OCR Level 1/2 GCSE (9–1) in Chemistry B (Twenty First Century Science) (J258)

Specification

Version 1: First assessment 2018

This draft qualification has not yet been accredited by Ofqual. It is published to enable teachers to have early sight of our proposed approach to GCSE (9–1) in Chemistry B. Further changes may be required and no assurance can be given at this time that the proposed qualification will be made available in its current form, or that it will be accredited in time for first teaching in 2016 and first award in 2018.

Contents

1 Why choose an OCR GCSE (9–1) in Chemistry B (Twenty First Century Science)?

1a. Why choose an OCR qualification?

Choose OCR and you've got the reassurance that you're working with one of the UK's leading exam boards. Our new OCR GCSE (9–1) in Chemistry B (Twenty First Century Science) course has been developed in consultation with teachers, employers and Higher Education to provide learners with a qualification that's relevant to them and meets their needs.

We're part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment plays a leading role in developing and delivering assessments throughout the world, operating in over 150 countries.

We work with a range of education providers, including schools, colleges, workplaces and other institutions in both the public and private sectors. Over 13,000 centres choose our A Levels, GCSEs and vocational qualifications including Cambridge Nationals, Cambridge Technicals and Cambridge Progression.

Our Specifications

We believe in developing specifications that help you bring the subject to life and inspire your learners to achieve more.

We've created teacher-friendly specifications based on extensive research and engagement with the teaching community. They're designed to be straightforward and accessible so that you can tailor the delivery of the course to suit your needs. We aim to encourage learners to become responsible for their own learning, confident in discussing ideas, innovative and engaged.

We provide a range of support services designed to help you at every stage, from preparation through to the delivery of our specifications. This includes:

- A wide range of high-quality creative resources including:
  - Delivery Guides
  - Transition Guides
  - Topic Exploration Packs
  - Lesson Elements
  - …and much more.
- Access to subject specialists to support you through the transition and throughout the lifetime of the specification.
- CPD/Training for teachers including face-to-face events to introduce the qualifications and prepare you for first teaching.
- Active Results – our free results analysis service to help you review the performance of individual learners or whole schools.
- ExamCreator – our new online past papers service that enables you to build your own test papers from past OCR exam questions.

All GCSE (9–1) qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's GCSE (9–1) in Chemistry B (Twenty First Century Science) is QNXXXXXX

1b. Why choose an OCR GCSE (9–1) in Chemistry B (Twenty First Century Science)?

We appreciate that one size doesn't fit all so we offer two suites of qualifications in each science:

Chemistry A – Provides a flexible approach to teaching. The specification is divided into topics, each covering different key concepts of chemistry. Teaching of practical skills is integrated with the theoretical topics and they are assessed through the written papers.

Chemistry B – Learners study chemistry using a narrative-based approach. Ideas are introduced within relevant and interesting settings which help learners to anchor their conceptual knowledge of the range of chemical topics required at GCSE level. Practical skills are embedded within the specification and learners are expected to carry out practical work in preparation for a written examination that will specifically test these skills.

Chemistry B (Twenty First Century Science) specifications have been developed with the University of York Science Education Group (UYSEG) in conjunction with subject and teaching experts. Together we have aimed to produce a specification with up to date relevant content accompanied by a narrative to give context and an idea of the breath of teaching required. Our new GCSE (9–1) in Chemistry B (Twenty First Century Science) qualification builds on our existing popular course. We have based the development of our GCSE sciences on an understanding of what works well in centres large and small. We have undertaken a significant amount of consultation through our science forums (which include representatives from learned societies, HE, teaching and industry) and through focus groups with teachers.

The content is clear and logically laid out for both existing centres and those new to OCR, with assessment models that are straightforward to administer. We have worked closely with teachers to provide high quality support materials to guide you through the new qualifications.

Aims and learning outcomes

The Twenty First Century Science suite will:

- develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics
- develop understanding of the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them
- develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

1c. What are the key features of this specification?

Building on research, and on the principles of *Beyond 2000*, the Twenty First Century Science suite was originally developed by the University of York Science Education Group (UYSEG), the Nuffield Foundation and OCR.

The 2016 suite continues to recognise the diversity of interests and future intentions of the learner population who take a science qualification at GCSE level. The specifications will prepare learners for progression to further study of science, whilst at the same time offering an engaging and satisfying course for those who choose not to study academic science further.

The Twenty First Century Science suite will:

- take opportunities to link science to issues relevant to all learners as citizens, and to the cultural aspects of science that are of value and interest to all
- develop learners' abilities to evaluate knowledge claims critically, by looking at the nature, quality and extent of the evidence, and at the arguments that link evidence to conclusions
- develop learners' understanding of the concepts and models that scientists use to explain natural phenomena
- develop learners' ability to plan and carry out practical investigations and their understanding of the role of experimental work in developing scientific explanations.

Teacher support

The extensive support offered alongside this specification includes:

- **Delivery guides** – providing information on assessed content, the associated conceptual development and contextual approaches to delivery
- **Transition guides** – identifying the levels of demand and progression for different key stages for a particular topic and going on to provide links to high quality resources and 'checkpoint tasks' to assist teachers in identifying learners 'ready for progression'
- **Lesson elements –** written by experts, providing all the materials necessary to deliver creative classroom activities
- **Active Results** (see Section 1a)
- **ExamCreator** (see Section 1a).
- **Mock examinations service** – a free service offering a mock question paper and mark scheme (downloadable from a secure location).

Along with:

- Subject Specialists within the OCR science team to help with course queries
- Teacher training
- *Science Spotlight* (our termly newsletter)
- OCR Science community
- Practical Skills Handbook
- Maths Skills Handbook.

1d. How do I find out more information?

Whether new to our specifications, or continuing on from our legacy offerings, you can find more information on our webpages at www.ocr.org.uk

Visit our subject pages to find out more about the assessment package and resources available to support your teaching. The science team also release a termly newsletter *Science Spotlight* (despatched to centres and available from our subject pages).

Want to find out more?

You can contact the Science Subject Specialists:

ScienceGCSE@ocr.org.uk, 01223 553998

Join our Science community: http://social.ocr.org.uk/

Check what CPD events are available: www.cpdhub.ocr.org.uk

Follow us on Twitter: @ocr_science

2 The specification overview

2a. OCR's GCSE (9–1) in Chemistry B (Twenty First Century Science) (J258)

Learners are entered for either Foundation tier (components 01 and 02) **or** Higher tier (components 03 and 04) to be awarded the OCR GCSE (9–1) in Chemistry B (Twenty First Century Science).

<table>
<tr><th>Content Overview</th><th colspan="2">Assessment Overview</th></tr>
<tr><td colspan="3">Foundation tier, grades 5 to 1</td></tr>
<tr><td rowspan="2">Content is split into seven teaching chapters:
• Chapter C1: Air and water
• Chapter C2: Chemical patterns
• Chapter C3: Chemicals of the naturals environment
• Chapter C4: Material choices
• Chapter C5: Chemical analysis
• Chapter C6: Making useful chemicals
• Chapter C7: Ideas about Science
Both papers assess content from all seven chapters.</td><td>Breadth in chemistry
J258/01
90 marks
1 hour 45 minutes
Written paper</td><td>50%
of total
GCSE</td></tr>
<tr><td>Depth in chemistry
J258/02
90 marks
1 hour 45 minutes
Written paper</td><td>50%
of total
GCSE</td></tr>
<tr><td colspan="3">Higher tier, grades 9 to 4</td></tr>
<tr><td rowspan="2">Content is split into seven teaching chapters:
• Chapter C1: Air and water
• Chapter C2: Chemical patterns
• Chapter C3: Chemicals of the naturals environment
• Chapter C4: Material choices
• Chapter C5: Chemical analysis
• Chapter C6: Making useful chemicals
• Chapter C7: Ideas about Science
Both papers assess content from all seven chapters.</td><td>Breadth in chemistry
J258/03
90 marks
1 hour 45 minutes
Written paper</td><td>50%
of total
GCSE</td></tr>
<tr><td>Depth in chemistry
J258/04
90 marks
1 hour 45 minutes
Written paper</td><td>50%
of total
GCSE</td></tr>
</table>

2b. Content of GCSE (9–1) in Chemistry B (Twenty First Century Science) (J258)

Layout of specification content

The specification content is divided into seven chapters. The first six chapters describe the science content to be taught and assessed. The final chapter describes the *Ideas about Science* that should be taught, and will be assessed, in contexts from any of the preceding chapters. The *Ideas about Science* cover the requirements of *Working Scientifically*.

Within each chapter:

An overview summarises the science ideas included in the chapter, explaining why these ideas are relevant to learners living in the twenty first century and why it is desirable for learners to understand them.

Following the overview is a summary of the knowledge and understanding that learners should have gained from study at Key Stages 1 to 3. Some of these ideas are repeated in the content of the specification and while this material need not be retaught, it can be drawn upon to develop ideas at GCSE 9–1).

Learning at GCSE (9–1) is described in the tables that follows.

Teaching and learning narrative	Assessable learning outcomes	*Linked learning opportunities*
The teaching and learning narrative summarises the science story, including relevant *Ideas about Science* to provide contexts for the assessable learning outcomes.	The assessable learning outcomes set out the level of knowledge and understanding that learners are expected to demonstrate. The statements give guidance on the breadth and depth of learning. **Emboldened statements will only be assessed in Higher Tiers papers**. ⓘ *Advisory notes clarify the depth of cover required.*	The linked learning opportunities suggest ways to develop *Ideas about Science* and practical skills in context, and also highlight links to ideas in other chapters. Note, however, that *Ideas about Science* and practical skills may be taught, and can be assessed, in any context.

The Assessment Objectives in Section 3b make clear the range of ways in which learners will be required to demonstrate their knowledge and understanding in the assessments, and the Sample Assessment Materials (provided on the OCR website at www.ocr.org.uk) provide examples.

A summary of the content for the GCSE (9–1) Chemistry B (Twenty First Century Science) course is as follows:

Chapter C1: Air and water	Chapter C2: Chemical patterns	Chapter C3: Chemicals of the natural environment
C1.1 How has the Earth's atmosphere changed over time, and why? C1.2 Why are there temperatures changes in chemical reactions? C1.3 What is the evidence for climate change, why is it occurring? C1.4 How can scientists help improve the supply of potable water?	C2.1 How have our ideas about atoms developed over time? C2.2 What does the Periodic Table tell us about the elements? C2.3 How do metals and non-metals combine to form compound? C2.4 How are equations used to represent chemical reactions? C2.5 What are the properties of transition metals?	C3.1 How are the atoms held together in a metal? C3.2 How are metals with different reactivities extracted? C3.3 What are electrolytes and what happens during electrolysis? C3.4 Why is crude oil important as a source of new materials?
Chapter C4: Material choices	**Chapter C5: Chemical analysis**	**Chapter C6: Making useful chemicals**
C4.1 How is data used to choose a material for a particular use? C4.2 What are the different types of polymers? C4.3 How do bonding and structure affect properties of materials? C4.4 Why are nanoparticles so useful? C4.5 What happens to products at the end of their useful life?	C5.1 How are chemicals separated and tested for purity? C5.2 How do chemists find the composition of unknown samples? C5.3 How are the amounts of substances in reactions calculated? C5.4 How are the amounts of chemicals in solution measured?	C6.1 What useful products can be made from acids? C6.2 How do chemists control the rate of reactions? C6.3 What factors affect the yield of chemical reactions? C6.4 How are chemicals made on an industrial scale?

Chapter C7: Ideas about Science
IaS1 What needs to be considered when investigating a phenomenon scientifically? IaS2 What conclusions can we make from data? IaS3 How are scientific explanations developed? IaS4 How do science and technology impact society?

2c. Content of chapters C1 to C7

Chapter C1: Air and water

Overview

The quality of our air and water is a major world concern. Chemists monitor our air and water, and work to minimise the impact of human activities on their quality.

In topic C1.1, the context of changes in the Earth's atmosphere is used to explore the particle model and its limitations when explaining changes of state, and the principles of balancing equations for combustion reactions. Topic C1.2 explores the evidence for climate change, asking why it might be occurring and how serious a threat it is. Learners consider environmental and health consequences of some air pollutants and climate change, and learn how scientists are helping to provide options for improving air quality and combatting global warming.

As a development of ideas about burning fuels, topic C1.3 considers bonding in small molecules and temperature changes in chemical reactions.

Finally, topic C1.4 explores the need for increasing the amount of potable water worldwide, and techniques for obtaining potable water from ground, waste and salt water.

Learning about air and water before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- be able to explain the properties of the different states of matter (solid, liquid and gas) in terms of the particle model, including gas pressure
- appreciate the differences between atoms, elements and compounds
- be familiar with the use of chemical symbols and formulae for elements and compounds
- know about conservation of mass, changes of state and chemical reactions
- be able to explain changes of state in terms of the particle model
- know that there are energy changes on changes of state (qualitative)
- know about exothermic and endothermic chemical reactions (qualitative)
- understand the carbon cycle
- know the composition of the Earth's atmosphere today
- know about the production of carbon dioxide by human activity and its impact on climate.

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

Learning about air and water at GCSE (9–1)

C1.1 How has the Earth's atmosphere changed over time, and why?

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
The Earth, its atmosphere and its oceans are made up from elements and compounds in different states. The particle can be used to describe the states of these substances and what happens to the particles when they change state. The particle model can be represented in different ways, but these are limited because they do not accurately represent the scale or behaviour of actual particles, they assume that particles are inelastic spheres, and they do not fully take into account the different interactions between particles. The formation of our early atmosphere and oceans, and the state changes involved in the water cycle, can be described using the particle model.	1. recall and explain the main features of the particle model in terms of the states of matter and change of state, distinguishing between physical and chemical changes and recognise that the particles themselves do not have the same properties as the bulk substances
	2. explain the limitations of the particle model in relation to changes of state when particles are represented by inelastic spheres
	3. use ideas about energy transfers and the relative strength of forces between particles to explain the different temperatures at which changes of state occur
	4. use data to predict states of substances under given conditions
Explanations about how the atmosphere was formed and has changed over time are based on evidence, including the types and chemical composition of ancient rocks, and fossil evidence of early life. (IaS3) Explanations include ideas about early volcanic activity followed by cooling of the Earth resulting in formation of the oceans. The evolution of photosynthesising organisms, formation of sedimentary rocks, oil and gas, and the evolution of animals led to changes in the amounts of carbon dioxide and oxygen in the atmosphere.	5. interpret evidence for how it is thought the atmosphere was originally formed
	6. describe how it is thought an oxygen-rich atmosphere developed over time

Linked learning opportunities

Practical work:

- measure temperature against time and plot a cooling curve for stearic acid or heating curve for ice

Ideas about Science:

- use the particle model to explain state changes (IaS3)
- distinguish data from explanatory ideas in accounts of how the atmosphere was formed (IaS3)

C1.1 How has the Earth's atmosphere changed over time, and why?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Our modern lifestyle has created a high demand for energy. Combustion of fossil fuels for transport and energy generation leads to emissions of pollutants. Carbon monoxide, sulfur dioxide, nitrogen oxides and particulates directly harm human health. Some pollutants cause indirect problems to humans and the environment by the formation of acid rain and smog. Scientists monitor the concentration of these pollutants in the atmosphere and strive to develop approaches to maintaining air quality. (IaS4)	7. describe the major sources of carbon monoxide and particulates (incomplete combustion), sulfur dioxide (combustion of sulfur impurities in fuels), oxides of nitrogen (oxidation of nitrogen at high temperatures and further oxidation in the air)
	8. explain the problems caused by increased amounts of these substances and describe approaches to decreasing the emissions of these substances into the atmosphere including the use of catalytic converters, low sulfur petrol and gas scrubbers to decrease emissions
The combustion reactions of fuels and the formation of pollutants can be represented using word and symbol equations. The formulae involved in these reactions can be represented by models, diagrams or written formulae. The equations should be balanced. When a substance chemically combines with oxygen it is an example of oxidation. Combustion reactions are therefore oxidation. Some gases involved in combustion reactions can be identified by their chemical reactions.	9. use chemical symbols to write the formulae of elements and simple covalent compounds
	10. use the names and symbols of common elements and compounds and the principle of conservation of mass to write formulae and balanced chemical equations
	11. use arithmetic computations and ratios when balancing equations M1a, M1c
	12. describe tests to identify oxygen, hydrogen and carbon dioxide *PAG2*

Linked learning opportunities

Ideas about Science:

- unintended impacts of burning fossil fuels on air quality (IaS4)
- catalytic converters, low sulfur petrol and gas scrubbers as positive applications of science (IaS4)

C1.1 How has the Earth's atmosphere changed over time, and why?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
	13. explain oxidation in terms of gain of oxygen

Linked learning opportunities

C1.2 Why are there temperature changes in chemical reactions?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
When a fuel is burned in oxygen the surroundings are warmed; this is an example of an exothermic reaction. There are also chemical reactions that cool their surroundings; these are endothermic reactions. Energy has to be supplied before a fuel burns. For all reactions, there is a certain minimum energy needed to break bonds so that the reaction can begin. This is the activation energy. The activation energy, and the amount of energy associated with the reactants and products, can be represented using a a reaction profile. Atoms are rearranged in chemical reactions. This means that bonds between the atoms must be broken and then reformed. Breaking bonds requires energy (the activation energy) whilst making bonds gives out energy. **Energy changes in a reaction can be calculated if we know the bond energies involved in the reaction.**	1. distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings
	2. draw and label a reaction profile for an exothermic and an endothermic reaction, identifying activation energy
	3. explain activation energy as the energy needed for a reaction to occur
	4. interpret charts and graphs when dealing with reaction profiles
	5. calculate energy changes in a chemical reaction by considering bond breaking and bond making energies M1a, M1c, M1d
	6. carry out arithmetic computations when calculating energy changes M1a, M1c, M1d
	7. describe how you would investigate a chemical reaction to determine whether it is endothermic or exothermic

Linked learning opportunities

Practical work:

investigate different chemical reactions to find out if they are exothermic or endothermic

C1.2 Why are there temperature changes in chemical reactions?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Using hydrogen fuel cells as an alternative to fossil fuels for transport is one way to decrease the emission of pollutants in cities (IaS4). The reaction in the fuel cell is equivalent to the combustion of hydrogen and gives the same product (water) but the energy drives an electric motor rather than an internal combustion engine. However, hydrogen is usually produced by electrolysis, which may use electricity generated from fossil fuels so pollutants may be produced elsewhere. There are difficulties in storing gaseous fuel for fuel cells which limits their practical value for use in cars.	8. recall that a chemical cell produces a potential difference until the reactants are used up 9. evaluate the advantages and disadvantages of hydrogen/oxygen and other fuel cells for given uses	**Ideas about Science:** fuel cells as a positive application of science to mitigate the effects of emissions (IaS4)

C1.3 What is the evidence for climate change, why is it occurring?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Some electromagnetic radiation from the Sun passes through the atmosphere and is absorbed by the Earth warming it. The warm Earth emits infrared radiation which some gases, including carbon dioxide and methane, absorb and re-emit in all directions; this keeps the Earth warmer than it would otherwise be and is called the greenhouse effect. Without the greenhouse effect the Earth would be too cold to support life. The proportion of greenhouse gases in the Earth's atmosphere has increased over the last 200 years as a result of human activities. There are correlations between changes in the composition of the atmosphere, consumption of fossil fuels and global temperatures over time. Although there are uncertainties in the data, most scientists now accept that recent climate change can be explained by increased greenhouse gas emissions. Patterns in the data have been used to propose models to predict future climate changes. As more data is collected, the uncertainties in the data decrease, and our confidence in models and their predictions increases (IaS3). Scientists aim to reduce emissions of greenhouse gases, for example by reducing fossil fuel use and removing gases from the atmosphere by carbon capture and reforestation. These actions need to be supported by public regulation. Even so, it is difficult to mitigate the effect of emissions due to the very large scales involved. Each new measure may have unforeseen impacts on	1. describe the greenhouse effect in terms of the interaction of radiation with matter 2. evaluate the evidence for additional anthropogenic causes of climate change, including the correlation between change in atmospheric carbon dioxide concentration and the consumption of fossil fuels, and describe the uncertainties in the evidence base 3. describe the potential effects of increased levels of carbon dioxide and methane on the Earth's climate, including where crops can be grown, extreme weather patterns, melting of polar ice and flooding of low land 4. describe how the effects of increased levels of carbon dioxide and methane may be mitigated, including consideration of scale, risk and environmental implications 5. extract and interpret information from charts, graphs and tables M2c, M4a 6. use orders of magnitude to evaluate the significance of data M2h

Linked learning opportunities

Specification links:

- What is global warning and what is the evidence for it? (P1.3)

Practical work:

- Investigate climate change models – both physical models and computer models

Ideas about Science:

- Use ideas about correlation and cause, about models and the way science explanations are developed when discussing climate change (IaS 3)
- Risks, costs and benefits of fuel use and its sustainability and effects on climate (IaS4)

C1.3 What is the evidence for climate change, why is it occurring?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
the environment, making it difficult to make reasoned judgments about benefits and risks (IaS4).	

Linked learning opportunities

- public regulation of targets for emissions and reasons why different decisions on issues related to climate change might be made in view of differences in personal, social, or economic context (IaS4)

C1.4 How can scientists help improve the supply of potable water?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
The increase in global population means there is a greater need for potable water. Obtaining potable water depends on the availability of waste, ground or salt water and treatment methods. Chlorine is used to kill microorganisms in water. The benefits of adding chlorine to water to stop the spread of waterborne diseases outweigh risks of toxicity. In some countries the chlorination of water is subject to public regulation, but other parts of the world are still without chlorinated water and this leads to a higher risk of disease. (IaS4)	1. describe the principal methods for increasing the availability of potable water, in terms of the separation techniques used, including the ease of treating waste, ground and salt water including filtration and membrane filtration; aeration, use of bacteria; chlorination and distillation (for salt water). 2. describe a test to identify chlorine (using blue litmus paper) *PAG2*

Linked learning opportunities

Ideas about Science:

- technologies to increase the availability of potable water can make a positive difference to people's lives (IaS4)
- access to treated water raises issues about risk, cost and benefit and providing treated water for all raises ethical issues (IaS4)

Practical work:

- identify unknown gases

Chapter C2: Chemical patterns

Overview

This chapter features a central theme of modern chemistry: it traces the development of ideas about the structure of the atom and the arrangement of elements in the modern Periodic Table. Both stories show how scientific theories develop as new evidence is made available that either supports or contradicts current ideas.

Atomic structure is used to help explain the behaviour of the elements. Trends and patterns shown by the physical and chemical properties in groups and in the transition metals are studied.

The first two topics of the chapter give opportunities for learners to develop understanding of ideas about science; how scientific knowledge develops, the relationship between evidence and explanations, and how the scientific community responds to new ideas. The later topics present some of the most important models which underpin an understanding of atoms, chemical behaviour and patterns and how reactions are represented in chemical equations.

Topic C2.1 looks at the development of ideas about the atom and introduces the modern model for atomic structure, including electron arrangements. Topic C2.2 considers the development of the modern Periodic Table and the patterns that exist within it, focusing on Groups 1 and 7, with some reference to Group 0. Topic C2.3 focuses on extending an understanding of atomic structure to explain the ionic bonding between ions in ionic compound. This leads on to Topic C2.4 which studies using equations and symbols to summarise reactions. **Finally in C2.5, separate science only content addresses the unique nature of the transition elements.**

Learning about Chemical Patterns before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- know the properties of the different states of matter (solid, liquid and gas) in terms of the particle model, including gas pressure
- know changes of state in terms of the particle model
- be aware of a simple (Dalton) atomic model
- know differences between atoms, elements and compounds
- know chemical symbols and formulae for elements and compounds
- know conservation of mass changes of state and chemical reactions
- understand chemical reactions as the rearrangement of atoms
- be able to represent chemical reactions using formulae and using equations
- know some displacement reactions
- know what catalysts do
- be aware of the principles underpinning the Mendeleev Periodic Table
- know some ideas about the Periodic Table: periods and groups; metals and non-metals
- know how some patterns in reactions can be predicted with reference to the Periodic Table
- know some properties of metals and non-metals.

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

Learning about chemical patterns at GCSE (9–1)

C2.1 How have our ideas about atoms developed over time?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
The modern model of the atom developed over time. Stages in the development of the model included ideas by the ancient Greeks (4 element ideas), Dalton (first particle model), Thomson ('plum pudding' model), Rutherford (idea of atomic nucleus) and Bohr (shells of electrons). Models were rejected, modified and extended as new evidence became available. The development of the atomic model involved scientists suggesting explanations, making and checking predictions based on their explanations, and building on each other's work (IaS3). The Periodic Table can be used to find the atomic number and relative atomic mass of an atom of an element, and then work out the numbers of protons, neutrons and electrons. The number of electrons in each shell can be represented by simple conventions such as dots in circles or as a set of numbers (for example, sodium as 2.8.1). Atoms are small – about 10^{-10} m across, and the nucleus is at the centre, about a hundred-thousandth of the diameter of the atom. Molecules are larger, containing from two to hundreds of atoms. Objects that can be seen with the naked eye contain millions of atoms.	1. describe how and why the atomic model has changed over time to include the main ideas of Dalton, Thomson, Rutherford and Bohr
	2. describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with most of the mass in the nucleus
	3. recall relative charges and approximate relative masses of protons, neutrons and electrons
	4. estimate the size and scale of atoms relative to other particles M1d
	5. recall the typical size (order of magnitude) of atoms and small molecules
	6. relate size and scale of atoms to objects in the physical world M1d
	7. calculate numbers of protons, neutrons and electrons in atoms, given atomic number and mass number of isotopes or by extracting data from the Periodic Table M1a

Linked learning opportunities

Specification links:

- atoms and radiation (P5.1What is radioactivity?)

Ideas about Science:

- understanding how scientific explanations and models develop in the context of changing ideas about the atomic model (IaS3)

C2.2 What does the Periodic Table tell us about the elements?

<table>
<tr><th>Teaching and learning narrative</th><th>Assessable learning outcomes
Learners will be required to:</th></tr>
<tr><td rowspan="6">Elements in the modern Periodic Table are arranged in periods and groups, based on their atomic numbers. Elements in the same group have the same number of electrons in their outer shells. The number of electron shells increases down a group but stays the same across a period.

Mendeleev proposed the first arrangement of elements in the Periodic Table. Although he did not know about atomic structure, he reversed the order of some elements with respect to their masses, left gaps for undiscovered elements and predicted their properties. His ideas were accepted because when certain elements were discovered they fitted his gaps and the development of a model for atomic structure supported his arrangement. The later determination of the number of protons in atoms provided an explanation for the order he proposed (IaS3).

The Periodic Table shows repeating patterns in the properties of the elements. Metals and non-metals can be identified by their position in the Periodic Table and by comparing their properties (physical properties including electrical conductivity).

Properties of elements within a group show trends. The reactivity of Group 1 metals elements increases down the group, shown by their reactivity with moist air, water and chlorine.

The Group 7 halogens are non-metals and become less reactive down the group. This is shown in reactions such</td><td>1. explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms and hence to its atomic number</td></tr>
<tr><td>2. describe how Mendeleev organised the elements based on their properties and relative atomic masses</td></tr>
<tr><td>3. describe how discovery of new elements and the ordering elements by atomic number supports Mendeleev’s decisions to leave gaps and reorder some elements</td></tr>
<tr><td>4. describe metals and non-metals and explain the differences between them on the basis of their characteristic physical and chemical properties, including melting point, boiling point, state and appearance, density, formulae of compounds and relative reactivity</td></tr>
<tr><td>5. recall the simple properties of Group 1 elements including their reaction with moist air, water, and chlorine</td></tr>
<tr><td>6. recall the simple properties of Group 7 elements including their states and colours at room temperature and pressure, their colours as gases, their reactions with Group 1 elements and their displacement reactions with other metal halides</td></tr>
</table>

Linked learning opportunities

Practical work:

- reactions of Group 1 (demonstration) and Group 7 (for example displacement)

Ideas about Science:

- understanding how scientific explanations and models develop, in the context of the Periodic Table (IaS3)

Ideas about Science:

- making and testing predictions about trends and patterns in the Periodic Table (IaS1)

C2.1 How have our ideas about atoms developed over time?		Linked learning opportunities
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
as their displacement reactions with compounds of other halogens in the group.	7. predict possible reactions and probable reactivity of elements from their positions in the Periodic Table	
	8. describe experiments to identify the reactivity pattern of Group 7 elements including displacement reactions *PAG1*	
	9. describe experiments to identify the reactivity pattern of Group 1 elements	

C.2.3 How do metals and non-metals combine to form compounds?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Group 0 contains elements with a full outer shell of electrons. This arrangement is linked to their inert, unreactive properties. They exist as single atoms and hence are gases with low melting and boiling points. Group 1 elements combine with Group 7 elements by ionic bonding. This involves a transfer of electrons leading to charged ions. Atoms and ions can be represented using dot and cross diagrams as simple models (IaS3). Metals, such as Group 1 metals, lose electrons from the outer shell of their atoms to form ions with complete outer shells and with a positive charge. Non-metals, such as Group 7, form ions with a negative charge by gaining electrons to fill their outer shell. The number of electrons lost or gained determines the charge on the ion. The properties of ionic compounds such as Group 1 halides can be explained in terms of the ionic bonding. Positive ions and negative ions are strongly attracted together and form giant lattices. Ionic compounds have high melting points in comparison to many other substances due to the strong attraction between ions which means a large amount of energy is needed to break the attraction between the ions. They dissolve in water because their charges allow them to interact with water molecules. They conduct electricity when molten or in solution because the charged ions can move, but not when solid because the ions are held in fixed positions. The arrangement of ions can be represented in both 2-D	1. recall the simple properties of Group 0 including their low melting and boiling points, their state at room temperature and pressure and their lack of chemical reactivity 2. explain how observed simple properties of Groups 1, 7 and 0 depend on the outer shell of electrons of the atoms and predict properties from given trends down the groups 3. explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number 4. explain how the atomic structure of metals and non-metals relates to their position in the Periodic Table 5. describe the nature and arrangement of chemical bonds in ionic compounds 6. explain ionic bonding in terms of electrostatic forces and transfer of electrons 7. calculate numbers of protons, neutrons and electrons in atoms and ions, given atomic number and mass number or by using the Periodic Table M1a 8. construct dot and cross diagrams for simple ionic substances 9. explain how the bulk properties of ionic materials are related to the type of bonds they contain

Linked learning opportunities

Practical work:

- test the properties of ionic compounds

Ideas about Science:

- dot and cross diagrams as models of atoms and ions ,and the limitations of these models (IaS3)
- 2-D and 3-D representations as simple models of the arrangement of ions, and the limitations of these models (IaS3)

C.2.3 How do metals and non-metals combine to form compounds?		Linked learning opportunities
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
and 3-D. These representations are simple models which have limitations, for example they do not fully show the nature or movement of the electrons or ions, the interaction between the ions, their arrangement in space, their relative sizes or scale (IaS3).	10. use ideas about energy transfers and the relative strength of attraction between ions to explain the melting points of ionic compounds compared to substances with other types of bonding	
	11. describe the limitations of particular representations and models of ions and ionically bonded compounds, including dot and cross diagrams, and 3-D representations	
	12. translate information between diagrammatic and numerical forms and represent three dimensional shapes in two dimensions and vice versa when looking at chemical structures for ionic compounds M4a, M5b	

C.2.4 How are equations used to represent chemical reactions?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
The reactions of Group 1 and Group 7 elements can be represented using word equations and balanced symbol equations with state symbols. The formulae of ionic compounds, including Group 1 and Group 7 compounds can be worked out from the charges on their ions. Balanced equations for reactions can be constructed using the formulae of the substances involved, including hydrogen, water, halogens (chlorine, bromine and iodine) and the hydroxides, chlorides, bromides and iodides (halides) of Group 1 metals.	1. use chemical symbols to write the formulae of elements and simple covalent and ionic compounds 2. use the formulae of common ions to deduce the formula of Group 1 and Group 7 compounds 3. use the names and symbols of the first 20 elements, Groups 1, 7 and 0 and other common elements from a supplied Periodic Table to write formulae and balanced chemical equations where appropriate 4. describe the physical states of products and reactants using state symbols (s, l, g and aq)	

C2.5 What are the properties of the transition metals?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
The transition metals do not show group properties like the elements in Group 1 and Group 7; they form a family of elements with general properties that are different from those of other metals. These properties make the transition metals particularly useful. They all have relatively high melting points and densities. Transitions metals are generally less reactive than Group 1 metals, and some are very unreactive (for example silver and gold). Some transition metal elements and their compounds are used widely in the manufacture of consumer goods and as catalysts in industry, both of which represent beneficial applications of science (IaS4).	1. recall the general properties of transition metals (melting point, density, reactivity, formation of coloured ions with different charges and uses as catalysts) and exemplify these by reference to copper, iron, chromium, silver and gold

Linked learning opportunities

Practical work:

- investigate colours of transition metal compounds, and their effectiveness as catalysts

Chapter C3: Chemicals of the natural environment

Overview

Our way of life depends on a wide range of products made from natural resources. The Earth's crust provides us with metal ores and crude oil and our use of these impacts on the natural environment. Chemistry is fundamental to an understanding of the scale and significance of this human activity.

In topic C3.1 the properties of metals are related to their structure and bonding, and in C3.2 learners discover why the reactivity of a metal determines how it is extracted from its ores and how new technologies enable us to extract metals from poor quality ores.

Electrolysis is explained in topic C3.3, and learners learn about the wide variety of products made by electrolysis.

Finally, topic C3.4 covers the separation of crude oil into fractions and the use of these fractions to make other chemicals and polymers. Within this context learners study the properties of simple molecules in relation to covalent bonding and intermolecular forces.

Learning about chemicals of the natural environment before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- know the differences between atoms, elements and compounds
- be familiar with the use of chemical symbols and formulae for elements and compounds
- be familiar with the use of formulae and equations to represent chemical reactions
- understand chemical reactions as the rearrangement of atoms
- know about reactions of acids with metals to produce a salt plus hydrogen
- know some displacement reactions
- know the order of metals and carbon in the reactivity series
- know that carbon is used to obtain metals from metal oxides.

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

Learning about chemicals of the natural environment at GCSE (9–1)

C3.1 How are the atoms held together in a metal?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Chemists use a model of metal structure to explain the properties of metals (IaS3). In the model, metal atoms are arranged closely together in a giant structure, held together by attraction between the positively charged atoms and a 'sea' of negatively charged electrons. Metals are malleable and ductile because the ions can slide over each other but still be held together by the electrons; they conduct electricity and heat because their electrons are free to move; and they have high boiling points and melting points due to the strong electrostatic attraction between metal ions and the electrons. These properties of metals make them useful.	1. describe the nature and arrangement of chemical bonds in metals 2. explain how the bulk properties of metals are related to the type of bonds they contain

Linked learning opportunities

Ideas about Science:

- use the model of metal structure to explain properties of metals (IaS3)

C3.2 How are metals with different reactivities extracted?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Metals can be placed in an order of reactivity by looking at their reactions with water, dilute acid and compounds of other metals. The relative reactivity of metals enables us to make predictions about which metals react fastest or which metal will displace another. When metals react they form ionic compounds. The metal atoms gain one or more electrons to become positive ions. The more easily this happens the more reactive the metal. These reactions can be represented by word and symbol equations including state symbols. **Ionic equations show only the ions that change in the reaction and show the gain or loss of electrons. They are useful for representing displacement reactions because they show what happens to the metal ions during the reaction.** The way a metal is extracted depends on its reactivity. Some metals are extracted by reacting the metal compound in their ores with carbon. Carbon is a non-metal but can be placed in the reactivity series of the metals between aluminium and zinc. Metals below carbon in the reactivity series are extracted from their ores by displacement by carbon. The metal in the ore is reduced and carbon is oxidised. Highly reactive metals above carbon in the reactivity series are extracted by electrolysis. Scientists are developing methods of extracting the more unreactive metals from their ores using bacteria or plants. These methods can extract metals from waste	1. deduce an order of reactivity of metals based on experimental results including reactions with water, dilute acid and displacement reactions with other metals 2. explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion to include potassium, sodium, calcium, aluminium, magnesium, zinc, iron, lead, [hydrogen], copper, silver 3. use the names and symbols of common elements and compounds and the principle of conservation of mass to write formulae and balanced chemical equations **and ionic equations** 4. explain, using the position of carbon in the reactivity series, the principles of industrial processes used to extract metals, including the extraction of zinc 5. explain why electrolysis is used to extract some metals from their ores **6. evaluate alternative biological methods of metal extraction (bacterial and phytoextraction)**

Linked learning opportunities

Practical work:

- Investigate the reactivity of different metals with water and dilute acid
- Investigate the reactivity of Zn, Fe and Cu by heating each metal with oxides of each of the other two metals

Specification links:

- C1.1 introduces oxidation

Ideas about Science:

- impacts of metal extraction on the environment, the measures scientists are taking to mitigate them, and the risks, costs and benefits of different courses of action

C3.2 How are metals with different reactivities extracted?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
material, reduce the need to extract 'new' ores, reduce energy costs, and reduce the amount of toxic metals in landfill. However, these methods do not produce large quantities of metals quickly (IaS4).		(IaS4)

C3.3 What are electrolytes and what happens during electrolysis?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Electrolysis is used to extract reactive metals from their ores. Electrolysis is the decomposition of an electrolyte by an electric current. Electrolytes include molten and dissolved ionic compounds. In both cases the ions are free to move. During electrolysis non-metal ions lose electrons to the anode to become neutral atoms. Metal (or hydrogen) ions gain electrons at the cathode to become neutral atoms. The addition or removal of electrons can be used to identify which species are reduced and which are oxidised. These changes can be summarised using half equations. Electrolysis is used to extract reactive metals from their molten compounds. During the electrolysis of aluminium, aluminium oxide is heated to a very high temperature. Positively charged aluminium ions gain electrons from the cathode to form atoms. Oxygen ions lose electrons at the anode and form oxygen molecules which react with carbon electrodes to form carbon dioxide. The	1. describe electrolysis in terms of the ions present and reactions at the electrodes 2. predict the products of electrolysis of binary ionic compounds in the molten state 3. recall that metals (or hydrogen) are formed at the cathode and non-metals are formed at the anode in electrolysis using inert electrodes **4. use the names and symbols of common elements and compounds and the principle of conservation of mass to write half equations** **5. explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced** 6. explain how electrolysis is used to extract some metals from their ores including the extraction of aluminium 7. describe competing reactions in the electrolysis of	**Practical work:** • investigate what type of substances are electrolytes **Practical work:**

process uses a large amount of energy for both the high temperature and the electricity involved in electrolysis. Some extraction methods, such as the recovery of metals from waste heaps, give a dilute aqueous solution of metals ions. When an electric current is passed through an aqueous solution the water is electrolysed as well as the ionic compound. Less reactive metals such as silver or copper form on the negative electrode. If the solution contains ions of more reactive metals, hydrogen gas forms from the hydrogen ions from the water. Similarly, oxygen usually forms at the positive electrode from hydroxide ions from the water. A concentrated solution of chloride ions forms chlorine at the positive electrode.	aqueous solutions of ionic compounds in terms of the different species present, including the formation of oxygen, chlorine and the discharge of metals or hydrogen linked to their relative reactivity 8. describe the technique of electrolysis of an aqueous solution of a salt *PAG2*	• investigate the effects of concentration of aqueous solution, current, voltage on the electrolysis of sodium chloride

C3.4 Why is crude oil important as a source of new materials?

Teaching and learning narrative

Crude oil is mixture of hydrocarbons. It is used as a source of fuels and as a feedstock for making chemicals (including polymers) for a very wide range of consumer products. Almost all of the consumer products we use involve the use of crude oil in their manufacture or transport.

Crude oil is finite. If we continue to burn it at our present rate it will run out in the near future. Crude oil makes a significant positive difference to our lives, but our current use of crude oil is not sustainable. Decision about the use of crude oil must balance short-term benefits with the need to conserve this resource for future g Crude oil is a mixture. It needs to be separated into groups of molecules of similar size called fractions. This is done by fractional distillation. Fractional distillation depends on the different boiling points of the hydrocarbons, which in turn is related to the size of the molecules and the intermolecular forces between them.

The fractions are mixtures, mainly of alkanes, with a narrow range of boiling points. The first four alkanes show typical properties of a homologous series: each subsequent member increases in size by CH_2, they have a general formula and show trends in their physical and chemical properties.

The molecular formula of an alkane shows the number of atoms present in each molecule. These formulae can be simplified to show the simplest ratio of carbon to

Assessable learning outcomes

Learners will be required to:

1. recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry
2. explain how modern life is crucially dependent upon hydrocarbons and recognise that crude oil is a finite resource
3. describe and explain the separation of crude oil by fractional distillation
   PAG3
4. describe the fractions of crude oil as largely a mixture of compounds of formula C_nH_{2n+2} which are members of the alkane homologous series
5. use ideas about energy transfers and the relative strength of chemical bonds and intermolecular forces to explain the different temperatures at which changes of state occur
6. deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or diagram and vice versa
7. use arithmetic computation and ratio when determining empirical formulae
   M1c

Linked learning opportunities

Ideas about Science:

- decision making in the context of the use of crude oil for fuels and as a feedstock (IaS4)

C3.4 Why is crude oil important as a source of new materials?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
hydrogen atoms. This type of formula is an empirical formula (IaS4). Small molecules like alkanes and many of those met in chapter C1 contain non-metal atoms which are bonded to each other by covalent bonds. A covalent bond is a strong bond between two atoms that formed from a shared pair of electrons. A covalent bond can be represented by a dot and cross diagram. Molecules can be shown as molecular or empirical formulae, displayed formulae (which show all of the bonds in the molecule) or in a 3 dimensional 'balls and stick' model. Simple molecules have strong covalent bonds joining the atoms within the molecule, but they only have weak intermolecular forces. No covalent bonds are broken when simple molecules boil. The molecules move apart when given enough energy to overcome the intermolecular forces. This explains their low melting and boiling points. Cracking long chain alkanes makes smaller more useful molecules that are in great demand as fuels (for example petrol). Cracking also yields alkenes – hydrocarbons with carbon-carbon double bonds. Alkenes are much more reactive than alkanes and can react to make a very wide range of products including polymers. Without cracking, we would need to extract a	8. describe the arrangement of chemical bonds in simple molecules 9. explain covalent bonding in terms of the sharing of electrons 10. construct dot and cross diagrams for simple covalent substances 11. represent three dimensional shapes in two dimensions and vice versa when looking at chemical structures for simple molecules M5b 12. describe the limitations of dot and cross diagrams, ball and stick models and two and three dimensional representations when used to represent simple molecules 13. translate information between diagrammatic and numerical forms M4a 14. explain how the bulk properties of simple molecules are related to the covalent bonds they contain and their bond strengths in relation to intermolecular forces 15. describe the production of materials that are more useful by cracking

Linked learning opportunities

Ideas about Science:

the use and limitations of models to represent bonding in simple molecules (IaS3)

Ideas about Science:

cracking as a positive application of science, to reduce extraction of crude oil and so conserves oil reserves (IaS4)

C3.4 Why is crude oil important as a source of new materials?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
lot more crude oil to meet demand for petrol and would waste some longer chain alkanes which are not as useful. Alkanes and alkenes burn in plenty of air to make carbon dioxide and water. The double bond makes alkenes more reactive than alkenes. Addition across the double bond means that alkenes decolourise bromine water and can form polymers. An alcohol has a structure like an alkane, but with one hydrogen replaced by an OH group. Alcohols burn to make carbon dioxide and water, and can also be oxidised to make carboxylic acids. All of these compounds are useful to make consumer products. They have different properties due to their different functional groups. Alkanes do not have a functional group and so are unreactive. The functional group of alkenes – the double bond – is used for addition reactions. The OH functional group in alcohols give them a range of uses including their use as solvents that are miscible with water. The carboxylic acid functional group behaves as a weak acid, and these acids are found in foods and personal care products.	16. recognise functional groups and identify members of the same homologous series 17. name and draw the structural formulae, using fully displayed formulae, of the first four members of the straight chain alkanes and alkenes, alcohols and carboxylic acids 18. predict the formulae and structures of products of reactions (combustion, addition across a double bond and oxidation of alcohols to carboxylic acids) of the first four and other given members of these homologous series 19. recall that it is the generality of reactions of functional groups that determine the reactions of organic compounds

Linked learning opportunities

Practical work:

- investigate the reactions of alkanes, alkenes and alcohols

Ideas about Science:

- the use of models to represent functional groups in homologous series (IaS3)

Chapter C4: Material choices

Overview

Our society uses a large range of materials and products that have been developed, tested and modified by the work of chemists. Materials used to make a particular product need to meet a specification which describes the properties the material needs to make it suitable for a particular use. This chapter looks at a range of different materials and investigates their properties in the context of their suitability for making consumer products. The chapter also considers how the life cycle of a product is assessed in its journey from raw material to final disposal.

Topic C4.1 considers the variety of materials that we use. Learners use data and information about the properties of ‘pure’ and composite materials to consider their suitability for making consumer products. Ceramics, glass, polymers, materials with giant structure and polymers are all considered.

Topic C4.2, moves on to look in detail at materials made using polymers. The topic covers the chemical reactions that happen when addition and condensation polymers form, and also studies naturally occurring polymers. This topic links closely to the discussion of bonding and structure in C4.3.

Topic C4.3 extends the study of properties to looking at bonding and structure in order to explain why a particular material behaves as it does. Learners learn about the bonding in metals, polymers and giant covalent structures and link the bonding and structure to the properties of the materials. They consider the usefulness of diagrams and models of bonding and structure to chemists who need to investigate and predict properties of materials so that they can make judgements about their usefulness or model likely changes in their properties if their structures are modified. A range of materials are studied, including new materials such as fullerenes and graphene.

Topic C4.4 looks specifically at the nature and uses of nanoparticles.

Topic C4.5 considers the life cycle of materials. The learners learn about the corrosion of metals such as iron and look at ways of extending the life of metal products by working to prevent corrosion. They also learn how the impact of our manufacture, use and disposal of consumer products is assessed using life cycle assessments.

Learning about material choices before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- distinguish between an object and the material from which it is made
- identify and name a variety of everyday materials, including wood, plastic, glass, metal, water, and rock
- describe the simple physical properties of a variety of everyday materials
- compare and group together a variety of everyday materials on the basis of their simple physical properties.
- have observed that some materials change state when they are heated or cooled, and measured the temperature at which this happens in degrees Celsius (°C)
- compare and group together everyday materials on the basis of their properties, including their hardness, solubility, transparency, conductivity (electrical and thermal), and response to magnets
- identify and compare the suitability of a variety of everyday materials, including wood, metal, plastic, glass, brick, rock, paper and cardboard for particular use
- know the differences between atoms, elements and compounds
- recognise chemical symbols and formulae for some elements and compounds
- know about the properties of ceramics, polymers and composites (qualitative).

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

Learning about material choices at GCSE (9–1)

C4.1 How is data used to choose a material for a particular use?

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Our society uses a large range of materials and products developed by chemists. Chemists assess materials by measuring their physical properties, and use data to compare different materials and to match materials to the specification of a useful product (IaS4). Composites have a very broad range of uses as they allow the properties of several materials to be combined. Composites may have materials combined on a bulk scale (for example using steel to reinforce concrete) or have nanoparticles incorporated in a material or embedded in a matrix. The range of uses of metals has been extended by the development of alloys. Alloys have different properties to pure metals due to the disruption of the metal lattice by atoms of different sizes. Chemists can match an alloy to the specification of properties for a new product.	1. compare quantitatively the physical properties of glass and clay ceramics, polymers, composites and metals, including melting point, softening temperature (for polymers), electrical conductivity, strength (in tension or compression), stiffness, flexibility, brittleness, hardness, density, ease of reshaping
	2. explain how the properties of materials are related to their uses and select appropriate materials given details of the usage required
	3. describe the composition of some important alloys in relation to their properties and uses, including steel

Linked learning opportunities

Practical work:

- Practical investigation of a range of materials leading to classification into categories.

Ideas about Science:

- The range of materials developed by chemists enhances the quality of life. (IaS4)
- Use and limitations of a model to represent alloy structure. (IaS3)

C4.2 What are the different types of polymers?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Polymers are long chain molecules that occur naturally and can also be made synthetically. Monomers based on alkenes from crude oil can be used to make a wide range of addition polymers that are generally known as 'plastics'. Addition polymers form when the double bonds in small molecules open to join the monomers together into a long chain. **Condensation polymers were developed to make materials that are substitutes for natural fibres such as wool and silk.** **Condensation polymers usually form from two different monomer molecules which contain different functional groups. The OH group from a carboxylic acid monomer and an H atom from another monomer join together to form a water molecule. Monomers that react with carboxylic acid monomers include alcohols (to make polyesters) and amines (to make polyamides). To make a polymer, each monomer needs two functional groups. The structure of the repeating unit of a condensation polymer can be worked out from the formulae of its monomers and vice versa.**	1. recall the basic principles of addition polymerisation by reference to the functional group in the monomer and the repeating units in the polymer 2. deduce the structure of an addition polymer from a simple monomer with a double bond and vice versa **3. explain the basic principles of condensation polymerisation by reference to the functional groups of the monomers, the minimum number of functional groups within a monomer, the number of repeating units in the polymer, and simultaneous formation of a small molecule** ***ⓘ Learners are not expected to recall the formulae of dicarboxylic acid, diamine and diol monomers***

Linked learning opportunities

Specification links:

The extraction and processing of crude oil, including the formation of alkenes by cracking. (C3.4)

Functional groups including carboxylic acids and alcohols. (C3.4)

Practical work:

Cracking poly(ethane) and testing the gas for unsaturation.

Testing properties of different polymer fibres.

C4.2 What are the different types of polymers?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Many natural polymers are essential to life. Genes are made of DNA, a polymer of four nucleotide monomers. Proteins (which are similar in structure to polyamides) are polymers of amino acids. Carbohydrates, including starch and cellulose, are polymers of sugars.	4. recall that DNA is a polymer made from four different monomers called nucleotides and that other important naturally-occurring polymers are based on sugars and amino-acids

Linked learning opportunities

Specification links:

Structure and function of DNA, and protein synthesis (B1.1)
The synthesis and breakdown of carbohydrates and proteins (B3.3)

Practical work

Breaking down starch using an enzyme and using food tests to identify starch and sugars

C4.3 How do bonding and structure affect properties of materials?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Different materials can be made from the same atoms but have different properties if they have different types of bonding or structures. Chemists use ideas about bonding and structure when they predict the properties of a new material or when they are researching how an existing material can be adapted to enhance its properties.	1. explain how the bulk properties of materials (including strength, melting point, electrical and thermal conductivity, brittleness, flexibility, hardness and ease of reshaping) are related to the different types of bonds they contain, their bond strengths in relation to intermolecular forces and the ways in which their bonds are arranged, recognising that the atoms themselves do not have these properties	**Specification links** ionic bonding and structure (C2.3) metallic bonding (C3.1) covalent bonds and intermolecular forces (C3.4) **Practical work:** Testing properties of simple covalent compounds, giant ionic and giant covalent substances, metals and polymers.
Carbon is an unusual element because it can form chains and rings with itself. This leads to a vast array of natural and synthetic compounds of carbon with a very wide range of properties and uses. 'Families' of carbon compounds are homologous series.	2. recall that carbon can form four covalent bonds 3. explain that the vast array of natural and synthetic organic compounds occurs due to the ability of carbon to form families of similar compounds, chains and rings	**Specification link:** The alkanes as a homologous series. (C3.4) **Ideas about Science:** Identify patterns in data related to polymers and allotropes of

C4.3 How do bonding and structure affect properties of materials?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Polymer molecules have the same strong covalent bonding as simple molecular compounds, but there are more intermolecular forces between the molecules due to their length. The strength of the intermolecular forces affects the properties of the solid. Giant covalent structures contain many atoms bonded together in a three-dimensional arrangement by covalent bonds. The ability of carbon to bond with itself gives rise to a variety of materials which have different giant covalent structures of carbon atoms. These are allotropes, and include diamond and graphite. These materials have different properties which arise from their different structures.	4. describe the nature and arrangement of chemical bonds in polymers with reference to their properties including strength, flexibility or stiffness, hardness and melting point of the solid
	4. describe the nature and arrangement of chemical bonds in polymers with reference to their properties including strength, flexibility or stiffness, hardness and melting point of the solid
	5. describe the nature and arrangement of chemical bonds in giant covalent structures
	6. explain the properties of diamond and graphite in terms of their structures and bonding, include melting point, hardness and (for graphite) conductivity and lubricating action
	7. represent three dimensional shapes in two dimensions and vice versa when looking at chemical structures e.g. allotropes of carbon M5b
	8. describe and compare the nature and arrangement of chemical bonds in ionic compounds, simple molecules, giant covalent structures, polymers and metals

Linked learning opportunities

carbon.(IaS2)

Use and limitations of a model to represent the structures of a range of materials. (IaS3)

C4.4 Why are nanoparticles so useful?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Nanoparticles have a similar scale to individual molecules. Their extremely small size means they can penetrate into biological tissues and can be incorporated into other materials to modify their properties. Nanoparticles have a very high surface area to volume ratio. This makes them excellent catalysts. Fullerenes form nanotubes and balls. The ball structure enables them to carry small molecules, for example carrying drugs into the body. The small size of fullerene nanotubes enables them to be used as molecular sieves and to be incorporated into other materials (for example to increase strength of sports equipment). Graphene sheets have specialised uses because they are only a single atom thick but are very strong with high electrical and thermal conductivity. Developing technologies based on fullerenes and graphene required leaps of imagination from creative thinkers (IaS3). There are concerns about the safety of some nanoparticles because not much is known about their effects on the human body. Judgements about a	1. compare 'nano' dimensions to typical dimensions of atoms and molecules 2. describe the surface area to volume relationship for different-sized particles and describe how this affects properties 3. describe how the properties of nanoparticulate materials are related to their uses including properties which arise from their size, surface area and arrangement of atoms in tubes or rings 4. explain the properties fullerenes and graphene in terms of their structures 5. explain the possible risks associated with some nanoparticulate materials including: a) possible effects on health due to their size and surface area b) reasons that there is more data about uses of nanoparticles than about possible health effects c) the relative risks and benefits of using nanoparticles for different purposes

Linked learning opportunities

Ideas about Science:

Discuss the potential benefits and risks of developments in nanotechnology (IaS4)

Development of nanoparticles and graphene relied on imaginative thinking. (IaS3)

C4.4 Why are nanoparticles so useful?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
particular use for nanoparticles depend on balancing the perceived benefit and risk (IaS4).	6. estimate size and scale of atoms and nanoparticles including the ideas that: a) nanotechnology is the use and control of structures that are very small (1 to 100 nanometres in size) b) data expressed in nanometres is used to compare the sizes of nanoparticles, atoms and molecules M1d	
	7. interpret, order and calculate with numbers written in standard form when dealing with nanoparticles M1b	
	8. use ratios when considering relative sizes and surface area to volume comparisons M1c	
	9. calculate surface areas and volumes of cubes M5c	

C4.5 What happens to products at the end of their useful life?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Iron is the most widely used metal in the world. The useful life of products made from iron is limited because iron corrodes. This involves an oxidation reaction with oxygen from the air. Barrier methods to prevent corrosion extend the useful life of metal products, which is good for consumers and has a positive outcome in terms of the life cycle assessment. Sacrificial protection uses a more reactive metal such as zinc to oxidise in preference to iron. This continues to prevent corrosion even if the coating on the metal is damaged.	1. describe the conditions which cause corrosion and the process of corrosion, and explain how mitigation is achieved by creating a physical barrier to oxygen and water and by sacrificial protection 2. explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced **3. explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced**
Life cycle assessments (LCAs) are used to consider the overall impact of our making, using and disposing of a product. LCAs involve considering the use of resources and the impact on the environment of all stages of making materials for a product from raw materials, making the finished product, the use of the product, transport and the method used for its disposal at the end of its useful life. It is difficult to make secure judgments when writing LCAs because there is not always enough data and people do not always follow recommended disposal advice (IaS4).	4. describe the basic principles in carrying out a life-cycle assessment of a material or product including a) the use of water, energy and the environmental impact of each stage in a life cycle, including its manufacture, transport and disposal b) incineration, landfill and electricity generation schemes c) biodegradable and non-biodegradable materials 5. interpret data from a life-cycle assessment of a material or product
Some products can be recycled at the end of their useful life. In recycling, the products are broken down into the materials used to make them; these materials are then used to make something else. Reusing products uses	6. describe the process where PET drinks bottles are reused and recycled for different uses, and explain why this is viable

Linked learning opportunities

Practical work:

Investigating the factors needed for rusting of iron or corrosion of other metals.

Investigating the effectiveness of corrosion prevention (barrier and sacrificial protection methods).

Ideas about Science:

use the example of applying scientific solutions to the problem of corrosion of metals to explain the idea of improving sustainability (IaS4)

use life cycle assessments to compare the sustainability of products and processes (IaS4)

C4.5 What happens to products at the end of their useful life?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
less energy than recycling them. Reusing and recycling both affects the LCA. Recycling conserves resources such as crude oil and metal ores, but will not be sufficient to meet future demand for these resources unless habits change. The viability of a recycling process depends on a number of factors: the finite nature of some deposits of raw materials (such as metal ores and crude oil), availability of the material to be recycled, economic and practical considerations of collection and sorting, removal of impurities, energy use in transport and processing, scale of demand for new product, environmental impact of the process. Products made from recycled materials do not always have a lower environmental impact than those made from new resources (IaS4).	7. evaluate factors that affect decisions on recycling with reference to products made from crude oil and metal ores	

Chapter C5: Chemical analysis

Overview

This chapter looks at how chemicals are analysed. Chemical analysis is important in chemistry for the quality control of manufactured products and also to identify or quantify components in testing of new products, mineral extraction, forensics and environmental monitoring. Chemists need to both identify which substances are present (qualitative analysis) and the quantity of each substance (quantitative analysis). Measuring purity and separating mixtures is important in manufacturing to ensure quality and to separate useful products from bi-products and waste. Being able to analyse quantities of chemicals enables chemists to plan for the amounts of reactants they need to use to make a product, or predict quantities of products from known amounts of reactants.

The chapter begins in C5.1 by considering why it is necessary to purify chemicals and how the components of mixtures are separated. Methods of testing for purity and separating mixtures are studied, including chromatography and a range of practical separation techniques.

C5.2 is concerned with qualitative analysis. This topic uses standard laboratory techniques, such as flame tests, precipitation reactions and anion tests to identify the ions in unknown substances. Gas chromatography is introduced as an example of an instrumental technique, and used as a context for comparison between standard laboratory and instrumental techniques.

C5.3 introduces quantitative work. The mole is used as a measure of amounts of substance and learners process data from formulae and equations to work out quantities of reactants and products. This topic ends by considering how molar amounts of gas relate to their volumes.

C5.4 develops quantitative work further to show how the concentrations of solutions are determined. This has applications for the testing and quality control of manufactured chemical products and also allows the analysis of unknown chemicals for a range of purposes (for example in forensics, in drug production, mineral exploration and environmental monitoring). Learners make a standard solution and analyse the concentration of unknown solutions using titrations.

Learning about Chemical analysis before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- use knowledge of solids, liquids and gases to decide how mixtures might be separated, including through filtering, sieving and evaporating
- understand the concept of a pure substance and how to identify a pure substance
- know about simple techniques for separating mixtures: filtration, evaporation, distillation and chromatography
- know about the pH scale for measuring acidity/alkalinity; and indicators.

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

Learning about Chemical Analysis at GCSE (9–1)

C5.1 How are chemicals separated and tested for purity?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Many useful products contain mixtures. It is important that consumer products such as drugs or personal care products do not include impurities. Mixtures in many consumer products contain pure substances mixed together in definite proportions called formulations. Pure substances contain a single element or compound. Chemists test substances made in the laboratory and in manufacturing processes to check that they are pure. One way of assessing the purity of a substance is by testing its melting point; pure substances have sharp melting points and can be identified by matching melting point data to reference values. Chromatography is used to see if a substance is pure or to identify the substances in a mixture. Components of a mixture are identified by the relative distance travelled compared to the distance travelled by the solvent. Rf values can be calculated and used to identify unknown components by comparison to reference samples. Some substances are insoluble in water, so other solvents are used. Chromatography can be used on colourless substances but locating agents are needed to show the spots.	1. explain that many useful materials are formulations of mixtures 2. explain what is meant by the purity of a substance, distinguishing between the scientific and everyday use of the term 'pure' 3. use melting point data to distinguish pure from impure substances 4. recall that chromatography involves a stationary and a mobile phase and that separation depends on the distribution between the phases 5. interpret chromatograms, including calculating Rf values M3c *6.* suggest chromatographic methods for distinguishing pure from impure substances *PAG4* Including the use of: a) paper chromatography b) aqueous and non-aqueous solvents c) locating agents	**Specification links:** • particle model and changes of state (C1.1) • Fractional distillation of crude oil on an industrial scale (C3.4) **Ideas about Science** • use the particle model to explain the idea of a pure substance

C5.1 How are chemicals separated and tested for purity?		Linked learning opportunities
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
Preparation of chemicals often produces impure products or a mixture of products. Separation processes in both the laboratory and in industry enable useful products to be separated from bi-products and waste products. The components of mixtures are separated using processes that exploit the different properties of the components, for example state, boiling points or solubility in different solvents. Separation processes are rarely completely successful and mixtures often need to go through several stages or through repeated processes to reach an acceptable purity.	7. describe, explain and exemplify the processes of filtration, crystallisation, simple distillation, and fractional distillation *PAG3, PAG7*	
	8. suggest suitable purification techniques given information about the substances involved *PAG3, PAG7*	

C5.2 How do chemists find the composition of unknown samples?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Chemists use qualitative analysis to identify components in a sample. The procedures have a wide range of applications, including testing chemicals during manufacturing process, testing mineral samples, checking for toxins in waste, environmental testing of water, testing soils. Chemists use sampling techniques to make sure that the samples used for the analysis are representative and will identify any variations in the bulk of the material that is represented in the analysis (IaS 1). Laboratory analysis can be used to identify the metal cations and the anions in salts. Cations can be identified using flame tests or by adding dilute sodium hydroxide. Anions can be identified using a range of dilute reagents.	1. describe the purpose of representative sampling in qualitative analysis 2. interpret flame tests to identify metal ions, including the ions of lithium, sodium, potassium, calcium and copper 3. describe the technique of using flame tests to identify metal ions *PAG5* 4. describe tests to identify aqueous cations and aqueous anions and identify species from test results including: *PAG5* a) tests and expected results for metal ions in solution by precipitation reactions using dilute sodium hydroxide (calcium, copper, iron(II), iron(III), zinc) b) tests and expected results for carbonate ions (using dilute acid), chloride, bromide and iodide ions (using acidified dilute silver nitrate) and sulfate ions (using acidified dilute barium chloride or acidified barium nitrate)
Instrumental analysis is widely used in research and in industry. Emission spectroscopy is a technique which relies on looking at the spectrum of light emitted from a hot sample. Each element gives a unique pattern of	5. interpret an instrumental result for emission spectroscopy given appropriate data in chart or tabular form, when accompanied by a reference set in the same form

Linked learning opportunities

Specification links:

- Symbols, formulae and ionic equations.(C2.4 and C3.2)

Ideas about Science:

- Suggest equipment and techniques and a strategy to carry out qualitative analysis (IaS1)

C5.2 How do chemists find the composition of unknown samples?		Linked learning opportunities
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
lines. Elements can be identified by matching the patterns and wavelengths of lines to reference data from known elements. Emission spectroscopy is used to identify elements in stars and in substances such as steel in industry. Instrumental analysis is preferred due to its greater sensitivity, speed and accuracy. Data is automatically recorded. However, the technology is expensive and is not as freely available as the standard glassware used in laboratory analysis.	6. describe the advantages of instrumental methods of analysis (sensitivity, accuracy and speed) 7. interpret charts, particularly in spectroscopy M4a	

C5.3 How are the amounts of substances in reactions calculated?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
During reactions, atoms are rearranged but the total mass does not change. Reactions in open systems often appear to have a change in mass because substances are gained or lost, usually to the air.	1.	recall and use the law of conservation of mass
	2.	explain any observed changes in mass in non-enclosed systems during a chemical reaction and explain them using the particle model
Chemists use relative masses to measure the amounts of chemicals. Relative atomic masses for atoms of elements can be obtained from the Periodic Table. The relative formula mass of a compound can be calculated using its formula and the relative atomic masses of the atoms it contains. **Relative masses are based on the mass of carbon 12. Counting atoms or formula units of compounds involves very large numbers, so chemists use a mole as a unit of counting. One mole contains the same number of particles as there are atoms in 12g of carbon -12, and has the value 6.0 x 10^{23} atoms; this is the Avogadro constant. It is more convenient to count atoms as 'numbers of moles'.** **The number of moles of a substance can be worked out from its mass, this is useful to chemists because they can use the equations for reactions to work out the amounts of reactants to use in the correct proportions to make a particular product, or to work out which reactant is used up when a**	3.	calculate relative formula masses of species separately and in a balanced chemical equation
	4.	**recall and use the definitions of the Avogadro constant (in standard form) and of the mole**
	5.	**explain how the mass of a given substance is related to the amount of that substance in moles and vice versa and use the relationship:** $$\textbf{number of moles} = \frac{\textbf{mass of substance (g)}}{\textbf{relative formula mass (g)}}$$ M3b, M3c, M2a
	6.	**deduce the stoichiometry of an equation from the masses of reactants and products and explain the effect of a limiting quantity of a reactant**
	7.	**use a balanced equation to calculate masses of reactants or products** M1a, M1c

Linked learning opportunities

Specification links

- The particle model (C1.1)

Maximising industrial yields (C6.3)

Practical Work:

- Comparison of theoretical and actual yield from the preparation of an organic compound (introduced in C3) or a salt (introduced in C5).
- Testing predictions of volumes of gases produced from reactions of acids.

Practical work:

- Making and testing predictions. Carrying out

C5.3 How are the amounts of substances in reactions calculated?		Linked learning opportunities
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
reaction stops. The equation for a reaction can also be used to work out how much product can be made starting from a known amount of reactants. This is useful to determine the amounts of reacting chemicals to be used in industrial processes so that processes can run as efficiently as possible. Chemists use the equation for a reaction to calculate the theoretical, expected yield of a product. This can then be compared to the actual yield. Actual yields are usually much lower than theoretical yields. This can be caused by a range of factors including reversible reactions, impurities in reactants or reactants and products being lost during the procedure. Information about actual yields is used to make improvements to procedures to maximise yields.	8. use arithmetic computation, ratio, percentage and multistep calculations throughout quantitative chemistry M1a, M1c, M1d **9. carry out calculations with numbers written in standard form when using the Avogadro constant** M1b 10. change the subject of a mathematical equation M3b, M3c 11. calculate the theoretical amount of a product from a given amount of reactant M1a, M1c, M1d 12. calculate the percentage yield of a reaction product from the actual yield of a reaction M1a, M1c, M1d, M3c 13. suggest reasons for low yields for a given procedure	investigations. Analysing and evaluating data. Using measuring apparatus. Safe handling of chemicals. **Ideas about Science:** • Using data to make quantitative predictions about yields and comparing them to actual yields. (IaS1, IaS2)

C5.3 How are the amounts of substances in reactions calculated?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
One mole of any gas has the same volume – 24 dm^3 at room temperature and pressure. **So the number of moles of molecules in a known volume of gas can be calculated, using the formula** **number of moles of gas = $\frac{\text{volume of gas in sample (dm}^3\text{)}}{24\ (\text{dm}^3)}$** **For reactions involving only gases, the relative volumes of reactant or product gases can be worked out directly from the equation.** **For reactions with substances in a mixture of states, calculations may involve using both masses and gas volumes to calculate amounts of products and reactants.**	**14. describe the relationship between molar amounts of gases and their volumes and vice versa, and calculate the volumes of gases involved in reactions, using the molar gas volume at room temperature and pressure (assumed to be 24dm^3)**	

C5.4 How are the amounts of chemicals in solution measured?

Teaching and learning narrative	**Assessable learning outcomes** Learners *will be required to:*
Quantitative analysis is used by chemists to make measurements and calculations to show the amounts of each component in a sample. **Concentrations sometimes use the units g/dm^3 but more often are expressed using moles, with the units mol/dm^3. Expressing concentration using moles is more useful because it links more easily to the reacting ratios in the equation.**	1. identify the difference between qualitative and quantitative analysis **2. explain how the mass of a solute and the volume of the solution is related to the concentration of the solution and calculate concentration using the formula:** **concentration (g/dm^3) = $\frac{\text{mass of solute (g)}}{\text{volume (dm}^3\text{)}}$** M3b, M3c
The concentration of acids and alkalis can be analysed using titrations. Alkalis neutralise acids. An indicator is used to identify the point when neutralisation is just reached. During the reaction, hydrogen ions from the acid react with hydroxide ions from the alkali to form water. The reaction can be represented using the equation $H^+ (aq) + OH^- (aq) \rightarrow H_2O(l)$	**3. explain how the concentration of a solution in mol/dm^3 is related to the mass of the solute and the volume of the solution (C7.5a) and calculate the molar concentration using the formula** **concentration (mol/dm^3) = $\frac{\text{number of moles of solute}}{\text{volume (dm}^3\text{)}}$** M3b, M3c
As with all quantitative analysis techniques, titrations follow a standard procedure to ensure that the data is collected safely and is of high quality, including selecting samples, making rough and multiple repeat readings and using equipment of an appropriate precision (such as a burette and pipette). Data from titrations can be assessed in terms of its accuracy, precision and validity. An initial rough measurement is used as an estimate and titrations are	4. describe neutralisation as acid reacting with alkali to form a salt plus water including the common laboratory acids hydrochloric acid, nitric acid and sulfuric acid and the common alkalis, the hydroxides of sodium, potassium and calcium

Linked learning opportunities

Specification links:

- Strong and weak acid chemistry (C6.1)

Practical Work:

- Making up a standard solution.

Practical work

- Acid-base titrations.
- Use of appropriate measuring apparatus, measuring pH, use of a volumetric flask to make a standard solution, titrations using burettes and pipettes, use of acid-base indicators, safe handling of chemicals.

C5.4 How are the amounts of chemicals in solution measured?	
Teaching and learning narrative	**Assessable learning outcomes** Learners *will be required to:*
repeated until a level of confidence can be placed in the data; the readings must be close together with a narrow range. The true value of a titration measurement can be estimated by discarding roughs and taking a mean of the results which are in close agreement. The results of a titration and the equation for the reaction are used to work out the concentration of an unknown acid or alkali.	5. recall that acids form hydrogen ions when they dissolve in water and solutions of alkalis contain hydroxide ions
	6. recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water
	7. describe and explain the procedure for a titration to give precise, accurate, valid and repeatable results *PAG6*
	8. Evaluate the quality of data from titrations
	9. explain the relationship between the volume of a solution of known concentration of a substance and the volume or concentration of another substance that react completely together

Linked learning opportunities

Ideas about Science:

- Justify a technique in terms of precision, accuracy and validity of data to be collected, minimising risk. Use of range and mean when processing titration results, analysis of data. (IaS1, IaS2)

Chapter C6: Making useful chemicals

Overview

This chapter considers the laboratory and large scale production of useful chemicals. Topic 6.1 begins with the laboratory synthesis of salts from acid reactions, and also looks at the characteristics of both acids and bases.

In C6.2, the story moves on to study how chemists manage the rate of reaction when these reactions take place, in the context of managing conditions both in the laboratory and in industry. This chapter gives the opportunity for a wide range of practical investigation and mathematical analysis of rates.

C6.3 looks at reversible reactions, with particular emphasis on the large scale production of ammonia.

C6.4 develops all the ideas in the chapter together to look at both how the conditions and 'routes' for a chemical process are chosen by thinking about the economic and environmental issues surrounding the production of chemicals on a large scale. The manufacture of fertilisers is used as a context for considering how chemists reach decisions about the optimum processes for large scale production of bulk chemicals.

Learning about Making useful Chemicals before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- explain that some changes result in the formation of new materials, and that this kind of change is not usually reversible
- represent chemical reactions using formulae and using equations
- define acids and alkalis in terms of neutralisation reactions
- describe the pH scale for measuring acidity/alkalinity; and indicators
- recall reactions of acids with metals to produce a salt plus hydrogen and reactions of acids with alkalis to produce a salt plus water
- know what catalysts do.
- know about energy changes on changes of state (qualitative)
- know about exothermic and endothermic chemical reactions (qualitative).

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

Learning about Making useful Chemicals at GCSE (9–1)

C6.1 What useful products can be made from acids?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Many products that we use every day are based on the chemistry of acid reactions. Products made using acids include cleaning products, pharmaceutical products and food additives. In addition, acids are made on an industrial scale to be used to make bulk chemicals such as fertilisers. Acids react in neutralisation reactions with metals, hydroxides and carbonates. All neutralisation reactions produce salts, which have a wide range of uses and can be made on an industrial scale. The strength of an acid depends on the degree of ionisation and hence the concentration of H^+ ions, which determines the reactivity of the acid. The pH of a solution is a measure of the concentration of H^+ ions in the solution. Strong acids ionise completely in solution, weak acids do not. Both strong and weak acids can be prepared at a range of different concentrations (i.e. different amounts of substance per unit volume). Weak acids and strong acids of the same concentration have different pH values. Weak acids are less reactive than strong acids of the same concentration (for example they react more slowly with metals and carbonates).	1. recall that acids react with some metals and with carbonates and write equations predicting products from given reactants 2. describe practical procedures to make salts to include appropriate use of filtration, evaporation, crystallisation and drying *PAG7* 3. use the formulae of common ions to deduce the formula of a compound 4. recall that relative acidity and alkalinity are measured by pH including the use of universal indicator and pH meters **5. use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids including differences in reactivity with metals and carbonates** **6. use the idea that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by one** **7. describe neutrality and relative acidity and alkalinity in terms of the effect of the concentration of hydrogen ions on the numerical value of pH (whole numbers only)**

Linked learning opportunities

Specification links

- Writing formulae, balanced symbol and ionic equations.(C3.2)
- Concentration of solutions (C5.4)

Practical Work:

- Reactions of acids and preparation of salts.
- pH testing
- Investigating strong and weak acid reactivity.
- use of indicators to test strong and weak acids, making standard solutions using volumetric flasks.

C6.2 How do chemists control the rate of reactions?

Teaching and learning narrative	Assessable learning outcomes *Learners will be required to:*
Controlling rate of reaction enables industrial chemists to optimise the rate at which a chemical product can be made safely. The rate of a reaction can be altered by altering conditions such as temperature, concentration, pressure and surface area. A model of particles colliding helps to explain why and how each of these factors affects rate; for example, increasing the temperature increases the rate of collisions and, more significantly, increases the energy available to the particles to overcome the activation energy and react. A catalyst increases the rate of a reaction but can be recovered, unchanged, at the end. Catalysts work by providing an alternative route for a reaction with a lower activation energy. Energy changes for uncatalysed and catalysed reactions have different reaction profiles. The use of a catalyst can reduce the economic and environmental cost of an industrial process, leading to more sustainable 'green' chemical processes.	1. describe the effect on rate of reaction of changes in temperature, concentration, pressure, and surface area on rate of reaction 2. explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of frequency and energy of collision between particles 3. explain the effects on rates of reaction of changes in the size of the pieces of a reacting solid in terms of surface area to volume ratio 4. describe the characteristics of catalysts and their effect on rates of reaction 5. identify catalysts in reactions 6. explain catalytic action in terms of activation energy

Linked learning opportunities

Specification links

- Endothermic and exothermic reactions and energy level diagrams. (C1)

Practical Work:

- Investigate the effect of temperature and concentration on rate of reactions.
- Compare methods of following rate

Ideas about Science:

- Use the particle model to explain factors that affect rates of reaction (IaS3)
- The use of catalysts supports more sustainable industrial processes.(IaS4)

C6.2 How do chemists control the rate of reactions?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Rate of reaction can be determined by measuring the rate at which a product is made or the rate at which a reactant is used. Some reactions involve a colour change or form a solid in a solution; the rate of these reactions can be measured by timing the changes that happen in the solutions by eye or by using apparatus such as a colorimeter. Reactions that make gases can be followed by measuring the volume of gas or the change in mass over time. On graphs showing the change in a variable such as concentration over time, the gradient of a tangent to the curve is an indicator of rate of change at that time. The average rate of a reaction can be calculated from the time taken to make a fixed amount of product.	*7.* suggest practical methods for determining the rate of a given reaction including*: PAG8* a) for reactions that produce gases: i. gas syringes or collection over water can be used to measure the volume of gas produced ii. mass change can be followed using a balance b) measurement of physical factors: **i. colour change** **ii. formation of a precipitate**	**Practical work:** • Designing and carrying out investigations into rates. Analysing and interpreting data. Use of apparatus to make measurements. Use of heating equipment. Safe handling of chemicals. Measuring rates of reaction using two different methods.
	8. interpret rate of reaction graphs M4a, M4b	
	9. interpret graphs of reaction conditions versus rate M4a, M4b ⓘ an understanding of orders of reaction is not required	
	10. use arithmetic computation and ratios when measuring rates of reaction M1a, M1c	
	11. draw and interpret appropriate graphs from data to determine rate of reaction M2b, M4b, M4c	
	12. determine gradients of graphs as a measure of rate of change to determine rate	

C6.2 How do chemists control the rate of reactions?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Enzymes are proteins that catalyse processes in living organisms. They work at their optimum within a narrow range of temperature and pH. Enzymes can be adapted and sometimes synthesised for use in industrial processes. Enzymes limit the conditions that can be used but this can be an advantage because if a process can be designed to use an enzyme at a lower temperature than a traditional process, this reduces energy demand.	M4b, M4d, M4e
	13. use proportionality when comparing factors affecting rate of reaction M1c
	14. describe the use of enzymes as catalysts in biological systems and some industrial processes

Linked learning opportunities

Specification link:

- enzymes in biological processes (B3.1)

C6.3 What factors affect the yield of chemical reactions?		Linked learning opportunities
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	
Industrial processes, are managed to get the best yield as quickly and economically as possible. Chemists select the conditions that give the best economic outcome in terms of safety, maintaining the conditions and equipment, and energy use. The reactions in some processes are reversible. This can be problematic in industry because the reactants never completely react to make the products. This wastes reactants and means that the products have to be separated out from the reactants, which requires extra stages and costs. Data about yield and rate of chemical processes are used to choose the best conditions to make a product. On industrial scales, very high temperatures and pressures are expensive to maintain due to the cost of energy and because equipment may fail under extreme conditions. Catalysts can be used to increase the rate of reaction without affecting yield. Chemical engineers choose the conditions that will make the process as safe and efficient as possible, reduce the energy costs and reduce the waste produced at all stages of the process.	1. recall that some reactions may be reversed by altering the reaction conditions including: a) reversible reactions are shown by the symbol ⇌ b) reversible reactions (in closed systems) do not reach 100% yield 2. recall that dynamic equilibrium occurs when the rates of forward and reverse reactions are equal **3. predict the effect of changing reaction conditions (concentration, temperature and pressure) on equilibrium position and suggest appropriate conditions to produce a particular product, including** **a) catalysts increase rate but do not affect yield** **b) the disadvantages of using very high temperatures or pressures**	**Specification links:** • Calculations of yields (C5.1) **Practical Work:** • Investigating reversible reactions. **Ideas about Science:** • Make predictions from data and graphs about yield of chemical products. **(**IaS1) • Consider the risks and costs of different operating conditions in an ammonia plant. (IaS4) **Practical work** • Analyse and evaluate data about yield and rate of ammonia production.

C6.4 How are chemicals made on an industrial scale?

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Nitrogen, phosphorus and potassium are essential plant nutrient elements; they are lost from the soil when crops use them for growth and then are harvested. Fertilisers are added to the soil to replace these essential elements.l	1. recall the importance of nitrogen, phosphorus and potassium compounds in agricultural production
The world demand for food cannot be met without the use of synthetic fertilisers. Natural fertilisers are not available in large enough quantities, their supply is difficult to manage and transport and their composition is variable. However, fertilisers can cause environmental harm when overused; if they are washed into rivers they cause excessive weed growth, which can lead to the death of the organisms that live there.	2. explain the importance of the Haber process in agricultural production and the benefits and costs of making and using fertilisers, including: a) the balance between demand and supply of food Worldwide b) the sustainability and practical issues of producing and using synthetic and natural fertilisers on a large scale c) the environmental impact of over-use of synthetic fertilisers (eutrophication)
Ammonia is one of the most important compounds used to make synthetic fertilisers. Ammonia is made in the Haber process, which involves a reversible reaction. **To get the greatest output as quickly and economically as possible chemical engineers consider the rate and the position of equilibrium for the reaction. In practice, industrial processes rarely reach equilibrium. In the Haber process unreacted reactants are continuously separated from the ammonia and recycled so that the nitrogen and hydrogen are not wasted.**	**3. explain how the commercially used conditions for the Haber process are related to the availability and cost of raw materials and energy supplies, control of equilibrium position and rate including:** **a) the sourcing of raw materials and production of the feedstocks; nitrogen (from air), and hydrogen (from natural gas and steam)** **b) the effect of a catalyst, temperature and pressure on the yield and rate of the reaction** **c) the separation of the ammonia and recycling of unreacted nitrogen and hydrogen**
Industrial processes need to be as economically profitable as possible. Atom economy is an indicator of the amount of useful product that is made in a reaction. This is a theoretical	**4. explain the trade-off between rate of production**

Linked learning opportunities

Specification links

- Haber Process (C4.3)

Practical Work:

- Laboratory preparation and purification of salts that are used as fertilisers.

Ideas about Science:

- Make predictions from data and graphs about yield of chemical products. (IaS1, IaS2)
- Consider the risks and costs of different operating conditions in an ammonia plant. (IaS4)
- Production of fertilisers to enhance the quality of people's

C6.3 What factors affect the yield of chemical reactions?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
value based on the reaction equation and is used alongside data about yields and efficiency when processes are evaluated. **Modern processes incorporate 'green chemistry' ideas, to provide a sustainable approach to production. Sustainability is a measure of how a process is able to meet current demand without having a long term impact on the environment. Reactions with high atom economy are more. Other issues which affect the sustainability of a process include; whether or not the raw materials are renewable; the impact of other competing uses for the same raw materials; the nature and amount of by-products or wastes; the energy inputs or outputs.**	**of a desired product and position of equilibrium in some industrially important processes** 5. define the atom economy of a reaction 6. calculate the atom economy of a reaction to form a desired product from the balanced equation using the formula: $$\text{atom economy} = \frac{\text{mass of atoms in desired product}}{\text{total mass of atoms in reactants}}$$ M3b, M3c 7. use arithmetic computation when calculating atom economy M1a, M1c **8. explain why a particular reaction pathway is chosen to produce a specified product given appropriate data such as atom economy (if not calculated), yield, rate, equilibrium position, usefulness of by-products and evaluate the sustainability of the process**	lives (IaS4) • Evaluation of industrial processes in terms of sustainability, risk, costs and benefits. (IaS4)

C6.3 What factors affect the yield of chemical reactions?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Synthetic fertilisers contain salts that are made in acid-base reactions and can be synthesised on a laboratory scale. Scaling up of fertiliser manufacture for industrial production uses some similar processes to the laboratory preparation, but these are adapted to handle the much larger quantities involved. Any one compound used in fertilisers can often be made using several different processes. An example is the manufacture of ammonium sulfate. The synthesis stage of manufacture could be the same as the process used in the laboratory; but alternatively a manufacturer might make use of bi-product or waste products from other production processes. Finding uses for bi-products is an important factor in ensuring the sustainability of industrial processes. Laboratory scale procedures such as choosing reactants, synthesis, monitoring the reaction, separation techniques, disposal of waste and testing of purity have parallel counterparts in the industrial process.	9. describe the industrial production of fertilisers as several integrated processes using a variety of raw materials and compare with laboratory syntheses. including: a) demand for fertilisers (including ammonium sulfate) is often met from more than one process b) some fertilisers are made as a bi-product or waste product of another process c) process flow charts are used to summarise industrial processes and give information about raw materials, stages in the process, products, by-products and waste d) lab processes prepare chemicals in batches, industrial processes are usually continuous. 10. compare the industrial production of fertilisers with laboratory syntheses of the same products

Linked learning opportunities

Ideas about Science

- Industrial processes can be modelled in the laboratory and using computers before making decisions about full scale production (IaS3)

Chapter C7: Ideas about Science

Overview

In order to make sense of the scientific ideas that learners encounter in lessons and in everyday life outside of school, they need an understanding of how science explanations are developed, the kinds of evidence and reasoning behind them, their strengths and limitations, and how far we can rely on them.

Learners also need opportunities to consider the impacts of science and technology on society, and how we respond individually and collectively to new ideas, artefacts and processes that science makes possible.

It is intended that the *Ideas about Science* will help learners understand how scientific knowledge is obtained, how to respond to science stories and issues in the world outside the classroom, and the impacts of scientific knowledge on society.

Note that:

- although particular *Ideas about Science* have been linked to particular contexts throughout the specification as examples, the assessable learning outcomes in this chapter should be developed, and can be assessed, in any context from chapters 1–6
- the assessable learning outcomes in this chapter will be assessed in all of the written examination papers
- terms associated with measurement and data analysis are used in accordance with their definitions in the Association of Science Education publication *The Language of Measurement* (2010).

Learning about How Science Works before GCSE (9–1)

From study at Key Stages 1 to 3 learners should:

- understand that science explanations are based on evidence and that as new evidence is gathered, explanations may change
- have devised and carried out scientific enquiries, in which they have selected the most appropriate techniques and equipment, collected and analysed data and drawn conclusions.

Tiering

Statements shown in **bold** type will only be tested in the Higher tier papers.

All other statements will be assessed in both Foundation and Higher tier papers.

IaS1 What needs to be considered when investigating a phenomenon scientifically?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
The aim of science is to develop good explanations for natural phenomena. There is no single 'scientific method' that leads to explanations, but scientists do have characteristic ways of working. In particular, scientific explanations are based on data. Usually, developing an explanation begins with proposing a hypothesis. A hypothesis is a tentative explanation for an observed phenomenon ("this happens because…"). The hypothesis is used to make a prediction about how, in a particular experimental context, a change in a factor will affect the outcome. A prediction can be presented in a variety of ways, for example in words or as a sketch graph. In order to test a prediction, and the hypothesis upon which it is based, it is necessary to plan an experimental strategy that enables data to be collected in a safe, accurate and repeatable way.	1. in a given context : a) identify a testable hypothesis that tentatively explains an observed phenomenon b) identify the outcome and factors that may affect the outcome c) make a prediction based on a hypothesis d) use scientific knowledge and understanding to justify a hypothesis and prediction 2. identify factors that need to be controlled, and the ways in which they could be controlled 3. suggest appropriate equipment, materials and techniques, justifying the choice with reference to the precision, accuracy and validity of the data that will be collected 4. suggest an appropriate sample size and/or range of values to be measured and justify the suggestion M2d 5. construct a clear and logically sequenced strategy for data collection 6. identify hazards associated with the data collection and suggest ways of minimizing the risk

Linked learning opportunities

Making and testing predictions

- trends and patterns in the Periodic Table (C2)
- reactivity of metals (C3.2)

IaS2 What conclusions can we make from data?

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
All data have to be interpreted, and this usually involves mathematical processing, graphical display and analysis. A set of repeat measurements can be processed to calculate a range within which the true value probably lies and to give a best estimate of the value (mean). Displaying data graphically can help to show trends or patterns, and to assess the spread of repeated measurements. Mathematical comparisons between results and statistical methods can help with further analysis.	1. for a set of repeated measurements, use: a) the range to show the spread of data b) the mean as the best estimate of the true value M2b, M2f	
	2. when processing data: a) use an appropriate number of significant figures b) use SI units where appropriate c) interconvert units d) use prefixes (tera to nano) and powers of ten for orders of magnitude M2a	
	3. when displaying data graphically: a) select an appropriate graphical form b) use appropriate axes and scales c) plot data points correctly d) draw an appropriate line of best fit e) indicate uncertainty (e.g. range bars M2c, M4a, M4c	
	4. when analysing data: a) identify patterns/trends b) use statistics (range and mean) c) obtain values from a line on a graph (including gradient, interpolation and extrapolation) M2b, M2g, M4b, M4d, M4e, M4f	

IaS2 What conclusions can we make from data?

Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Data can never be relied on completely because observations may be incorrect and all measurements are subject to uncertainty (arising from the limitations of the measuring equipment and the person using it). The experimental strategy and the data obtained must be evaluated critically before we can make conclusions based on the results. There could be many reasons why the quality (accuracy, precision, repeatability and reproducibility) of the data could be questioned, and a number of ways in which they could be improved. A result that appears to be an outlier should be treated as data, unless there is a reason to reject it (e.g. measurement or recording error).	5. in a given context suggest: a) reasons why a measurement may not be the true value of the quantity being measured, or why several measurements of the same quantity gave different values, with reference to random and systematic error b) improvements to an experimental strategy, and explain why they would increase the quality of the data collected	
	6. for a given set of data: a) explain the decision to discard or retain an outlier b) consider critically the accuracy and repeatability of the data, with reference to the pattern of results or degree of scatter between repeats	
Agreement between the collected data and the original prediction increases confidence in the explanation (hypothesis) upon which the prediction is based, but does not prove that the explanation is correct. Disagreement between the data and the prediction indicates that one or other is wrong, and decreases our confidence in the explanation.	7. in a given context: a) use data to make or justify a conclusion b) explain the extent to which data increase or decrease confidence in a prediction or hypothesis	*Drawing conclusions from data* • patterns in the periodic table (C2) • properties of polymers (C4.3)

IaS3 How are scientific explanations developed?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
Scientists often look for patterns in data as a means of identifying correlations that can suggest cause-effect links – for which an explanation might then be sought. The first step is to identify a correlation between a factor and an outcome. The factor may then be the cause, or one of the causes, of the outcome. In many situations, a factor may not always lead to the outcome, but increases the chance (or the risk) of it happening. In order to claim that the factor causes the outcome we need to identify a process or mechanism that might account for the observed correlation.	1. use ideas about correlation and cause to: a) identify a correlation in data presented as text, in a table, or as a graph distinguish between a correlation and a cause-effect link b) suggest factors that might increase the chance of a particular outcome in a given situation, but do not invariably lead to it c) explain why individual cases do not provide convincing evidence for or against a correlation d) identify the presence (or absence) of a plausible mechanism as reasonable grounds for accepting (or rejecting) a claim that a factor is a cause of an outcome	*Considering correlation and cause:* • identifying causal relationships to explain climate change (C1.2)
Scientific explanations and theories do not 'emerge' automatically from data, and are separate from the data. Proposing an explanation involves creative thinking. Collecting sufficient data from which to develop an explanation often relies on technological developments that enable new observations to be made. As more evidence becomes available, a hypothesis may be modified and may eventually become an accepted explanation or theory. A scientific theory is a general explanation that applies to a large number of situations or examples (perhaps to all possible ones), which has been tested and used successfully, and is widely accepted by scientists. A scientific explanation of a specific event or phenomenon is often based on applying a scientific theory to the situation in question.	2. in a given account of scientific work, distinguish statements that report data from statements of explanatory ideas (hypotheses, explanations, theories) 3. describe and explain examples of scientific explanations that: a) resulted from a leap of imagination from a creative thinker b) were modified when new evidence became available	*Developing scientific explanations:* • explanatory accounts of how atmosphere was formed (C1.1) • contribution of peer review to climate change debate (C1.2) • changing ideas about the atomic model (C2.1) • Development of nano particles, and graphene (C4.3)

IaS3 How are scientific explanations developed?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Findings reported by an individual scientist or group are carefully checked by the scientific community before being accepted as scientific knowledge. Scientists are usually sceptical about claims based on results that cannot be reproduced by anyone else, and about unexpected findings until they have been repeated (by themselves) or reproduced (by someone else). Two (or more) scientists may legitimately draw different conclusions about the same data. A scientist's personal background, experience or interests may influence his/her judgements. An accepted scientific explanation is rarely abandoned just because new data disagree with it. It usually survives until a better explanation is available. Models are used in science to help explain ideas and to test explanations. A model identifies features of a system and rules by which the features interact. It can be used to predict possible outcomes. Representational models use physical analogies or spatial representations to help visualise scientific explanations and mechanisms. Descriptive models are used to explain phenomena. Mathematical models use patterns in data of past events, along with known scientific relationships, to predict behaviour; often the calculations are complex and can be done more quickly by computer. Models can be used to investigate phenomena quickly and without ethical and practical limitations, but their usefulness is limited by how accurately the model represents the real world.	4. describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists 5. identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim and explain why scientists see this as important **6. suggest plausible reasons why the same data might be interpreted in more than one way** 7. suggest reasons why scientists might not give up an accepted explanation if new evidence appears to conflict with it 8. for a variety of given models (including representational, descriptive and mathematical models): a) describe the main features of the model b) suggest how it can be used to explain or investigate a phenomenon c) use the model to make a prediction d) identify limitations of the model 9. identify benefits and limitations of using modelling as an alternative to practical experiments

Linked learning opportunities

Explanations that resulted from a leap of imagination:

- Mendeleev and the periodic table (C2.2);

Examples of models:

- The particle model (C1.1, C5.1, C6.2);
- Computational models to predict future climate change (C1.2);
- representations of atoms, ions and molecules (C2.3)
- using models of structure of materials to explain properties (C3.1, C4.1, C4.2, C4.3)
- half equations (C3.3)
- representations of bonding (C3.4)

IaS3 How are scientific explanations developed?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*

Linked learning opportunities
• functional groups (C3.4) • modelling industrial processes (C6.4)

IaS4 How do science and technology impact society?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
Science and technology provide people with many things that they value, and which enhance their quality of life. However some applications of science can have unintended and undesirable impacts on the quality of life or the environment. Scientists can devise ways of reducing these impacts and of using natural resources in a sustainable way (at the same rate as they can be replaced). Everything we do carries a certain risk of accident or harm. New technologies and processes can introduce new risks. The size of a risk can be assessed by estimating its chance of occurring in a large sample, over a given	1. describe and explain examples of applications of science that have made significant positive differences to people's lives 2. explain the idea of sustainability, and use data to compare the sustainability of alternative products or processes in specific situations 3. identify examples of unintended impacts of human activity on the environment and describe ways in which scientists work to mitigate these effects 4. identify examples of risks that have arisen from a new scientific or technological advance 5. interpret and discuss information on the size of a given risk, taking account of both the chance of it occurring and the consequences if it did

Linked learning opportunities
Positive applications of science: • catalytic converters, low sulfur petrol and gas scrubbers (C1.1) • **fuel cells (C1.2);** • increasing supply of potable water (C1.4); • uses of metals **(C2.5,** C3.1**)**

IaS4 How do science and technology impact society?	
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*
period of time. To make a decision about a course of action, we need to take account of both the risks and benefits to the different individuals or groups involved. People are generally more willing to accept the risk associated with something they choose to do than something that is imposed, and to accept risks that have short-lived effects rather than long-lasting ones. People's perception of the size of a particular risk may be different from the statistically estimated risk. People tend to over-estimate the risk of unfamiliar things (like flying as compared with cycling), and of things whose effect is invisible or long-term (like ionising radiation). Governments and public bodies may have to assess what level of risk is acceptable in a particular situation. Their decisions may be controversial, especially if those most at risk are not those who benefit. Some forms of scientific research, and some applications of scientific knowledge, have ethical implications. In discussions of ethical issues, a common argument is that the right decision is one which leads to the best outcome for the greatest number of people. Scientists must communicate their work to a range of audiences, including the public, other scientists and politicians in ways that can be understood. This enables decision-making based on information about risks, benefits, costs and ethical issues. However, some questions (such as those involving values) cannot be answered by science, and certain actions may be	6. for a given situation: a) identify risks and benefits to the different individuals and groups involved b) discuss a course of action, taking account of who benefits and who takes the risks c) suggest reasons for people's willingness to accept the risk **d) distinguish between perceived and calculated risk** 7. discuss the public regulation of risk, and explain why it may in some situations be controversial 8. where an ethical issue is involved: a) say clearly what this issue is b) summarise different views that may be held 9. suggest reasons why different decisions on the same issue might be appropriate in view of differences in personal, social, or economic context 10. explain why scientists should communicate their work to a range of audiences 11. distinguish questions that could in principle be answered using a scientific approach, from those that could not

Linked learning opportunities

- Catalysts **(C2.5, C6.2))**
- cracking (C3.4)
- Many new materials (C4)
- Salts (C6.1)
- fertilisers (C6.4)

Sustainability:

- energy demands use of fuels (C1.2)
- use of crude oil (C3.4)
- reducing corrosion (C4.5)
- life cycle assessment (C4.5)
- catalysts (C6.2)
- chemical processes (C6.4)
- *Unintended impacts:* Burning fossil fuels (C1.1)
- extraction of metals (C3.2)

IaS4 How do science and technology impact society?		
Teaching and learning narrative	**Assessable learning outcomes** *Learners will be required to:*	***Linked learning opportunities***
considered right or wrong whatever the consequences. People may disagree about what should be done (or permitted).		*Considering risks, benefits and ethical issues:* • managing global warming (C1.2); • access to potable water for all (C1.4); • extraction of metals (C3.2) • use of crude oil (C3.4) • nanotechnology (C4.4) • ammonia plants (C6.3) *Public regulation of risk* • targets for vehicle emissions (C1.2)

2d. Prior knowledge, learning and progression

- Learners in England who are beginning a GCSE (9–1) course are likely to have followed a Key Stage 3 programme of study.
- There are no prior qualifications required in order for learners to enter for a GCSE (9–1) in Chemistry B (Twenty First Century Science).
- GCSEs (9–1) are qualifications that enable learners to progress to further qualifications either Vocational or General.

There are a number of Science specifications at OCR.

Find out more at www.ocr.org.uk

3 Assessment of GCSE (9–1) in Chemistry B (Twenty First Century Science)

3a. Forms of assessment

The GCSE (9–1) in Chemistry B (Twenty First Century Science) is a linear qualification with 100% external assessment.

OCR's GCSE (9–1) in Chemistry B (Twenty First Century Science) consists of four examined components that are externally assessed. Two are at Foundation tier and two are at Higher tier. Each component carries an equal weighting of 50% for that tier of the GCSE (9–1) qualification. Each component has a duration of 1 hour and 45 minutes.

Breadth in chemistry (Components 01 and 03)

These components, one at Foundation tier and one at Higher tier, are each worth 90 marks and assess content from across all teaching chapters 1 to 7. Learners answer all the questions. Question styles include short answer styles (structured questions, problem solving, calculations and practical).

Depth in chemistry(Components 02 and 04)

These components, one at Foundation tier and one at Higher tier, are each worth 90 marks and assess content from across all teaching chapters 1 to 7. Learners answer all the questions. Question style includes short answer and extended Level of Response questions (6 marks each).

Practical Science Written Statement

Centres must provide a written 'practical science statement' to OCR confirming that it has taken reasonable steps to secure that each learner:

a) has completed the practical activities set by OCR as detailed in Section 5i
b) has made a contemporaneous record of:
   (i) the work which the learner has undertaken during those practical activities, and
   (ii) the knowledge, skills and understanding which that learner has derived from those practical activities.

Centres must provide practical science opportunities for their learners. This does not go so far as to oblige centres to ensure that all of their learners take part in all of the practical science opportunities. There is always a risk that an individual learner may miss the arranged practical science work, for example because of illness. It could be costly for the centre to run additional practical science opportunities for the learner. However, the opportunities to take part in the specified range of practical work must be given to all learners. Learners who do not take up the full range of opportunities may be disadvantaged as there will be questions on practical science in the GCSE (9–1) Chemistry B (Twenty First Century) assessment.

Centres must provide the practical science statement by 15 May in the year the learner certificates. Any failure by a centre to provide a practical science statement to OCR in a timely manner will be treated as malpractice and/or maladministration (under General Condition A8 (*Malpractice and maladministration*)).

3b. Assessment objectives (AO)

There are three Assessment Objectives in OCR GCSE (9–1) in Chemistry B (Twenty First Century Science).

These are detailed in the table below.

Assessment Objectives		Weighting	
		Higher	**Foundation**
AO1	**Demonstrate knowledge and understanding of:** • scientific ideas • scientific techniques and procedures.	40%	40%
AO2	**Apply knowledge and understanding of:** • scientific ideas • scientific enquiry, techniques and procedures.	40%	40%
AO3	**Analyse information and ideas to:** • interpret and evaluate • make judgements and draw conclusions • develop and improve experimental procedures.	20%	20%

AO weightings in OCR GCSE (9–1) Chemistry B (Twenty First Century Science)

The relationship between the Assessment Objectives and the components are shown in the following table:

	% of overall GCSE (9–1) in Chemistry B (Twenty First Century Science) (J258)			
Component (Foundation Tier)	**AO1**	**AO2**	**AO3**	**Total**
Breadth in chemistry (Foundation Tier) J258/01	24	18	8	50
Depth in chemistry (Foundation Tier) J258/02	16	22	12	50
Total	40	40	20	100
Component (Higher Tier)	**AO1**	**AO2**	**AO3**	**Total**
Breadth in chemistry (Higher Tier) J258/03	24	18	8	50
Depth in chemistry (Higher Tier) J258/04	16	22	12	50
Total	40	40	20	100

3c. Tiers

This scheme of assessment consists of two tiers: Foundation tier and Higher tier. Foundation tier assesses grades 5 to 1 and Higher tier assesses grades 9 to 4. An allowed grade 3 may be awarded on the Higher tier option for learners who are a small number of marks below the grade 3/4 boundary. Learners must be entered for either the Foundation tier or the Higher tier.

3d. Assessment availability

There will be one examination series available each year in May/June to **all** learners.

All examined components must be taken in the same examination series at the end of the course.

This specification will be certificated from the June 2018 examination series onwards

3e. Retaking the qualification

Learners can retake the qualification as many times as they wish.

They retake all components of the qualification.

3f. Assessment of extended response

The assessment materials for this qualification provide learners with the opportunity to demonstrate their ability to construct and develop a sustained and coherent line of reasoning and marks for extended responses are integrated into the marking criteria. Extended response will be assessed in Depth in chemistry, components 02 and 04.

3g. Synoptic assessment

Synoptic assessment tests the learners' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the GCSE (9–1) course. The emphasis of synoptic assessment is to encourage the development of the understanding of Chemistry B (Twenty First Century Science) as a discipline. All papers contain an element of synoptic assessment.

Synoptic assessment requires learners to make and use connections within and between different areas of Chemistry, for example by:

- applying knowledge and understanding of more than one area to a particular situation or context
- using knowledge and understanding or principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

3h. Calculating qualification results

A learner's overall qualification grade for OCR GCSE (9–1) in Chemistry B (Twenty First Century Science) will be calculated by adding together their marks from the two components taken to give their total weighted mark. This mark will then be compared to the qualification level grade boundaries for the entry option taken by the learner and for the relevant exam series to determine the learner's overall qualification grade.

4 Admin: what you need to know

The information in this section is designed to give an overview of the processes involved in administering this qualification so that you can speak to your exams officer. All of the following processes require you to submit something to OCR by a specific deadline.

More information about these processes, together with the deadlines, can be found in the OCR *Admin Guide and Entry Codes: 14–19 Qualifications*, which can be downloaded from the OCR website: www.ocr.org.uk

4a. Pre-assessment

Estimated entries

Estimated entries are your best projection of the number of learners who will be entered for a qualification in a particular series.

Estimated entries should be submitted to OCR by the specified deadline. They are free and do not commit your centre in any way.

Final entries

Final entries provide OCR with detailed data for each learner, showing each assessment to be taken. It is essential that you use the correct entry code, considering the relevant entry rules.

Final entries must be submitted to OCR by the published deadlines or late entry fees will apply.

All learners taking a GCSE (9–1) in Chemistry B (Twenty First Century Science) must be entered for one of the following entry options:

Entry option		**Components**		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
J258 F	Chemistry B (Twenty First Century Science) (Foundation tier)	01	Breath in Chemistry Foundation tier	External Assessment
		02	Depth in Chemistry Foundation tier	External Assessment
J258 H	Chemistry B (Twenty First Century Science) (Higher tier)	03	Breath in Chemistry Higher tier	External Assessment
		04	Depth in Chemistry Higher tier	External Assessment

4b. Special consideration

Special consideration is a post-assessment adjustment to marks or grades to reflect temporary injury, illness or other indisposition at the time the assessment was taken.

Detailed information about eligibility for special consideration can be found in the JCQ publication *A guide to the special consideration process*.

4c. External assessment arrangements

Regulations governing examination arrangements are contained in the JCQ *Instructions for conducting examinations*.

4d. Results and certificates

Grade Scale

GCSE (9–1) qualifications are graded on the scale: 9–1, where 9 is the highest. Learners who fail to reach the minimum standard of 1 will be Unclassified (U). Only subjects in which grades 9 to 1 are attained will be recorded on certificates.

Results

Results are released to centres and learners for information and to allow any queries to be resolved before certificates are issued.

Centres will have access to the following results information for each learner:

- the grade for the qualification
- the raw mark for each component
- the total weighted mark for the qualification.

The following supporting information will be available:

- raw mark grade boundaries for each component
- weighted mark grade boundaries for each entry option.

Until certificates are issued, results are deemed to be provisional and may be subject to amendment.

A learner's final results will be recorded on an OCR certificate. The qualification title will be shown on the certificate as 'OCR Level 1/2 GCSE (9–1) in Chemistry B (Twenty First Century Science)'.

4e. Post-results services

A number of post-results services are available:

- **Enquiries about results** – If you are not happy with the outcome of a learner's results, centres may submit an enquiry about results.
- **Missing and incomplete results** – This service should be used if an individual subject result for a learner is missing, or the learner has been omitted entirely from the results supplied.
- **Access to scripts –** Centres can request access to marked scripts.

4f. Malpractice

Any breach of the regulations for the conduct of examinations and non-exam assessment may constitute malpractice (which includes maladministration) and must be reported to OCR as soon as it is detected. Detailed information on malpractice can be found in the JCQ publication *Suspected Malpractice in Examinations and Assessments: Policies and Procedures*.

5 Appendices

5a. Grade descriptors

Ofqual to confirm.

5b. Overlap with other qualifications

There is a small degree of overlap between the content of this specification and those for GCSE (9–1) Combined Science B (Twenty First Century Science), GCSE (9–1) Biology B (Twenty First Century Science) and GCSE (9–1) Physics B (Twenty First Century Science) courses. The links between the specifications may allow for some co-teaching, particularly in the area of working scientifically.

5c. Accessibility

Reasonable adjustments and access arrangements allow learners with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do, without changing the demands of the assessment. Applications for these should be made before the examination series. Detailed information about eligibility for access arrangements can be found in the JCQ *Access Arrangements and Reasonable Adjustments.*

The GCSE (9–1) qualification and subject criteria have been reviewed in order to identify any feature which could disadvantage learners who share a protected Characteristic as defined by the Equality Act 2010. All reasonable steps have been taken to minimise any such disadvantage.

5d. Units in science

It is expected that learners will show understanding of the physical quantities and corresponding units, SI and derived units listed below. They will be able to use them in qualitative work and calculations. These units and their associated quantities are dimensionally independent.

Fundamental physical quantities		
Physical quantity	Unit(s)	SI unit(s)
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	degree Celsius; kelvin	°C; K
Current	ampere	A
Voltage	volt	V

Derived quantities and units		
Physical quantity	Unit(s)	Unit(s)
Area	metre squared	m^2
Volume	metre cubed; litre; decimetre cubed	m^3; l, dm^3
Density	kilogram per metre cubed	kg/m^3
Specific heat capacity	Joule per kilogram per degree Celsius	J/kg°C
Specific latent heat	Joule per kilogram	J/kg

Other frequently used units in chemistry		
Physical quantity	Unit	Unit
Energy	Joule	J
Pressure	Pascal	Pa
Chemical substance	mole	mol
Electric potential difference	Volt	V

5e. Mathematical skills

The mathematical skills required for the GCSE (9–1) in biology (B), chemistry (C), physics (P) and combined science (CS) are shown in the table below.

	Mathematical skills	Subject			
1	Arithmetic and numerical computation				
a	Recognise and use expressions in decimal form	B	C	P	CS
b	Recognise expressions in standard form	B	C	P	CS
c	Use ratios, fractions and percentages	B	C	P	CS
d	Make estimates of the results of simple calculations, without using a calculator	B	C	P	CS
2	Handling data				
a	Use an appropriate number of significant figures	B	C	P	CS
b	Find arithmetic means	B	C	P	CS
c	Construct and interpret frequency tables and diagrams, bar charts and histograms	B	C	P	CS
d	Understand the principles of sampling as applied to scientific data	B			CS
e	Understand simple probability	B			CS
f	Understand the terms mean, mode and median	B		P	CS
g	Use a scatter diagram to identify a correlation between two variables	B		P	CS
h	Make order of magnitude calculations	B	C	P	CS
3	**Algebra**				
a	Understand and use the symbols: $=, <, \ll, \gg, >, \propto, \sim$	B	C	P	CS
b	Change the subject of an equation		C	P	CS
c	Substitute numerical values into algebraic equations using appropriate units for physical quantities		C	P	CS
d	Solve simple algebraic equations	B		P	CS
4	**Graphs**				
a	Translate information between graphical and numeric form	B	C	P	CS
b	Understand that y=mx+c represents a linear relationship	B	C	P	CS
c	Plot two variables from experimental or other data	B	C	P	CS
d	Determine the slope and intercept of a linear graph	B	C	P	CS
e	Draw and use the slope of a tangent to a curve as a measure of rate of change		C		CS
f	Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate			P	CS
5	**Geometry and trigonometry**				
a	Use angular measures in degrees			P	CS
b	Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects		C	P	CS
c	Calculate areas of triangles and rectangles, surface areas and volumes of cubes.	B	C	P	CS

5f Mathematical skills requirement

In order to be able to develop their skills, knowledge and understanding in GCSE (9–1) Chemistry B (Twenty First Century Science), learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

The assessment of quantitative skills would include at least 20% GCSE (or above) mathematical skills at the appropriate tier for chemistry.

These skills will be applied in the context of the relevant chemistry.

This list of examples is not exhaustive and is not limited to GCSE examples. These skills could be developed in other areas of specification content from those indicated.

	Mathematical skills	**Specification statement**
1	**Arithmetic and numerical computation**	
a	Recognise and use expressions in decimal form	1.1.11, 1.2.5, 1.2.6, 2.1.7, 2.3.7, 5.3.7, 5.3.8, 5.3.11, 5.3.12, 6.2.10, 6.4.7
b	Recognise expressions in standard form	4.4.7, 5.3.9
c	Use ratios, fractions and percentages	1.1.11, 1.2.5, 1.2.6, 3.4.7, 4.4.8, 5.3.7, 5.3.8, 5.3.11, 5.3.12, 6.2.10, 6.2.13, 6.4.7
d	Make estimates of the results of simple calculations, without using a calculator	1.2.5, 1.2.6, 2.1.4, 2.1.6, 4.4.6, 5.3.8, 5.3.11, 5.3.12
2	**Handling data**	
a	Use an appropriate number of significant figures	IaS2.2, 5.3.5
b	Find arithmetic means	6.2.11, IaS2.1b, IaS2.4b
c	Construct and interpret frequency tables and diagrams, bar charts and histograms	1.3.5, IaS2.3
d	Understand the principles of sampling as applied to scientific data	IaS1.4
h	Make order of magnitude calculations	1.3.6
3	**Algebra**	
a	Understand and use the symbols: =, <, <<, >>, >, ∝, ~	No direct specification statement but skill will be assessed.
b	Change the subject of an equation	5.3.5, 5.3.10, 5.4.2, 5.4.3, 6.4.6
c	Substitute numerical values into algebraic equations using appropriate units for physical quantities	5.1.5, 5.3.5, 5.3.10, 5.3.12, 5.4.2, 5.4.3, 6.4.6, IaS2.3
4	**Graphs**	
a	Translate information between graphical and numeric form	1.3.5, 2.3.12, 3.4.13, 5.2.7, 6.2.8, IaS2.3, 6.2.9
b	Understand that y=mx+c represents a linear relationship	6.2.8, 6.2.9, 6.2.11, 6.2.12, IaS2.4
c	Plot two variables from experimental or other data	6.2.11,
d	Determine the slope and intercept of a linear graph	6.2.12, IaS2.4
e	Draw and use the slope of a tangent to a curve as a measure of rate of change	6.2.12, IaS2.4
5	**Geometry and trigonometry**	
a	Use angular measures in degrees	2.3.12, 3.4.11, 4.3.7
b	Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects	4.4.9

5g. The Periodic Table of elements

Key
atomic number
Symbol
name
relative atomic mass

(1) 1	(2) 2	3	4	5	6	7	8	9	10	11	12	(3) 13	(4) 14	(5) 15	(6) 16	(7) 17	(0) 18
1 **H** hydrogen 1.0																	2 **He** helium 4.0
3 **Li** lithium 6.9	4 **Be** beryllium 9.0											5 **B** boron 10.8	6 **C** carbon 12.0	7 **N** nitrogen 14.0	8 **O** oxygen 16.0	9 **F** fluorine 19.0	10 **Ne** neon 20.2
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3											13 **Al** aluminium 27.0	14 **Si** silicon 28.1	15 **P** phosphorus 31.0	16 **S** sulfur 32.1	17 **Cl** chlorine 35.5	18 **Ar** argon 39.9
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	24 **Cr** chromium 52.0	25 **Mn** manganese 54.9	26 **Fe** iron 55.8	27 **Co** cobalt 58.9	28 **Ni** nickel 58.7	29 **Cu** copper 63.5	30 **Zn** zinc 65.4	31 **Ga** gallium 69.7	32 **Ge** germanium 72.6	33 **As** arsenic 74.9	34 **Se** selenium 79.0	35 **Br** bromine 79.9	36 **Kr** krypton 83.8
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	42 **Mo** molybdenum 95.9	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

5h. Health and safety

In UK law, health and safety is primarily the responsibility of the employer. In a school or college the employer could be a local education authority, the governing body or board of trustees. Employees (teachers/lecturers, technicians etc.), have a legal duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must carry out a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at: https://www.ase.org.uk

For members, the CLEAPSS® guide, *PS90*, *Making and recording risk assessments in school science*[1] offers appropriate advice.

Most education employers have adopted nationally available publications as the basis for their Model Risk Assessments.

Where an employer has adopted model risk assessments an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the learners were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded in a "*point of use text* ", for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed for each practical activity, although a minority of employers may require this.

Where project work or investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS®

[1] These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications website www.cleapss.org.uk. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk

5i. Practical activities/skills

OCR has split the requirements from the Department for Education 'GCSE subject content and assessment objectives' – Appendix 4 into eight Practical Activity Groups or PAGs. The following table illustrates the skills required for each PAG and an example practical that may be used to contribute to the PAG. Within the specification there are a number of practical specification statements, indicated as, for example, *PAG1*, which count towards each PAG. We are expecting that centres will do a wide range of practical activities during the course. These can be the ones illustrated in the specification or can be practicals that are devised by the centre. Activities can range from whole investigations to simple starters and plenaries. Safety is an overriding requirement for all practical work. Centres are responsible for ensuring appropriate safety procedures are followed whenever their learners complete practical work.

Use and production of appropriate scientific diagrams to set up and record apparatus and procedures used in practical work is common to all science subjects and should be included wherever appropriate.

Where appropriate learners will be expected to use appropriate apparatus to make and record measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH. Learners should be encouraged to tackle complex and problem solving contexts including the identification of an unknown substance.

Practical Activity Group (PAG)	Skills	Suggested C21 Chemistry practical that will allow Appendix 5 to be covered *
1 Reactivity trend	Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products	Using displacement reactions to identify the reaction trend of Group 7 elements
2 Electrolysis	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests	Electrolysis of aqueous Sodium Chloride or aqueous Copper Sulfate solution testing for the gases produced
3 Distillation	Safe use of a range of equipment to purify and/or separate chemical mixtures including distillation Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater Use of appropriate apparatus to make and record a range of measurements accurately, including the measurement of temperature	Distillation of a mixture, for example orange juice, cherry cola, hydrocarbons, inks
4 Separation Techniques	Safe use of a range of equipment to purify and/or separate chemical mixtures including Chromatography	Using chromatography to identify the mixtures of dyes in an unknown ink
5 Identification of species	Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including Safe use of appropriate heating devices and techniques including use of a Bunsen burner	Identification of an unknown compound using cation tests, anion tests and flame tests.

Practical Activity Group (PAG)	Skills	Suggested C21 Chemistry practical that will allow Appendix 5 to be covered *
6 Titration	Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations	Titration of a strong acid and strong alkali to find the concentration of the acid using an appropriate pH indicator
	Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including the determination of concentrations of strong acids and strong alkalis	
	Use of appropriate apparatus to make and record a range of measurements accurately, including volume of liquids	
7 Production of salts	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration and crystallisation	Production of pure dry sample of a salt
	Use of appropriate apparatus to make and record a range of measurements accurately, including mass and volume of liquids	
	Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products	
8 Measuring rates of reaction	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature and volume of liquids and gases	Investigation of the effect of surface area or concentration on the rate of an acid /carbonate reaction
	Making and recording of appropriate observations during chemical reactions including the measurement of rates of reaction by a variety of methods such as production of gas and colour change	

*** Centres are free to substitute alternative practical activities that also cover the skills detailed above.**