for halide ions: • white precipitate with Cl^- • cream precipitate with Br^- • bright yellow precipitate with I^-. Describe how barium chloride solution can be used to test for sulfate ions (form a white precipitate).
	Identify the reactants and the products from an ionic equation. Recognise and use the state symbols (aq), (s), (g) and (l).
Preparation of an insoluble salt using precipitation e.g. lead(II) iodide or magnesium carbonate.	Label the apparatus used during the preparation of an insoluble compound by precipitation.

Module C5: How Much? (Quantitative Analysis)

Item C5h: Ionic equations and precipitation

Links to other items: C4e: The Group 7 elements, C4f: Transition elements, C4h: Purifying and testing water, C6a: Electrolysis

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that ionic substances contain ions which are in fixed positions in the solid but can move in solution. Understand that in a precipitation reaction ions must collide with other ions to react to form a precipitate.	Explain, in terms of collisions between ions, why most precipitation reactions are extremely fast.
Interpret experimental data about the testing of solutions using aqueous barium chloride and aqueous lead nitrate.	
Construct word equations for simple precipitation reactions e.g. for the reaction between solutions of barium chloride and sodium sulfate (products not given).	Construct ionic equations, with state symbols, for simple precipitation reactions, given the formulae of the ions that react. Explain the concept of 'spectator ions'.
Describe the stages involved in the preparation of a dry sample of an insoluble compound by precipitation given the names of the reactants: • mix solutions of reactants • filtration • wash and dry residue.	

3.9 Module C6: Chemistry Out There

Module C6: Chemistry Out There

Item C6: Fundamental Chemical Concepts

Summary: Throughout the study of chemistry in GCSE science there are a number of ideas and concepts that are fundamental. These ideas and concepts have not been put into a particular item but should permeate through all the GCSE Chemistry Modules C1 to C6.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
These learning outcomes are intended to be taught throughout this specification.	Understand that in a chemical reaction reactants are changed into products. Recognise the reactants and products in a word equation. Construct word equations given the reactants and products.
These learning outcomes are intended to be taught throughout this specification.	Recognise the reactants and the products in a symbol equation.
These learning outcomes are intended to be taught throughout this specification.	Deduce the number of elements in a compound given its formula. Deduce the number of atoms in a formula with no brackets. Deduce the number of each different type of atom in a formula with no brackets.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a substance is an element or a compound from its formula. Deduce the names of the different elements in a compound given its formula.
These learning outcomes are intended to be taught throughout this specification.	Understand that a molecule is made up of more than one atom joined together. Understand that a molecular formula shows the numbers and types of atom in a molecule. Deduce the number of atoms in a displayed formula. Deduce the names of the different elements in a compound given its displayed formula. Deduce the number of each different type of atom in a displayed formula.
These learning outcomes are intended to be taught throughout this specification.	Recognise whether a particle is an atom, molecule or ion given its formula. Understand that atoms contain smaller particles one of which is a negative electron.
These learning outcomes are intended to be taught throughout this specification.	Recall that two types of chemical bond holding atoms together are: • ionic bonds • covalent bonds.

Module C6: Chemistry Out There

Item C6: Fundamental Chemical Concepts

Links to other modules: C1 to C6

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct word equations (not all reactants and products given).	
Construct balanced symbol equations given the formulae (no brackets) of the reactants and products. Explain why a symbol equation is balanced.	Construct balanced symbol equations given the formulae (some or all with brackets) of the reactants and products. Construct balanced symbol equations given the names of the reactants and products (limited to the learning outcomes in C6).
Deduce the number of atoms in a formula with brackets. Deduce the number of each type of different atom in a formula with brackets. Recall the formula of the following substances: • chlorine, hydrogen, oxygen and water • calcium carbonate and carbon dioxide • ethanoic acid.	Recall the formula of the following substances: • sulfates and chlorides of calcium, iron(II), magnesium, tin(II) and zinc • calcium hydrogencarbonate and sodium carbonate • ethanol and glucose.
Understand that a displayed formula shows both the atoms and the bonds in a molecule. Write the molecular formula of a compound given its displayed formula.	Construct balanced equations using displayed formulae.
Understand that positive ions are formed when electrons are lost from atoms. Understand that negative ions are formed when electrons are gained by atoms.	
Understand that an ionic bond is the attraction between a positive ion and a negative ion. Understand that a covalent bond is a shared pair of electrons.	Explain how an ionic bond is formed. Explain how a covalent bond is formed.

Module C6: Chemistry Out There

Item C6a: Electrolysis

Summary: Some industrial processes involve electrolysis. This item describes how it is possible to predict the products of electrolysis. It explains how it is possible to predict the amount of product formed during electrolysis and provides the opportunity to plan to test a scientific idea. Predicting the outcome of the electrolysis of molten lead bromide illustrates the use of scientific modelling.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
	Describe electrolysis as the decomposition of a liquid by passing an electric current through it. Recall the anode is the positive electrode and the cathode is the negative electrode. Recall that cations are positively charged and anions are negatively charged. Describe the electrolyte as the liquid which conducts electricity and is decomposed during electrolysis. Recognise anions and cations from their formula.
Class investigation to identify the products of electrolysis of aqueous solutions such as NaOH(aq) and H_2SO_4(aq).	Identify the apparatus needed to electrolyse aqueous solutions in a school laboratory: • anode, cathode, d.c. power supply. Recognise that positive ions discharge at the negative electrode and negative ions at the positive electrode. Describe the chemical tests for hydrogen and oxygen: • hydrogen burns with a 'pop' when lit using a lighted splint • oxygen relights a glowing splint.
Class practical – the electrolysis of copper(II) sulfate using carbon electrodes either qualitative or quantitative. Use of Hoffmann voltameter to investigate the effect of current and time on the volume of oxygen and/or hydrogen produced.	Describe the observations of the electrolysis of copper(II) sulfate solution using carbon electrodes: • the cathode gets plated with copper and bubbles are formed at the anode • blue colour will slowly disappear. Recall the factors that affect the amount of substance produced during electrolysis: • time • current.
Fume cupboard demonstration of the electrolysis of molten $PbBr_2$ or PbI_2.	Predict the products of electrolytic decomposition of the molten electrolytes.

Module C6: Chemistry Out There

Item C6a: Electrolysis

Links to other items: C2c: Metals and alloys, C5h: Ionic equations and precipitation

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe electrolysis in terms of flow of charge by moving ions and the discharge of ions at the electrodes.	
Recall the products of the electrolysis of: • NaOH(aq) – hydrogen at cathode and oxygen at anode • H_2SO_4(aq) – hydrogen at cathode and oxygen at anode.	Construct the half equations for the electrode processes that happen during the electrolysis of NaOH(aq) or H_2SO_4(aq) given the formula of the ions present in the electrolyte: • cathode – $2H^+ + 2e^- \rightarrow H_2$ • anode – $4OH^- - 4e^- \rightarrow O_2 + 2H_2O$ Explain why the electrolysis of NaOH(aq) makes H_2 rather than Na at the cathode.
Recall the products of the electrolysis of $CuSO_4$(aq) with carbon electrodes: • copper is formed at the cathode and oxygen at the anode. Understand how the amount of substance produced during electrolysis varies with time and current.	Construct the half equations for electrode processes that happen during the electrolysis of $CuSO_4$(aq) using carbon electrodes: • cathode – $Cu^{2+} + 2e^- \rightarrow Cu$ • anode – $4OH^- - 4e^- \rightarrow O_2 + 2H_2O$ Perform calculations based on current, time and the amount of substance produced in electrolysis.
Explain why an ionic solid cannot be electrolysed but the molten liquid can be electrolysed: • ionic solid has ions which are in fixed positions and cannot move • ions in the molten liquid can move.	Construct the half equations for the electrode processes that happen during the electrolysis of molten binary ionic compounds given the formulae of the ions present in the electrolyte.

Module C6: Chemistry Out There

Item C6b: Energy transfers – fuel cells

Summary: This item describes the use of hydrogen in fuel cells. The item also considers the advantages of fuel cells over the use of more conventional fossil fuels.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Carry out an experiment blowing air through a straw next to one of a pair of copper electrodes dipped in brine to produce a measurable potential difference.	Recall that the reaction between hydrogen and oxygen is exothermic. Understand why fuel cells use exothermic reactions. Construct the word equation for the reaction between hydrogen and oxygen.
Carry out an experiment to electrolyse sodium hydroxide and then measure a potential difference between the electrodes (see Nuffield Sample Scheme Teachers Guide II p619). Internet research about fuel cells.	Describe a fuel cell as a cell supplied with fuel and oxygen that uses the energy released from the reaction between the fuel and oxygen to produce electrical energy efficiently. Recall that hydrogen is the fuel in a hydrogen-oxygen fuel cell.
	Recall that one important use of fuel cells is to provide electrical power in spacecraft.
	Explain why a hydrogen-oxygen fuel cell does not form a polluting waste product. Recall that the combustion of fossil fuels, such as petrol, produce carbon dioxide which has been linked to climate change and global warming.

Module C6: Chemistry Out There

Item C6b: Energy transfers – fuel cells

Links to other items: C1b: Using carbon fuels, C3f: Energy

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Construct the balanced symbol equation for the reaction between hydrogen and oxygen.	Draw and interpret an energy level diagram for the reaction between hydrogen and oxygen. Draw and interpret energy level diagrams for other reactions given appropriate information.
Construct the balanced symbol equation for the overall reaction in a hydrogen-oxygen fuel cell.	Explain the changes that take place at each electrode in a hydrogen-oxygen fuel cell: • construct the equations for the electrode reactions given the formula of the ions present and the products • redox reactions at each electrode.
List some advantages of using a hydrogen-oxygen fuel cell to provide electrical power in a spacecraft: • provides water that can be used by astronauts • lightweight • compact • no moving parts.	Explain the advantages of a hydrogen-oxygen fuel cell over conventional methods of generating electricity.
Explain why the car industry is developing fuel cells: • no carbon dioxide emissions from the car • fossil fuels such as petrol are non-renewable • large source of hydrogen available by decomposing water.	Explain why the use of hydrogen-oxygen fuel cells will still produce pollution: • fuel cells often contain poisonous catalysts that have to be disposed of at the end of the lifetime of the fuel cell • production of the hydrogen and oxygen will involve the use of energy which may have come from the burning of fossil fuels.

Module C6: Chemistry Out There

Item C6c: Redox reactions

Summary: Redox is an important type of chemical reaction. Examples of redox reactions include corrosion of metals and electrolysis. This item will describe redox reactions using an electron transfer model.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Teacher exposition about redox reactions.	Describe oxidation as the addition of oxygen or the reaction of a substance with oxygen. Describe reduction as the removal of oxygen from a substance.
Carry out experiments to find the conditions necessary for rusting of iron and steel to take place.	Recall that rusting of iron and steel requires both oxygen (or air) and water.
Research ways of rust protection. Preventing rusting as demonstration or class practical – see www.practicalchemistry.org.	List methods of preventing rust limited to: • oil and grease • paint • galvanising • sacrificial protection • alloying • tin plate. Understand how oil, grease and paint prevent iron from rusting because they stop oxygen or water reaching the surface of the iron.
Carry out displacement reactions between metals and metal salt solutions limited to zinc, magnesium, iron and tin. Exothermic metal displacement reactions – see RSC website www.practicalchemistry.org.	Interpret observations made during displacement reactions including temperature changes. Recall the following order of reactivity (most to least): • magnesium, zinc, iron and tin. Predict, with a reason, whether a displacement reaction will take place.

Module C6: Chemistry Out There

Item C6c: Redox reactions

Links to other items: C1h: Paints and pigments, C2c: Metals and alloys, C2d: Making cars, C4d: The Group 1 elements, C4e: The Group 7 elements, C4f: Transition elements

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Understand that redox reactions involve both oxidation and reduction.	Understand that oxidation involves loss of electrons and reduction involves the gain of electrons. Recognise and use the terms: • oxidation and reduction • oxidising agent and reducing agent. Explain, in terms of oxidation and reduction, the interconversion of the following types of systems: • Fe and Fe^{2+} • Fe^{2+} and Fe^{3+} • Cl_2 and Cl^- • electrode reactions.
Understand that rusting of iron is a redox reaction. Construct the word equation for the rusting of iron: iron + oxygen + water → hydrated iron(III) oxide.	Explain why rusting is a redox reaction: • iron loses electrons • oxygen gains electrons.
Explain how galvanising protects iron from rusting: • galvanised iron is covered with a layer of zinc • layer of zinc stops water and oxygen from reaching the surface of the iron • zinc also acts as a sacrificial metal.	Explain how sacrificial protection protects iron from rusting: • use of a metal such as magnesium or zinc • sacrificial metal is more reactive than iron • sacrificial metal will lose electrons in preference to iron. Explain the disadvantage of using tin plate as a means of protecting iron from rusting: • tin only acts as a barrier stopping water and air reaching the surface of the iron • when the tin layer is scratched the iron will lose electrons in preference to tin and so the iron rusts even faster than on its own. Evaluate different ways of rust prevention.
Construct word equations for displacement reactions between metals and metal salt solutions.	Construct symbol equations for displacement reactions between metals and metal salt solutions. Explain displacement reactions in terms of oxidation and reduction: • metal ion is reduced by gaining electrons • metal atom is oxidised by losing electrons.

Module C6: Chemistry Out There

Item C6d: Alcohols

Summary: There is a large group of compounds called alcohols. Ethanol is an example of an alcohol. Ethanol, which is renewable, can provide an alternative to crude oil as a source of fuel and organic compounds.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Use of molecular models.	Explain why alcohols are not hydrocarbons.
Carry out an experiment to produce ethanol by fermentation.	Recall the conditions needed for fermentation: • 25 – 50°C • presence of water • yeast.
The 'Whoosh' bottle demonstration – details from RSC website www.practicalchemistry.org.	Recall the main uses of ethanol: • alcoholic beverages • solvent (industrial methylated spirits) • fuel for cars.
ICT simulation.	Recall that hydration of ethene produces ethanol.

Module C6: Chemistry Out There

Item C6d: Alcohols

Links to other items: C1a: Making crude oil useful, C1b: Using carbon fuels, C3g: Batch or continuous?

Assessable learning outcomes both tiers: standard demand	**Assessable learning outcomes Higher Tier only: high demand**
Recall the molecular formula and displayed formula of ethanol.	Recall the general formula of an alcohol. Use the general formula of alcohols to write the molecular formula of an alcohol given the number of carbon atoms in one molecule of the alcohol. Draw the displayed formulae of alcohols containing up to five carbon atoms.
Recall the word equation for fermentation: • glucose → carbon dioxide + ethanol Construct the balanced symbol equation for fermentation (given all the formulae): $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ Describe how ethanol can be made by fermentation: • glucose solution • reaction catalysed by enzymes in yeast • absence of oxygen • fractional distillation to get ethanol.	Construct the balanced symbol equation for fermentation (some or no formulae given): $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ Explain the conditions used in fermentation: • temperature too low yeast inactive • temperature too high enzymes in yeast denatured • absence of air to prevent formation of ethanoic acid.
Explain why ethanol made by fermentation is a renewable fuel. Explain why ethanol made by hydration of ethene is a non-renewable fuel.	Evaluate the merits of the two methods of making ethanol (fermentation and hydration) in terms of: • conditions used • batch versus continuous • sustainability • purification • percentage yield and atom economy.
Describe how ethanol is produced for industrial use by passing ethene and steam over a heated phosphoric acid catalyst. Construct the word equation for the hydration of ethene: ethene + water → ethanol Construct the balanced symbol equation for the hydration of ethene: $C_2H_4 + H_2O \rightarrow C_2H_5OH$	

Module C6: Chemistry Out There

Item C6e: Depletion of the ozone layer

Summary: This item describes the environmental problem of the depletion of the ozone layer and how Chemistry can provide safer alternatives to CFCs.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Discussion on the use of chlorofluorocarbons (CFCs).	Recall that a chlorofluorocarbon (CFC) is an organic molecule containing chlorine, fluorine and carbon atoms. Recall the use of CFCs as refrigerants and aerosol propellants.
Data-search on CFCs and ozone depletion e.g. use of satellite data.	Recall that ozone is a form of oxygen with the formula O_3. Describe some properties of CFCs: • chemically inert • low boiling point • insoluble in water.
Data-search on CFCs and ozone depletion.	Describe that increased levels of ultraviolet light can lead to medical problems such as: • increased risk of sunburn • accelerated ageing of skin • skin cancer • increased risk of cataracts.
Survey of safer alternatives to CFCs.	Recall that hydrocarbons can provide safer alternatives to CFCs.

Module C6: Chemistry Out There

Item C6e: Depletion of the ozone layer

Links to other items: C1c: Clean air, C4e: The Group 7 elements

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain why the use of CFCs has been banned in the UK: • society has agreed with scientists' views that CFCs deplete the ozone layer.	Describe and explain how scientists' attitude to CFCs has changed: • initial enthusiasm for the use of CFCs based upon their inertness • later discovery of ozone depletion and link to presence of CFCs • acceptance by scientists and the rest of the world community that the use of CFCs should be banned.
Describe how CFCs deplete the ozone layer: • CFC molecules are broken down in the stratosphere by ultraviolet light to give highly reactive chlorine atoms • chlorine atoms react with ozone molecules • chlorine atoms are regenerated so can react with more ozone molecules. Construct an equation to show the formation of chlorine atoms from CFCs. Recall that a chlorine radical is a chlorine atom. Explain why CFCs are only removed slowly from the stratosphere.	Explain in terms of electrons how a carbon-chlorine bond can break to form highly reactive chlorine atoms. Explain why only a small number of chlorine atoms will destroy a large number of ozone molecules. Interpret the symbol equations for the reactions that take place when chlorine atoms and ozone react. Explain why CFCs will continue to deplete ozone a long time after their use has been banned.
Describe how depletion of the ozone layer allows more ultraviolet light to reach the surface of the Earth.	Explain how ozone absorbs ultraviolet light in the stratosphere.
Recall that CFCs can be replaced with alkanes or HFCs and that these will not damage the ozone layer.	

Module C6: Chemistry Out There

Item C6f: Hardness of water

Summary: Hardness of water is a problem in many areas for processes where water has to be heated or where soap is used. The survey on ways of removing water hardness allows the use of ICT tools to look at the benefits and drawbacks of technological developments.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Compare hard and soft water using soap. Compare hard and soft water using soapless detergents.	Recall that hard water does not lather well with soap but soft water does. Recall that both hard and soft water lather well with soapless detergents.
Which ions cause hardness in water? Class practical – details from RSC website www.practicalchemistry.org.	Recall that hardness is caused by dissolved calcium and magnesium ions in water. Recall that boiling destroys temporary hardness in water but not permanent hardness in water.
Survey ways of removing hardness by using water softeners.	Describe how hardness in water can be removed: • passing the water through an ion-exchange column • adding washing soda (sodium carbonate).
Carry out an experiment to compare the hardness of water samples using soap solution.	Interpret data about water hardness experiments for example: • choosing the softest or hardest water sample.

Module C6: Chemistry Out There

Item C6f: Hardness of water

Links to other items: C4h: Purifying and testing water

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Describe the origin of temporary hardness in water: • calcium carbonate in rocks reacts with dissolved carbon dioxide and water to form soluble calcium hydrogencarbonate. Construct the word equation for the reaction between calcium carbonate, water and carbon dioxide: calcium carbonate + water + carbon dioxide → calcium hydrogencarbonate	
Recall that temporary hardness is caused by dissolved calcium hydrogencarbonate. Recall that permanent hardness is caused by dissolved calcium sulfate.	
Describe how boiling removes temporary hardness: • decomposition of calcium hydrogencarbonate to give insoluble calcium carbonate (limescale), water and carbon dioxide • soluble calcium ions are changed into insoluble compounds. Explain how an ion-exchange resin can soften water.	Construct the symbol equation for the decomposition of calcium hydrogencarbonate occurring when water containing temporary hardness is boiled (formulae not given): $Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$ Explain how washing soda (sodium carbonate) can soften hard water.
Interpret data about water hardness experiments for example: • explaining why a sample of water contains permanent and temporary hardness. Plan experiments to compare the hardness in samples of different sources of water.	

Module C6: Chemistry Out There

Item C6g: Natural fats and oils

Summary: Plants are grown for the natural fats and oils that they contain. These fats and oils have a large number of industrial uses. They can provide alternatives to chemicals made from crude oil.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Research the composition of various plant oils and animal fats. Comparing the amount of unsaturated fats in food stuffs by titration against bromine – see RSC website www.practicalchemistry.org.	Understand that natural fats and oils are important raw materials for the chemical industry. Recall that vegetable oils can be used to make bio-diesel, an alternative to the fuel diesel from crude oil. Recall that, at room temperature: • oils are liquids • fats are solids.
Examine milk and butter under a microscope. Also examine after adding water or oil based dyes. Prepare a sample of an emulsion e.g. a cold cream.	Describe an emulsion. Recall that milk is an oil–in-water emulsion and butter is a water–in-oil emulsion.
Prepare a sample of a soap using a vegetable oil.	Recall that a vegetable oil reacts with sodium hydroxide to produce a soap.

Module C6: Chemistry Out There

Item C6g: Natural fats and oils

Links to other items: C1a: Making crude oil useful, C1f: Cooking and food additives, C1g: Smells, C6h: Detergents

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Recall that animal and vegetable fats and oils are esters. Explain whether a fat or oil is saturated or unsaturated given its displayed formula. Describe how unsaturation in fats and oils can be shown using bromine water: • with saturated fats the bromine water stays orange • with unsaturated fats the bromine water goes colourless. Describe how margarine is manufactured from vegetable oils.	Explain why unsaturated fats are healthier as part of a balanced diet. Explain why bromine can be used to test for unsaturated fats and oils: • addition reaction takes place at the carbon-carbon double bond • a colourless dibromo compound is formed • saturated compounds cannot react with bromine since they do not have a carbon-carbon double bond.
Describe how immiscible liquids, such as vegetable oil and water, can form an emulsion. Describe an oil-in-water emulsion and a water-in-oil emulsion.	
Describe how natural fats and oils can be split up by hot sodium hydroxide solution to produce soap and glycerol. Recall that this process of splitting up natural fats and oils using sodium hydroxide solution is called saponification.	Explain the saponification of fats and oils: • fat + sodium hydroxide → soap + glycerol • hydrolysis reaction.

Module C6: Chemistry Out There

Item C6h: Detergents

Summary: Many consumers are looking at effective and efficient cleaning agents that take less time and can work at low temperatures. This item develops ideas about the use of cleaning agents such as detergents and solvents. A simple explanation of the action of detergents and solvents is considered as well as the scientific accuracy of some advertisements for detergents.

Suggested practical and research activities to select from	Assessable learning outcomes Foundation Tier only: low demand
Look at the constituents of washing powders.	Relate each ingredient in a washing powder to its function: • active detergent does the cleaning • water softener to soften hard water • bleaches to remove coloured stains • optical brighteners to give the whiter than white appearance • enzymes used in low temperature washes to remove food stains.
Investigate the action of some solvents to remove stains, paints, varnishes, wax and grease.	Understand the terms solvent, solute, solution, soluble and insoluble. Recognise that different solvents will dissolve different substances. Identify the correct solvent to remove a stain given the appropriate information.
Survey of constituents of different brands of washing up liquids.	Relate each ingredient in a washing-up liquid to its function: • active detergent does the cleaning • water to thin out detergent so it can be dispensed easily • colouring agent and fragrance to improve attractiveness of product • rinse agent to help water drain off crockery.
Critical analysis of advertisements for washing up liquids and washing powders.	Interpret data from experiments on the effectiveness of washing up liquids and washing powders for example: • which detergent washed the most plates • description of a simple trend.

Module C6: Chemistry Out There

Item C6h: Detergents

Links to other items: C6g: Natural fats and oils

Assessable learning outcomes both tiers: standard demand	Assessable learning outcomes Higher Tier only: high demand
Explain the advantages of using low temperature washes in terms of energy saving and the type of clothes that can be washed. Describe detergents as molecules that have a hydrophilic head and a hydrophobic tail.	Explain how detergents can remove fat or oil stains: • hydrophilic end of detergent molecule forms strong intermolecular forces with water molecules • hydrophobic end of detergent forms strong intermolecular forces with molecules of oil and fat.
Describe dry cleaning as a process used to clean clothes that does not involve water: • solvent that is not water • stain will not dissolve in water.	Explain, in terms of intermolecular forces, how a dry cleaning solvent removes stains: • there are weak intermolecular forces between molecules of grease • there are weak intermolecular forces between solvent molecules • solvent molecules form intermolecular forces with molecules of grease and so solvent molecules can surround molecules of grease.
Interpret data from experiments on the effectiveness of washing up liquids and washing powders for example: • making simple conclusions from data.	Interpret data from experiments on the effectiveness of washing up liquids and washing powders for example: • deducing which detergent contains an enzyme.