TWENTY FIRST CENTURY SCIENCE SUITE

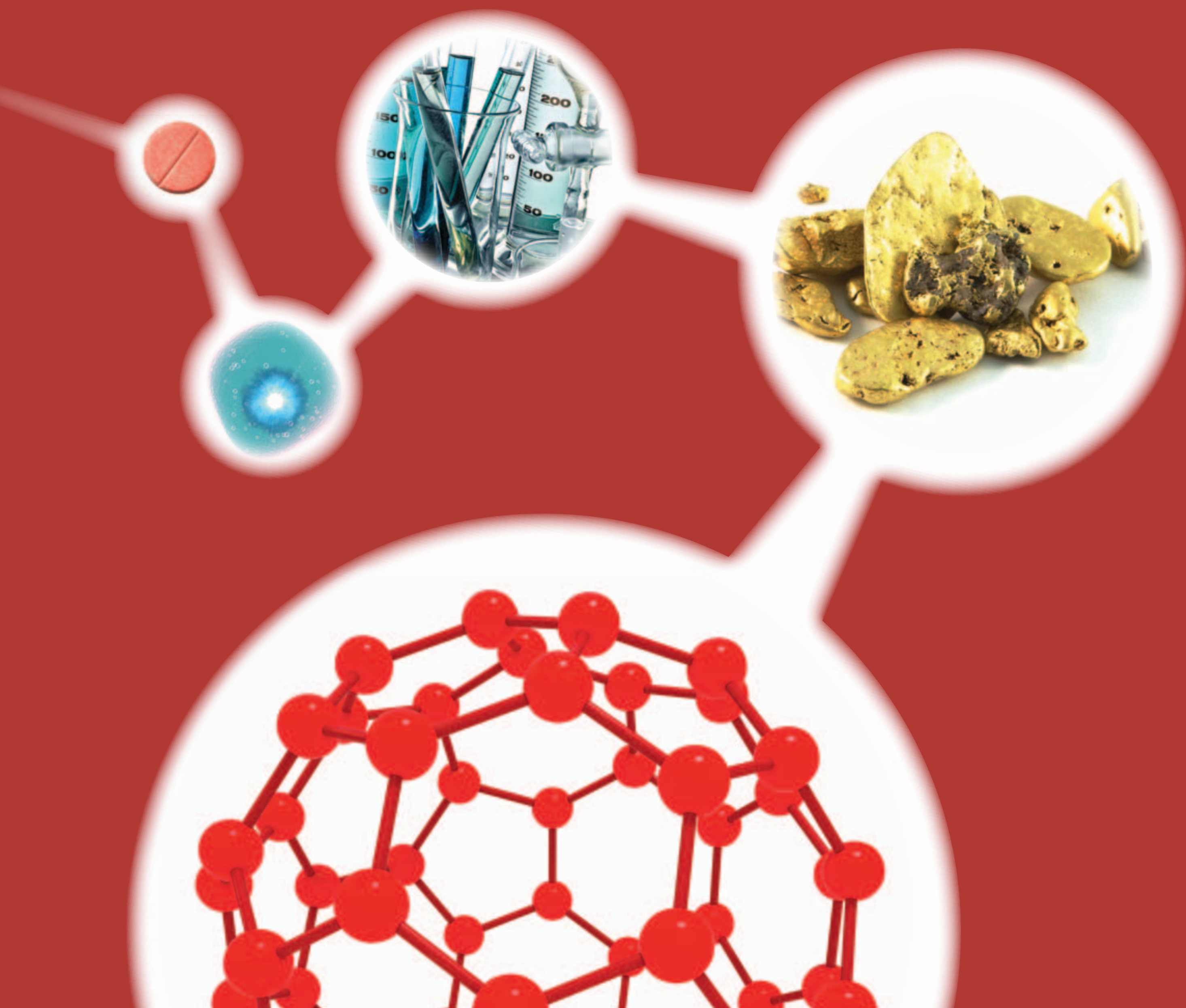
GCSE CHEMISTRY A

ACCREDITED SPECIFICATION

J244

VERSION 1

MARCH 2011



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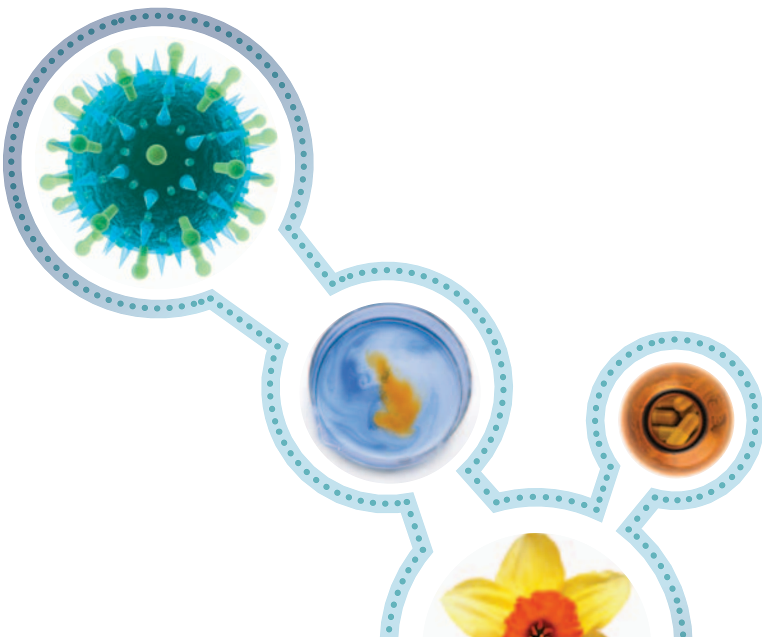

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TWENTY FIRST CENTURY SCIENCE SUITE

Science today – for scientists of tomorrow

Explore the science that underpins day-to-day life. Enthuse and motivate students using a mix of teaching strategies.

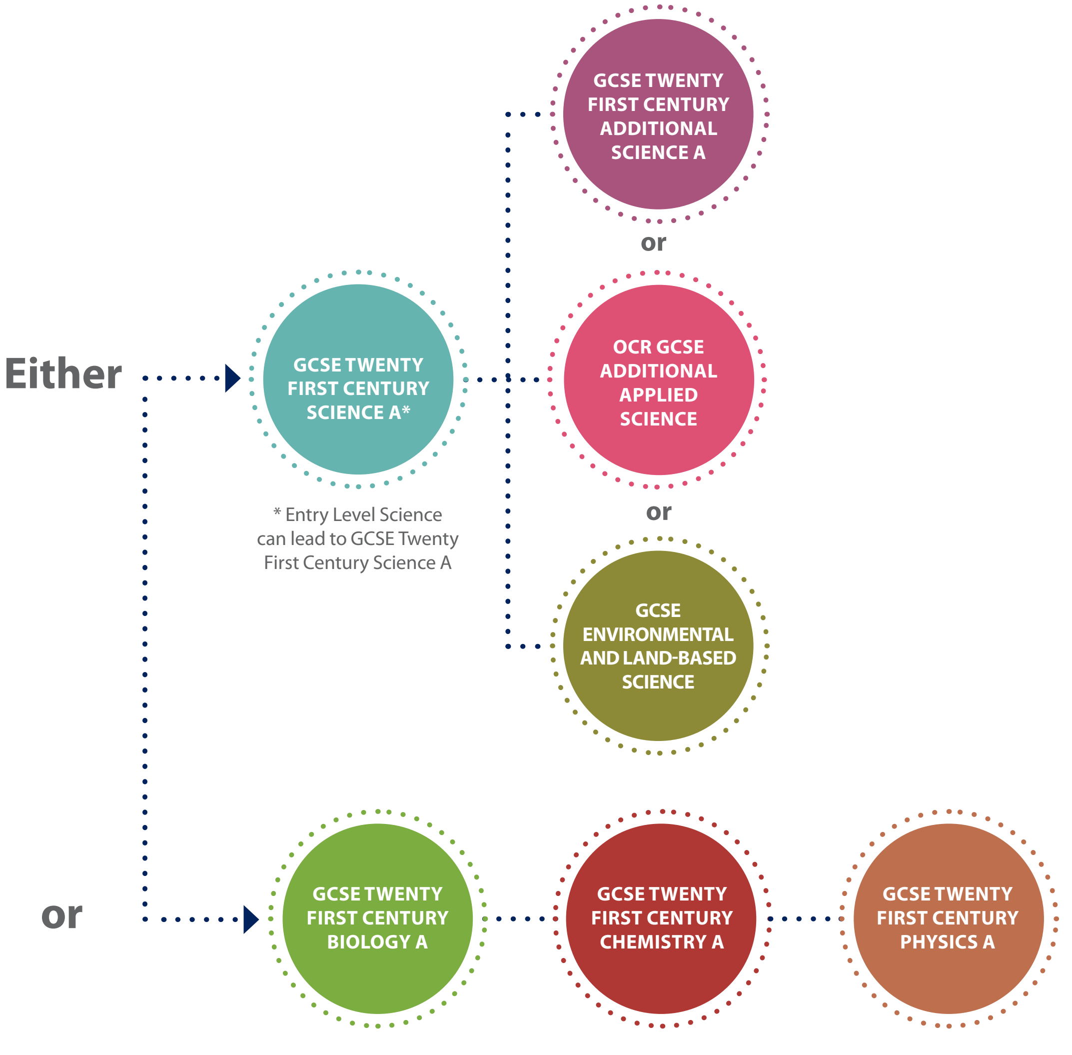
Our Twenty First Century Science suite:

- is engaging to study and motivating for you to teach
- will help your students engage with the course rather than just study it
- gives you the flexibility to choose a delivery style to engage students.

KEY FEATURES

- **Flexible assessments**, which can be arranged to suit your centre and your students – unit exams will be available twice a year, in January and June.
- An **ideal foundation** for students to progress to more-advanced studies and science-related careers.
- Well regarded and proven **concept led** teaching approach to science.

POSSIBLE GCSE COMBINATIONS



GCSE CHEMISTRY A

KEY FEATURES

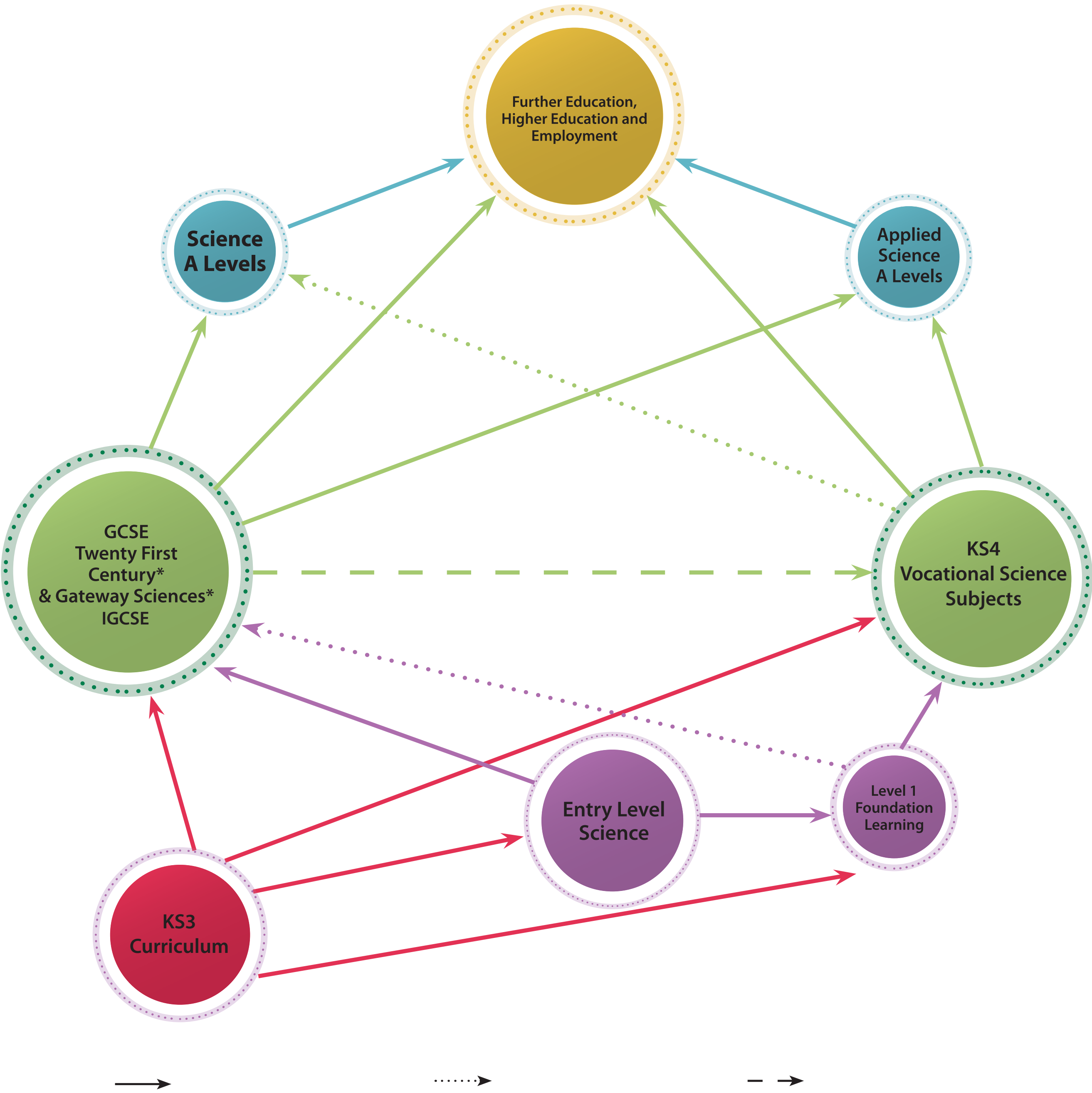
GCSE Chemistry A provides the opportunity to further develop:

- develop interest in, and enthusiasm for, chemistry
- develop a critical approach to scientific evidence and methods
- acquire and apply skills, knowledge and understanding of how science works and its essential role in society
- acquire scientific skills, knowledge and understanding necessary for progression to further learning.

GCSE Chemistry A provides distinctive and relevant experience for students who wish to progress to Level 3 qualifications.

COURSE OVERVIEW	ASSESSMENT OVERVIEW		
UNIT A171 Module C1: Air quality Module C2: Material choices Module C3: Chemicals in our lives: risks and benefits	60 marks 1 hour written paper	**25%** of total GCSE	Three written exams, assessed externally by OCR, each of which: • is offered in Foundation and Higher Tiers • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
UNIT A172 Module C4: Chemical patterns Module C5: Chemicals of the natural environment Module C6: Chemical synthesis	60 marks 1 hour written paper	**25%** of total GCSE	
UNIT A173 Module C7: Further chemistry	60 marks 1 hour written paper	**25%** of total GCSE	
UNIT A174 Controlled assessment	64 marks Approx 4.5–6 hours	**25%** of total GCSE	Comprises a Practical Investigation from a choice set by OCR Assessed by teachers, internally standardised and externally moderated by OCR Assesses the quality of written communication

PROGRESSION PATHWAYS IN SCIENCE



This could be a progression route along a particular curriculum pathway. (Stage, not age pathways)

This could be a progression route however students would require additional support.

Alternative qualification options

* Offered as
Science, Additional Science, Biology, Chemistry and Physics.

Contents

Contents

1 Introduction to the Twenty First Century Science suite

The Twenty First Century Science suite comprises five specifications which share a similar approach to teaching and learning, utilise common materials, use a consistent style of examination questions and have a common approach to skills assessment.

The qualifications available as part of this suite are:

- GCSE Science A
- GCSE Additional Science A
- GCSE Biology A
- GCSE Chemistry A
- GCSE Physics A.

GCSE Science A (J241)	which emphasises scientific literacy – the knowledge and understanding which candidates need to engage, as informed citizens, with science-based issues. As with other courses in the suite, this qualification uses contemporary, relevant contexts of interest to candidates, which can be approached through a range of teaching and learning activities.
GCSE Additional Science A (J242)	which is a concept-led course developed to meet the needs of candidates seeking a deeper understanding of basic scientific ideas. The course focuses on scientific explanations and models, and gives candidates an insight into how scientists develop scientific understanding of ourselves and the world we inhabit.
GCSE Biology A (J243) **GCSE Chemistry A (J244)** **GCSE Physics A (J245)**	each of which provides an opportunity for further developing an understanding of science explanations, how science works and the study of elements of applied science, with particular relevance to professional scientists.

The suite emphasises explanations, theories and modelling in science along with the implications of science for society. Strong emphasis is placed on the active involvement of candidates in the learning process and each specification encourages a wide range of teaching and learning activities.

The suite is supported by the Nuffield Foundation Curriculum Programme and the University of York Science Education Group, and by resources published by Oxford University Press.

In addition, an Additional Applied Science course (J251) is available. This can be used in conjunction with Science A as an alternative route to two science GCSEs, for candidates not following GCSE Additional Science A.

Introduction to GCSE Chemistry A

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2.1 Overview of OCR GCSE Chemistry A

Unit A171: ***Modules C1, C2, C3***	
This is a tiered unit offered in Foundation and Higher Tiers.	Written paper 1 hour 60 marks 25% of the qualification Candidates answer all questions. The unit uses both objective style and free response questions.

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Unit A172: ***Modules C4, C5, C6***	
This is a tiered unit offered in Foundation and Higher Tiers.	Written paper 1 hour 60 marks 25% of the qualification Candidates answer all questions. The unit uses both objective style and free response questions.

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Unit A173: ***Module C7***	
This is a tiered unit offered in Foundation and Higher Tiers.	Written paper 1 hour 60 marks 25% of the qualification Candidates answer all questions. The unit uses both objective style and free response questions.

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Unit A174: ***Controlled assessment***	
This unit is not tiered.	Controlled assessment Approximately 4.5–6 hours 64 marks 25% of the qualification

2.2 What is new in OCR GCSE Chemistry A?

	What stays the same?	What changes?
Structure	• The course can be taught as modular or linear. • Four units, comprising three externally assessed units and one internally assessed unit. • Externally assessed units are tiered – Foundation and Higher Tier.	• All four units have equal weightings of 25%. • Controlled assessment replaces coursework. • No 'Ideas in Context' paper, and no pre-release material for externally assessed units.
Content	• Content is divided into seven modules. • Module C7 is equivalent in length to any three modules from C1–C6.	• New module C3 'Chemicals in our lives', replaces 'Food Matters'.
Assessment	• The internally assessed unit is based on a Practical Investigation. • Modules are externally assessed within written examination papers. • Ideas about Science (How Science Works) are written into the specification content. • January and June assessments are available for written papers. • Controlled assessment is available in June series only.	• New terminal and re-sit rules apply to science GCSEs. • There will be a choice of controlled assessment tasks set by OCR, each valid for entry in a single examination series. • The controlled assessment for Chemistry will be based on a Practical Investigation only. • Controlled assessment is worth 25%, and will be simpler to mark and administer. • Ideas about Science are associated with all units. • Quality of written communication (QWC) will be assessed in all units. • Externally assessed papers are each 1 hour long, with a total of 60 marks divided between objective (worth 40%) and free-response style questions.

2.3 Guided learning hours

GCSE Chemistry A requires 120–140 guided learning hours in total.

Content of GCSE Chemistry A

3.1 Summary of content

A module defines the required teaching and learning outcomes.

The specification content is displayed as seven modules. The titles of these seven modules are listed below.

Modules C1 – C6 are designed to be taught in approximately **half a term each**, in 10% of the candidates' curriculum time. Module C7 is designed to be taught in approximately **one and a half terms** at 10% curriculum time.

Module C1: Air quality	Module C2: Material choices	Module C3: Chemicals in our lives – risks and benefits
• Which chemicals make up air, and which ones are pollutants? How do I make sense of data about air pollution? • What chemical reactions produce air pollutants? What happens to these pollutants in the atmosphere? • What choices can we make personally, locally, nationally or globally to improve air quality?	• How do we measure the properties of materials and why are the results useful? • Why is crude oil important as a source of new materials such as plastics and fibres? • Why does it help to know about the molecular structure of materials such as plastics and fibres? • What is nanotechnology and why is it important?	• What were the origins of minerals in Britain that contribute to our economic wealth? • Where does salt come from and why is it so important? • Why do we need chemicals such as alkalis and chlorine and how do we make them? • What can we do to make our use of chemicals safe and sustainable?
Module C4: Chemical patterns	**Module C5: Chemicals of the natural environment**	**Module C6: Chemical synthesis**
• What are the patterns in the properties of elements? • How do chemists explain the patterns in the properties of elements? • How do chemists explain the properties of compounds of Group 1 and Group 7 elements?	• What types of chemicals make up the atmosphere? • What reactions happen in the hydrosphere? • What types of chemicals make up the Earth's lithosphere? • How can we extract useful metals from minerals?	• Chemicals and why we need them • Planning, carrying out and controlling a chemical synthesis
Module C7: Further Chemistry		
• Green chemistry • Alcohols, carboxylic acids and esters	• Energy changes in chemistry • Reversible reactions and equilibria	• Analysis

3.2 Layout of specification content

The specification content is divided into seven modules assessed across three units. Three modules (C1 – C3), together with their associated Ideas about Science (see Appendix B), are assessed in Unit A171. The next three modules (C4 – C6) and their associated Ideas about Science are assessed in Unit A172. Module C7 is assessed in Unit A173, together with **any** of the Ideas about Science from Appendix B.

A summary of each unit precedes the modules that are assessed within that unit, indicating the modules and the associated Ideas about Science that can be assessed.

Each module starts with an overview which explains the background to the module and identifies:

- for Modules C1 – C3:
  - issues for citizens that are likely to be uppermost in their minds when considering the module topic, whatever their understanding of science
  - questions about the topic that science can help to address, which could reasonably be asked of a scientifically literate person
- for Modules C4 – C7:
  - a summary of the topics
- opportunities for mathematics
- opportunities for practical work
- opportunities for ICT.

Following the module overview, the Ideas about Science that can be introduced or developed in the module are outlined. Finally, the module content is presented in detail.

Within the detailed content of each module, several notations are used to give teachers additional information about the assessment. The table below summarises these notations.

Notation	Explanation
Bold	**These content statements will only be assessed on Higher Tier papers.**
ⓘ	*Advisory notes for teachers to clarify depth of cover required.*

3.3 Summary of Chemistry A Unit A171: *Modules C1, C2, C3*

Unit A171 is the first unit for GCSE Chemistry A. It assesses the content of Modules C1, C2 and C3 together with their associated Ideas about Science.

The modules in Unit A171 offer students the chance to develop the scientific literacy needed by active and informed citizens in a modern democratic society where science and technology play key roles in shaping our lives. The course content has a clear focus on scientific literacy. Teachers can use a wide range of teaching and learning styles, challenging students to consider critically the issues and choices raised by technology and science. Students will appreciate what science has to say about people, the environment and the Universe.

Ideas about Science in Unit A171

Modules C1, C2 and C3 present learning opportunities for a number of the Ideas about Science. The start of each module details the particular Ideas about Science that can be introduced or developed within the contexts covered in the module. Specific examples of contexts within which Ideas about Science can be taught are given in the OCR scheme of work for GCSE Chemistry A (published separately).

However, it is not intended that understanding and application of Ideas about Science should be limited to the context in which they are taught; they should be applicable to any appropriate scientific context.

Accordingly, questions in Unit A171 can assess any of the Ideas about Science linked to Modules C1, C2 and C3, and these Ideas about Science may be assessed in the context of any of the learning outcomes covered in the three modules.

In summary, the Ideas about Science that can be assessed in Unit A171, within any of the scientific contexts introduced by Modules C1, C2 and C3, are:

Data: their importance and limitations
IaS 1.1 – 1.6
Cause-effect explanations
IaS 2.1 – 2.5
Developing scientific explanations
IaS 3.3
The scientific community
IaS 4.1 – 4.4
Risk
IaS 5.1 – 5.7
Making decisions about science and technology
IaS 6.1 – 6.4

3.3.1 Module C1: Air quality

Overview

The quality of air is becoming a major world concern. In this module candidates learn about the gases that make up the Earth's atmosphere and how its composition has changed and is still changing. Candidates explore environmental and health consequences of certain air pollutants, and options for improving air quality in the future, such as the use of catalytic converters. The emphasis is on health issues arising from burning fuels rather than on global issues such as climate change, which is covered in Module P2: Radiation and life.

Candidates learn about the chemical relationship between the burning of fossil fuels and the production of air pollutants. This module introduces molecular elements and compounds to illustrate chemical explanations.

By analysing their own and given data on concentrations of pollutants, candidates learn about the way in which scientists use data, and also that all data have certain limitations.

Issues for citizens	Questions that science may help to answer
How do I make sense of data about air pollution? Where do pollutants come from? Is air pollution harmful to me, or to my environment? How can we improve air quality?	What chemicals make up air, and which ones are pollutants? What chemical reactions produce air pollutants? What happens to these pollutants in the atmosphere? What choices can we make personally, locally, nationally or globally to improve air quality?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of atoms, molecules and particulates
- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions and percentages
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use ideas about correlation in the context of air quality and health.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- experiments to calculate the proportion of air that is oxygen
- experiments to measure dust and particulates in the air
- combustion experiments.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- collecting, storing and displaying data from a large network of measuring instruments
- displaying data in a variety of charts, graphs and maps for analysis and evaluation.

Use of ICT in teaching and learning can include:

- using the internet to research local air quality data
- animations to illustrate chemical changes during reactions.

Module C1: Air quality – Ideas about Science

Module C1 provides opportunities to develop candidates' understanding of these Ideas about Science

1	Data: their importance and limitations Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2	Cause-effect explanations Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• suggest factors that might increase the chance of a particular outcome in a given situation, but do not invariably lead to it • explain why individual cases do not provide convincing evidence for or against a correlation.

4	The scientific community	
	Candidates should understand that:	A candidate who understands this can, for example:
4.1	• scientists report their claims to other scientists through conferences and journals. Scientific claims are only accepted once they have been evaluated critically by other scientists.	• describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists • recognise that there is less confidence in new scientific claims that have not yet been evaluated by the scientific community than there is in well-established ones.
4.2	• scientists are usually sceptical about claims that cannot be repeated by anyone else, and about unexpected findings until they have been replicated (by themselves) or reproduced (by someone else).	• identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim • explain why scientists see this as important.
4.3	• if explanations cannot be deduced from the available data, 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 judgments.	• show awareness that the same data might be interpreted, quite reasonably, in more than one way • suggest plausible reasons why scientists in a given situation disagree(d).
4.4	• an accepted scientific explanation is rarely abandoned just because some new data disagree with its predictions. It usually survives until a better explanation is available.	• discuss the likely consequences of new data that disagree with the predictions of an accepted explanation • **suggest reasons why scientists should not give up an accepted explanation immediately if new data appear to conflict with it.**

Module C1: Air quality

C1.1 Which chemicals make up air, and which ones are pollutants? How do I make sense of data about air pollution?

1. recall that the atmosphere (air) that surrounds the Earth is made up mainly of nitrogen, oxygen and argon, plus small amounts of water vapour, carbon dioxide and other gases
2. recall that air is a mixture of different gases consisting of small molecules with large spaces between them
3. recall that the relative proportions of the main gases in the atmosphere are approximately 78% nitrogen, 21% oxygen and 1% argon
4. understand that other gases or particulates may be released into the atmosphere by human activity or by natural processes (eg volcanoes), and that these can affect air quality
5. understand how the Earth's early atmosphere was probably formed by volcanic activity and consisted mainly of carbon dioxide and water vapour
6. understand that water vapour condensed to form the oceans when the Earth cooled
7. explain how the evolution of photosynthesising organisms added oxygen to, and removed carbon dioxide from, the atmosphere
8. explain how carbon dioxide was removed from the atmosphere by dissolving in the oceans and then forming sedimentary rocks, and by the formation of fossil fuels
9. understand how human activity has changed the composition of the atmosphere by adding:
    a. small amounts of carbon monoxide, nitrogen oxides and sulfur dioxide to the atmosphere
    b. extra carbon dioxide and small particles of solids (eg carbon) to the atmosphere
10. understand that some of these substances, called pollutants, are directly harmful to humans (eg carbon monoxide reduces the amount of oxygen that blood can carry), and that some are harmful to the environment and so cause harm to humans indirectly (eg sulfur dioxide causes acid rain).

Module C1: Air quality

C1.2 What chemical reactions produce air pollutants? What happens to these pollutants in the atmosphere?

1. recall that coal is mainly carbon
2. recall that petrol, diesel fuel and fuel oil are mainly compounds of hydrogen and carbon (hydrocarbons)
3. understand that, when fuels burn, atoms of carbon and/or hydrogen from the fuel combine with atoms of oxygen from the air to produce carbon dioxide and/or water (hydrogen oxide)
4. understand that a substance chemically combining with oxygen is an example of oxidation, that loss of oxygen is an example of reduction, and that combustion reactions therefore involve oxidation
5. understand that fuels burn more rapidly in pure oxygen than in air
6. recall that oxygen can be obtained from the atmosphere and can be used to support combustion (eg in oxy-fuel welding torches)
7. understand that in a chemical reaction the properties of the reactants and products are different
8. understand that atoms are rearranged during a chemical reaction
9. interpret representations of the rearrangement of atoms during a chemical reaction
10. understand that during the course of a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants, **thus conserving mass**
11. understand how sulfur dioxide is produced if the fuel that is burned contains any sulfur
12. understand how burning fossil fuels in power stations and for transport pollutes the atmosphere with:
    a. carbon dioxide and sulfur dioxide
    b. carbon monoxide and particulate carbon (from incomplete burning)
    c. nitrogen oxides (from the reaction between atmospheric nitrogen and oxygen at the high temperatures inside engines)
13. relate the formulae for carbon dioxide CO_2, carbon monoxide CO, sulfur dioxide SO_2, nitrogen monoxide NO, nitrogen dioxide NO_2 and water H_2O to visual representations of their molecules
14. **recall that nitrogen monoxide NO is formed during the combustion of fuels in air, and is subsequently oxidised to nitrogen dioxide NO_2 (NO and NO_2 are jointly referred to as 'NOx')**
15. understand that atmospheric pollutants cannot just disappear, they have to go somewhere:
    a. particulate carbon is deposited on surfaces, making them dirty
    b. sulfur dioxide and nitrogen dioxide react with water and oxygen to produce acid rain which is harmful to the environment
    c. carbon dioxide is used by plants in photosynthesis
    d. carbon dioxide dissolves in rain water and in sea water.

Module C1: Air quality

C1.3 What choices can we make personally, locally, nationally or globally to improve air quality?

1. understand how atmospheric pollution caused by power stations that burn fossil fuels can be reduced by:
    a. using less electricity
    b. removing sulfur from natural gas and fuel oil
    c. removing sulfur dioxide and particulates from the flue gases emitted by coal-burning power stations
2. **understand how the acid gas sulfur dioxide is removed from flue gases by wet scrubbing:**
    a. using an alkaline slurry eg a spray of calcium oxide and water
    b. using sea water
    ⓘ *Candidates are not required to write word or symbol equations*
3. understand that the only way of producing less carbon dioxide is to burn less fossil fuels
4. understand how atmospheric pollution caused by exhaust emissions from motor vehicles can be reduced by:
    a. burning less fuel, for example by having more efficient engines
    b. using low sulfur fuels
    c. using catalytic converters (in which nitrogen monoxide is reduced to nitrogen by loss of oxygen, and carbon monoxide is oxidised to carbon dioxide by gain of oxygen)
    d. adjusting the balance between public and private transport
    e. having legal limits to exhaust emissions (which are enforced by the use of MOT tests)
5. **understand the benefits and problems of using alternatives to fossil fuels for motor vehicles, limited to biofuels and electricity.**

3.3.2 Module C2: Material choices

Overview

Our way of life depends on a wide range of materials produced from natural resources. The Earth's crust provides us with crude oil, which is a source of fuel and raw material for producing synthetic polymers. Natural polymers can also be useful and can be obtained from living things. This module considers how measurements of the properties of materials can inform the choice of material for a particular purpose. By taking their own measurements, candidates can explore some of the issues that arise when trying to establish accurate and meaningful data.

Key ideas in this module are illustrated through polymers. Candidates learn how the molecules that make up a polymer fit together and how strongly they are bonded to each other, providing an explanation of the properties of materials. This provides an example of a scientific explanation that makes sense of a wide range of observations.

Candidates also learn how polymers can be modified to give them more desirable properties by the introduction of nanoparticles, which have different properties when compared with larger particles of the same material.

Issues for citizens	Questions that science may help to answer
How can we pick a suitable material for a particular product or task?	How do we measure the properties of materials and why are the results useful? Why is crude oil important as a source of new materials such as plastics and fibres? Why does it help to know about the molecular structure of materials such as plastics and fibres? What is nanotechnology and why is it important?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of polymers and nanoparticles
- carry out calculations using experimental data, including finding the mean and the range
- use ideas of proportion in the context of surface area
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts showing properties of materials.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- test the properties of materials
- make polymers and modifying their properties
- perform or observe the distillation of crude oil.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- logging and storing data, and displaying data in a variety of formats for analysis and evaluation.

Use of ICT in teaching and learning can include:

- using spreadsheets to record and display measurements of the properties of materials
- video clips to illustrate the main stages from extraction of oil to production of synthetic plastic or fibre
- using still images and diagrams to create presentations to show how the properties of a material depend on its molecular structure.

Module C2: Material choices – Ideas about Science

Module C2 provides opportunities to develop candidates' understanding of these Ideas about Science

1	Data: their importance and limitations Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2	**Cause-effect explanations**	
	Candidates should understand that:	A candidate who understands this can, for example:
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.

Module C2: Material choices

C2.1 How do we measure the properties of materials and why are the results useful?

1. interpret information about how solid materials can differ with respect to properties such as melting point, strength (in tension or compression), stiffness, hardness and density
2. relate properties to the uses of materials such as plastics, rubbers and fibres
3. relate the effectiveness and durability of a product to the materials used to make it
4. interpret information about the properties of materials such as plastics, rubbers and fibres to assess the suitability of these materials for particular purposes.

Module C2: Material choices

C2.2 Why is crude oil important as a source of new materials such as plastics and fibres?

1. recall that the materials we use are chemicals or mixtures of chemicals, and include metals, ceramics and polymers
2. recall that materials can be obtained or made from living things, and give examples such as cotton, paper, silk and wool
3. recall that there are synthetic materials that are alternatives to materials from living things
4. recall that raw materials from the Earth's crust can be used to make synthetic materials
5. interpret representations of rearrangements of atoms during a chemical reaction
6. understand that in a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants
7. recall that crude oil consists mainly of hydrocarbons, which are chain molecules of varying lengths made from carbon and hydrogen atoms only
8. recall that only a small percentage of crude oil is used for chemical synthesis and that most is used as fuels
9. understand that the petrochemical industry refines crude oil by fractional distillation; hydrocarbons are separated into fractions of different boiling points, to produce fuels, lubricants and the raw materials for chemical synthesis
10. relate the size of the forces between hydrocarbon molecules to the size of the molecules.
11. relate the strength of the forces between hydrocarbon molecules in crude oil to the amount of energy needed for them to break out of a liquid and form a gas, and to the temperature at which the liquid boils
12. understand that some small molecules called monomers can join together to make very long molecules called polymers, and that the process is called polymerisation
13. recall two examples of materials that, because of their superior properties, have replaced materials used in the past.

Module C2: Material choices

C2.3 Why does it help to know about the molecular structure of materials such as plastics and fibres?

1. understand that it is possible to produce a wide range of different polymers with properties that make them each suited to a particular use
2. understand how the properties of polymers depend on how their molecules are arranged and held together
3. relate the strength of the forces between the molecules in a polymer to the amount of energy needed to separate them from each other, and therefore to the strength, stiffness, hardness and melting point of the solid
4. understand how modifications in polymers produce changes to their properties (see C2.1), to include modifications such as:
   a. increased chain length
   b. cross-linking
   c. the use of plasticizers
   d. increased crystallinity.

Module C2: Material choices

C2.4 What is nanotechnology and why is it important?

1. recall that nanotechnology involves structures that are about the same size as some molecules
2. understand that nanotechnology is the use and control of structures that are very small (1 to 100 nanometres in size)
3. understand that nanoparticles can occur naturally (for example in seaspray), by accident (for example as the smallest particulates from combustion of fuels), and by design
4. understand that nanoparticles of a material show different properties compared to larger particles of the same material, and that one of the reasons for this is the much larger surface area of the nanoparticles compared to their volume
5. understand that nanoparticles can be used to modify the properties of materials, and give examples including:
    a. the use of silver nanoparticles to give fibres antibacterial properties
    b. adding nanoparticles to plastics for sports equipment to make them stronger
6. understand that some nanoparticles may have harmful effects on health, and that there is concern that products with nanoparticles are being introduced before these effects have been fully investigated.

3.3.3 Module C3: Chemicals in our lives – risks and benefits

Overview

Thanks to its geological history, Britain is a country that has large deposits of valuable resources including salt and limestone as well as coal, gas and oil. These raw materials have been the basis of a chemical industry for over 200 years. At first many of the industrial processes were highly polluting. This led to new laws and the establishment of regulatory organisations to control the industry. Today the industry is under great pressure to operate processes that are efficient in their use of energy and which do minimal harm to health and the environment.

Salt is particularly important. Salt is necessary in the diet but is hazardous if eaten to excess. Chemists have learnt to convert salt to alkalis and to chlorine, chemicals that are used to make many valuable products.

The use of manufactured chemicals has brought both benefits and risks. Society has become increasingly concerned that there are many chemicals that are used in large amounts, but which have never been thoroughly tested to evaluate their effects on people and the environment.

The data from Life Cycle Assessments shows that in selecting a product for a particular job we should assess not only its ‘fitness for purpose’ but also the total effects of using the materials that make up the product over its complete life cycle, from its production using raw materials to its disposal.

Issues for citizens	Questions that science may help to answer
Why do we need to use manufactured chemicals? What can society do to ensure that it uses chemicals in ways that are safe and sustainable? When choosing a product made from a particular chemical, what else should we consider besides its cost and how well it does its job?	Why are there valuable sources of raw materials for making chemicals in Britain? Why are salt and limestone so important for the chemical industry? What are the benefits and risks of making chemicals with chlorine?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of geological time
- carry out calculations using fractions and percentages
- interpret graphs and charts from secondary data
- extract information from charts, graphs and tables about water quality and health
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- purify rock salt
- experiments with acids and alkalis
- make soap
- perform the electrolysis of brine.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- simulating the movement of the continents over geological time periods.

Use of ICT in teaching and learning can include:

- video clips to illustrate the extraction of raw materials and the production of useful chemicals
- animations to illustrate chemical processes
- simulations to explore the impact of choices made during the life cycle of a product
- using the internet to explore case studies of the safe and sustainable use of polymers and materials.

Module C3: Chemicals in our lives – risks and benefits – Ideas about Science

Module C3 provides opportunities to develop candidates' understanding of these Ideas about Science

3	**Developing scientific explanations** Candidates should understand that:	A candidate who understands this can, for example:
3.3	• a scientific explanation should account for most (ideally all) of the data already known. It may explain a range of phenomena not previously thought to be linked. It should also enable predictions to be made about new situations or examples.	• recognise data or observations that are accounted for by, or conflict with, an explanation • give good reasons for accepting or rejecting a proposed scientific explanation • identify the better of two given scientific explanations for a phenomenon, and give reasons for the choice.
5	**Risk** Candidates should understand that:	A candidate who understands this can, for example:
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.
5.2	• we can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.	• interpret and discuss information on the size of risks, presented in different ways.
5.3	• to make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.	• discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.
5.4	• to make a decision about a course of action, we need to take account of both its risks and benefits, to the different individuals or groups involved.	• identify risks and benefits in a given situation, to the different individuals and groups involved • discuss a course of action, with reference to its risks and benefits, taking account of who benefits and who takes the risks • suggest benefits of activities that are known to have risk.

5	Risk Candidates should understand that:	A candidate who understands this can, for example:
5.5	• 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.	• offer reasons for people's willingness (or reluctance) to accept the risk of a given activity.
5.6	• **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).**	• **distinguish between perceived and calculated risk, when discussing personal choices** • **suggest reasons for given examples of differences between perceived and measured risk.**
5.7	• governments and public bodies may have to assess what level of risk is acceptable in a particular situation. This decision may be controversial, especially if those most at risk are not those who benefit.	• discuss the public regulation of risk, **and explain why it may in some situations be controversial.**
6	**Making decisions about science and technology** Candidates should understand that:	A candidate who understands this can, for example:
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.2	• scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	• identify, and suggest, examples of unintended impacts of human activity on the environment • explain the idea of sustainability, and apply it to specific situations • use data (for example, from a Life Cycle Assessment) to compare the sustainability of alternative products or processes.
6.3	• in many areas of scientific work, the development and application of scientific knowledge are subject to official regulations.	• in contexts where this is appropriate, show awareness of, **and discuss**, the official regulation of scientific research and the application of scientific knowledge.
6.4	• some questions, such as those involving values, cannot be answered by science.	• distinguish questions which could in principle be answered using a scientific approach, from those which could not.

Module C3: Chemicals in our lives – risks and benefits

C3.1 What were the origins of minerals in Britain that contribute to our economic wealth?

1. understand that geologists explain most of the past history of the surface of the Earth in terms of processes than can be observed today
2. understand that movements of tectonic plates mean that the parts of ancient continents that now make up Britain have moved over the surface of the Earth
3. understand how geologists use magnetic clues in rocks to track the very slow movement of the continents over the surface of the Earth
4. understand that the movements of continents means that different rocks in Britain formed in different climates
5. understand how processes such as mountain building, erosion, sedimentation, dissolving and evaporation have led to the formation of valuable resources found in England including coal, limestone and salt
6. understand how geologists study sedimentary rocks to find evidence of the conditions under which they were formed, to include:
   a. fossils
   b. shapes of water borne grains compared to air blown grains
   c. presence of shell fragments
   d. ripples from sea or river bottom
7. understand that chemical industries grow up where resources are available locally, eg salt, limestone and coal in north west England.

Module C3: Chemicals in our lives – risks and benefits

C3.2 Where does salt come from and why is it so important?

1. understand the importance of salt (sodium chloride) for the food industry, as a source of chemicals and to treat roads in winter
2. recall that salt can be obtained from the sea or from underground salt deposits
3. understand how underground salt can be obtained by mining, or by solution in water
4. understand why the method used to obtain salt may depend on how the salt is to be used
5. understand how the methods of obtaining salt can have an impact on the environment
6. understand the advantages of adding salt to food as flavouring and as a preservative
7. recall the health implications of eating too much salt
8. be able to evaluate data related to the content of salt in food and health
9. recall that Government departments, such as the Department of Health and the Department for Environment, Food and Rural Affairs, have a role in:
    a. carrying out risk assessments in relation to chemicals in food
    b. advising the public in relation to the effect of food on health.

Module C3: Chemicals in our lives – risks and benefits

C3.3 Why do we need chemicals such as alkalis and chlorine and how do we make them?

1. recall that, even before industrialisation, alkalis were needed to neutralise acid soils, make chemicals that bind natural dyes to cloth, convert fats and oils into soap and to manufacture glass
2. recall that traditional sources of alkali included burnt wood or stale urine
3. understand that alkalis neutralise acids to make salts
4. **recall that soluble hydroxides and carbonates are alkalis**
5. **predict the products of the reactions of soluble hydroxides and carbonates with acids**
6. understand that increased industrialisation led to a shortage of alkali in the nineteenth century
7. understand that the first process for manufacturing alkali from salt and limestone using coal as a fuel caused pollution by releasing large volumes of an acid gas (hydrogen chloride) and creating great heaps of waste that slowly released a toxic and foul smelling gas (hydrogen sulfide)
8. understand that pollution problems can sometimes be solved by turning wastes into useful chemicals
9. understand that oxidation can convert hydrogen chloride to chlorine, and that the properties of a compound are completely different from the elements from which it is made
10. recall that chlorine is used to kill microorganisms in domestic water supplies and as a bleach
11. understand how the introduction of chlorination to treat drinking water made a major contribution to public health
12. interpret data about the effects of polluted water on health and the impact of water treatment with chlorine to control disease
13. understand that there may be disadvantages of chlorinating drinking water, including possible health problems from traces of chemicals formed by reaction of chlorine with organic materials in the water
14. understand that an electric current can be used to bring about chemical change and make new chemicals through a process called electrolysis
15. recall that chlorine is now obtained by the electrolysis of salt solution (brine)

    ⓘ *Technical details and the ionic reactions are not required*

16. recall examples of important uses by industry of the sodium hydroxide, chlorine and hydrogen produced by electrolysis of brine
17. interpret data about the environmental impact of the large scale electrolysis of brine.

Module C3: Chemicals in our lives – risks and benefits

C3.4 What can we do to make our use of chemicals safe and sustainable?

1. understand that there is a large number of industrial chemicals with many widespread uses, including consumer products, for which there is inadequate data to judge whether they are likely to present a risk to the environment and/or human health
2. understand that some toxic chemicals cause problems because they persist in the environment, can be carried over large distances, and may accumulate in food and human tissues
3. recall that PVC is a polymer that contains chlorine as well as carbon and hydrogen
4. understand that the plasticizers used to modify the properties of PVC can leach out from the plastic into the surroundings where they may have harmful effects
5. understand that a Life Cycle Assessment (LCA) involves consideration of the use of resources including water, the energy input or output, and the environmental impact, of each of these stages:
    a. making the material from natural raw materials
    b. making the product from the material
    c. using the product
    d. disposing of the product
6. when given appropriate information from a Life Cycle Assessment (LCA), compare and evaluate the use of different materials for the same purpose.

3.4 Summary of Chemistry A Unit A172: *Modules C4, C5, C6*

Unit A172 is the second unit for GCSE Chemistry A. It assesses the content of Modules C4, C5 and C6 together with their associated Ideas about Science. Any of IaS 1 (Data: their importance and limitations) and IaS 2 (Cause-effect explanations) can also be assessed in this unit.

The modules in Unit A172 give emphasis and space to fundamental ideas in the sciences, ensure that appropriate skills are developed in preparation for further study, and provide a stimulating bridge to advanced level studies in science. The emphasis of the unit is on 'science for the scientist' and those aspects of 'How Science Works' that relate to the process of science.

Ideas about Science in Unit A172

Modules C4, C5 and C6 present learning opportunities for a number of the Ideas about Science. The start of each module details the particular Ideas about Science that can be introduced or developed within the contexts covered in the module. Specific examples of contexts within which Ideas about Science can be taught are given in the OCR scheme of work for GCSE Chemistry A (published separately).

However, it is not intended that understanding and application of Ideas about Science should be limited to the context in which they are taught; they should be applicable to any appropriate scientific context.

Accordingly, questions in Unit A172 can assess any of the Ideas about Science linked to Modules C4, C5 and C6, as well as IaS1 (Data: their importance and limitations) and IaS2 (Cause-effect explanations). These Ideas about Science may be assessed in the context of any of the learning outcomes covered in the three modules.

In summary, the Ideas about Science that can be assessed in Unit A172, within any of the scientific contexts introduced by Modules C4, C5 and C6, are:

Data: their importance and limitations
IaS 1.1 – 1.6
Cause-effect explanations
IaS 2.1 – 2.7
Developing scientific explanations
IaS 3.1 – 3.4
The scientific community
IaS 4.1, 4.2
Risk
IaS 5.1
Making decisions about science and technology
IaS 6.1, 6.2, 6.5, 6.6

3.4.1 Module C4: Chemical patterns

Overview

This module features a central theme of modern chemistry. It shows how theories of atomic structure can be used to explain the properties of elements and their compounds. The module also includes examples to show how spectra and spectroscopy have contributed to the development of chemical knowledge and techniques. This module shows how atomic structure can be used to help explain the behaviour of elements.

The first topic looks at the Periodic Table, the history of its development, and patterns that exist within it, focusing on Group 1 and Group 7. This topic also introduces the use of symbols and equations as a means of describing a chemical reaction. An explanation of the patterns is then developed in the next topic by linking atomic structure with chemical properties.

The third, and final, topic takes this further by introducing ions and showing how ionic theory can account for properties of compounds of Group 1 with Group 7 elements.

Topics	
C4.1	What are the patterns in the properties of elements?
The history of the development of the Periodic Table Classifying elements by their position in the Periodic Table Patterns in Group 1 and patterns in Group 7 Using symbols and equations to represent chemical reactions	
C4.2	How do chemists explain the patterns in the properties of elements?
Flame tests and spectra and their use for identifying elements and studying atomic structure Classifying elements by their atomic structure Linking atomic structure to chemical properties	
C4.3	How do chemists explain the properties of compounds of Group 1 and Group 7 elements?
Ions, and linking ion formation to atomic structure Properties of ionic compounds of alkali metals and halogens	

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of atomic structure
- use ideas of ratios in the context of the formulae of ionic compounds
- plot, draw and interpret graphs and charts from secondary data
- extract information from the Periodic Table
- extract information from charts and graphs including patterns in the properties of elements
- balance chemical equations.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- reactions of the alkali metals
- reactions of the halogens
- experiments to test the properties of ionic compounds.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- storing large sets of data
- selecting and presenting data in a variety of forms to explore patterns and trends.

Use of ICT in teaching and learning can include:

- using an interactive Periodic Table to explore similarities and differences between elements
- using a spreadsheet to display patterns in chemical data
- video clips to test predictions about the reactions of elements such as caesium and fluorine
- using the internet to research the uses of alkali metals or halogens and their compounds.

Module C4: Chemical patterns – Ideas about Science

Module C4 provides opportunities to develop candidates' understanding of these Ideas about Science

3	Developing scientific explanations Candidates should understand that:	A candidate who understands this can, for example:
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
3.3	• a scientific explanation should account for most (ideally all) of the data already known. It may explain a range of phenomena not previously thought to be linked. It should also enable predictions to be made about new situations or examples.	• recognise data or observations that are accounted for by, or conflict with, an explanation • give good reasons for accepting or rejecting a proposed scientific explanation • identify the better of two given scientific explanations for a phenomenon, and give reasons for the choice.
3.4	• scientific explanations are tested by comparing predictions based on them with data from observations or experiments.	• draw valid conclusions about the implications of given data for a given scientific explanation, in particular: – understand that agreement between a prediction and an observation increases confidence in the explanation on which the prediction is based but does not prove it is correct – understand that disagreement between a prediction and an observation indicates that one or other is wrong, and decreases our confidence in the explanation on which the prediction is based.

4	**The scientific community**	
	Candidates should understand that:	A candidate who understands this can, for example:
4.1	• scientists report their claims to other scientists through conferences and journals. Scientific claims are only accepted once they have been evaluated critically by other scientists.	• describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists • recognise that there is less confidence in new scientific claims that have not yet been evaluated by the scientific community than there is in well-established ones.
4.2	• scientists are usually sceptical about claims that cannot be repeated by anyone else, and about unexpected findings until they have been replicated (by themselves) or reproduced (by someone else).	• identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim • explain why scientists see this as important.

Module C4: Chemical patterns

C4.1 What are the patterns in the properties of elements?

1. understand that atoms of each element have different proton numbers
2. understand that arranging the elements in order of their proton numbers gives repeating patterns in the properties of elements
3. understand that early attempts to find connections between the chemical properties of the elements and their relative atomic mass were dismissed by the scientific community
4. recall the significant stages in the history of the development of the Periodic Table to include the ideas of Döbereiner, Newlands and Mendeleev
5. understand how Mendeleev used his Periodic Table to predict the existence of unknown elements
6. use the Periodic Table to obtain the names, symbols, relative atomic masses and proton numbers of elements
7. understand that a group of elements is a vertical column in the Periodic Table and that the elements in a group have similar properties
8. recall that a period is a row of elements in the Periodic Table
9. use the Periodic Table to classify an element as a metal or non-metal
10. use patterns in the Periodic Table to interpret data and predict properties of elements

    ⓘ *Candidates will be given a copy of the Periodic Table (as in Appendix F) with the examination paper*

11. recall and recognise the chemical symbols for the Group 1 metals (also known as the alkali metals) lithium, sodium and potassium
12. recall that the alkali metals are shiny when freshly cut but tarnish rapidly in moist air due to reaction with oxygen
13. use qualitative and quantitative data to identify patterns and make predictions about the properties of Group 1 metals (for example, melting point, boiling point, density, formulae of compounds and relative reactivity)
14. describe the reactions of lithium, sodium and potassium with cold water
15. recall that alkali metals react with water to form hydrogen and an alkaline solution of a hydroxide with the formula MOH
16. recall that alkali metals react vigorously with chlorine to form colourless, crystalline salts with the formula MCl
17. understand and give examples to show that the alkali metals become more reactive as the group is descended
18. recall the main hazard symbols and be able to give the safety precautions for handling hazardous chemicals (limited to explosive, harmful, toxic, corrosive, oxidizing, and highly flammable)
19. state and explain the precautions necessary when working with Group 1 metals and alkalis
20. recall and recognise the chemical symbols for the atoms of the Group 7 elements (also known as the halogens) chlorine, bromine and iodine
21. recall the states of these halogens at room temperature and pressure

C4.1 What are the patterns in the properties of elements?

22. recall the colours of these halogens in their normal physical state at room temperature and as gases
23. recall that the halogens consist of diatomic molecules
24. use qualitative and quantitative data to identify patterns and make predictions about the properties of the Group 7 elements (for example melting point, boiling point, formulae of compounds and relative reactivity)
25. understand that the halogens become less reactive as the group is descended and give examples to show this
26. understand how a trend in reactivity for halogens can be shown by their displacement reactions and by their reactions with alkali metals and with iron
27. state and explain the safety precautions necessary when working with the halogens
28. recall the formulae of:
    a. hydrogen, water and halogen (limited to chlorine, bromine and iodine) molecules
    b. the chlorides, **bromides and iodides (halides)** of Group 1 metals (limited to lithium, sodium and potassium)
29. write word equations for reactions of alkali metals and halogens in this module and for other reactions when given appropriate information
30. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products

    ⓘ *In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*
31. **balance unbalanced symbol equations**
32. **write balanced equations, including the state symbols (s), (g), (*l*) and (aq), for reactions of alkali metals and halogens in this module and for other reactions when given appropriate information**
33. recall the state symbols (s), (*l*), (g) and (aq) and understand their use in equations.

Module C4: Chemical patterns

C4.2 How do chemists explain the patterns in the properties of elements?

1. describe the structure of an atom in terms of protons and neutrons in a very small central nucleus with electrons arranged in shells around the nucleus
2. recall the relative masses and charges of protons, neutrons and electrons
3. understand that in any atom the number of electrons equals the number of protons
4. understand that all the atoms of the same element have the same number of protons
5. understand that the elements in the Periodic Table are arranged in order of proton number
6. recall that some elements emit distinctive flame colours when heated (for example lithium, sodium and potassium)

   ⓘ *Recall of specific flame colours emitted by these elements is not required*

7. understand that the light emitted from a particular element gives a characteristic line spectrum
8. understand that the study of spectra has helped chemists to discover new elements
9. understand that the discovery of some elements depended on the development of new practical techniques (for example spectroscopy)
10. **use the Periodic Table to work out the number of protons, electrons and neutrons in an atom**
11. use simple conventions, such as 2.8.1 and dots in circles, to represent the electron arrangements in the atoms of the first 20 elements in the Periodic Table, when the number of electrons or protons in the atom is given (**or can be derived from the Periodic Table**)
12. understand that a shell (or energy level) fills with electrons across a period
13. understand that elements in the same group have the same number of electrons in their outer shell and how this relates to group number
14. **understand that the chemical properties of an element are determined by its electron arrangement, illustrated by the electron configurations of the atoms of elements in Groups 1 and 7.**

Module C4: Chemical patterns

C4.3 How do chemists explain the properties of compounds of Group 1 and Group 7 elements?

1. understand that molten compounds of metals with non-metals conduct electricity and that this is evidence that they are made up of charged particles called ions
2. understand that an ion is an atom (or group of atoms) that has gained or lost electrons and so has an overall charge
3. account for the charge on the ions of Group 1 and Group 7 elements by comparing the number and arrangement of the electrons in the atoms and ions of these elements
4. **work out the formulae of ionic compounds given the charges on the ions**
5. **work out the charge on one ion given the formula of a salt and the charge on the other ion**
6. recall that compounds of Group 1 metals with Group 7 elements are ionic
7. understand that solid ionic compounds form crystals because the ions are arranged in a regular lattice
8. describe what happens to the ions when an ionic crystal melts or dissolves in water
9. explain that ionic compounds conduct electricity when molten or when dissolved in water because the ions are charged and they are able to move around independently in the liquid.

3.4.2 Module C5: Chemicals of the natural environment

Overview

Chemistry is fundamental to an understanding of the scale and significance of human impacts on the natural environment. Knowledge of natural processes makes it possible to appreciate the environmental consequences of extracting and processing minerals.

The module uses environmental contexts to introduce theories of structure and bonding. The first topic explains the characteristics of covalent bonding, and intermolecular forces in the context of the chemicals found in the atmosphere. The second topic explains ionic bonding in the context of reactions in the hydrosphere, and includes the detection and identification of ions.

The third topic looks at the properties of giant structures with strong covalent bonding found in the Earth's crust, including silicon dioxide. The final topic covers the distribution, structure and properties of metals through a study of their extraction from ores. This includes the use of relative atomic masses to give a quantitative interpretation of chemical formulae.

Topics
C5.1 What types of chemicals make up the atmosphere?
The structure and properties of chemicals found in the atmosphere
C5.2 What reactions happen in the hydrosphere?
The structure and properties of chemicals found in the hydrosphere, and detecting and identifying ions
C5.3 What types of chemicals make up the Earth's lithosphere?
Relating the properties of chemicals to their giant structure using examples found in the Earth's lithosphere
C5.4 How can we extract useful metals from minerals?
Relating the structure and properties of metals to suitable methods of extraction Using ionic theory to explain electrolysis Discussing issues relating to metal extraction and recycling

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of the Earth and its atmosphere
- carry out calculations to find the percentage of an element in a compound and the mass of an element that can be obtained from its compound
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts, graphs and tables including the abundance of elements on the Earth
- calculate relative formula masses
- balance ionic equations.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- crystallisation experiments
- using precipitation reactions to identify ions in salts
- extracting metals with carbon
- extracting metals by electrolysis.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- modelling molecules and giant structures to explain properties.

Use of ICT in teaching and learning can include:

- animations to show the movement of molecules in a gas over a range of temperatures
- modelling software to show the shapes of molecules and illustrate giant structures
- video clips to show metals being extracted on a large scale
- animations to illustrate the ionic theory of electrolysis.

Module C5: Chemicals of the natural environment – Ideas about Science

Module C5 provides opportunities to develop candidates' understanding of these Ideas about Science

	Candidates should understand that:	A candidate who understands this can, for example:
3	**Developing scientific explanations**	
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
5	**Risk**	
	Candidates should understand that:	A candidate who understands this can, for example:
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.

6	Making decisions about science and technology	
	Candidates should understand that:	A candidate who understands this can, for example:
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.2	• scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	• identify, and suggest, examples of unintended impacts of human activity on the environment • explain the idea of sustainability, and apply it to specific situations • use data (for example, from a Life Cycle Assessment) to compare the sustainability of alternative products or processes.
6.5	• some forms of scientific research, and some applications of scientific knowledge, have ethical implications. People may disagree about what should be done (or permitted).	• where an ethical issue is involved: – say clearly what this issue is – summarise different views that may be held.
6.6	• in discussions of ethical issues, one common argument is that the right decision is one which leads to the best outcome for the greatest number of people involved. Another is that certain actions are considered right or wrong whatever the consequences.	• in a given context, identify, **and develop**, arguments based on the ideas that: – the right decision is the one which leads to the best outcome for the greatest number of people involved – certain actions are considered right or wrong whatever the consequences.

Module C5: Chemicals of the natural environment

C5.1 What types of chemicals make up the atmosphere?

1. recall that dry air consists of gases, some of which are elements (for example, oxygen, nitrogen and argon) and some of which are compounds (for example, carbon dioxide)
2. recall that the relative proportions of the main gases in the atmosphere are about 78% nitrogen, 21% oxygen, 1% argon and 0.04% carbon dioxide
3. recall the symbols for the atoms and molecules of these gases in the air
4. recall that most non-metal elements and most compounds between non-metal elements are molecular
5. understand that molecular elements and compounds with small molecules have low melting and boiling points
6. interpret quantitative data (for example, melting and boiling points) and qualitative data about the properties of molecular elements and compounds
7. understand that molecular elements and compounds, such as those in the air, have low melting and boiling points, and are gases at room temperature, because they consist of small molecules with weak forces of attraction between the molecules
8. understand that pure molecular compounds do not conduct electricity because their molecules are not charged
9. understand that bonding within molecules is covalent **and arises from the electrostatic attraction between the nuclei of the atoms and the electrons shared between them**
10. understand that covalent bonds are strong, in contrast to the weak forces of attraction between small covalent molecules
11. translate between representations of molecules including molecular formulae, 2-D diagrams in which covalent bonds are represented by lines, and 3-D diagrams for:
    a. elements that are gases at 20°C
    b. simple molecular compounds.

Module C5: Chemicals of the natural environment

C5.2 What reactions happen in the hydrosphere?

1. recall that the Earth's hydrosphere (oceans, seas, lakes and rivers) consists mainly of water with some dissolved compounds, called salts
2. understand that the ions in crystals of a solid ionic compound are arranged in a regular way forming a lattice
3. understand that ions in a crystal are held together by forces of attraction between oppositely charged ions and that this is called ionic bonding
4. understand how the physical properties of solid ionic compounds (melting point, boiling point, electrical conductivity) relate to their bonding and giant, three-dimensional structures
5. describe what happens to the ions when an ionic crystal dissolves in water
6. explain that ionic compounds conduct electricity when dissolved in water because the ions are charged and they are able to move around independently in the solution
7. **work out the formulae for salts in seawater given the charges on ions (for example sodium chloride, magnesium chloride, magnesium sulfate, sodium sulfate, potassium chloride and potassium bromide)**
8. understand that the ions in an ionic compound can be detected and identified because they have distinct properties and they form compounds with distinct properties
9. understand that an insoluble compound may precipitate on mixing two solutions of ionic compounds
10. **be able to write ionic equations for precipitation reactions when given appropriate information**
11. **interpret given information on solubility to predict chemicals that precipitate on mixing solutions of ionic compounds**
12. understand that some metal ions can be identified in solution by adding alkali because they form insoluble hydroxides with characteristic colours
13. interpret the results of adding aqueous sodium hydroxide to solutions of salts, given a data sheet of tests for positively charged ions and appropriate results

    ⓘ *Candidates will be given a qualitative analysis data sheet showing tests for positively charged ions (as in Appendix G) with the examination paper*

14. understand that some negative ions in salts can be identified in solution by adding a reagent that reacts with the ions to form an insoluble solid
15. interpret the results of tests for carbonate, chloride, bromide, iodide and sulfate ions given a data sheet of tests for negatively charged ions and appropriate results (using dilute acid, lime water, silver nitrate and barium chloride or barium nitrate as the reagents).

    ⓘ *Candidates will be given a qualitative analysis data sheet showing tests for negatively charged ions (as in Appendix G) with the examination paper*

Module C5: Chemicals of the natural environment

C5.3 What types of chemicals make up the Earth's lithosphere?

1. recall that the Earth's lithosphere (the rigid outer layer of the Earth made up of the crust and the part of the mantle just below it) is made up of a mixture of minerals
2. recall that diamond and graphite are minerals, both of which are composed of carbon atoms
3. explain the properties of diamond in terms of a giant structure of atoms held together by strong covalent bonding (for example, melting point, boiling point, hardness, solubility and electrical conductivity)
4. understand how the giant structure of graphite differs from that of diamond, and how this affects its properties
5. recall that silicon, oxygen and aluminium are very abundant elements in the Earth's crust
6. interpret data about the abundances of elements in rocks
7. recall that much of the silicon and oxygen is present in the Earth's crust as the compound silicon dioxide
8. understand that silicon dioxide is another giant covalent compound and so has properties similar to diamond.

Module C5: Chemicals of the natural environment

C5.4 How can we extract useful metals from minerals?

1. recall that ores are rocks that contain varying amounts of minerals from which metals can be extracted

2. understand that for some minerals, large amounts of ore need to be mined to recover small percentages of valuable minerals (for example, in copper mining)

3. recall that zinc, iron and copper are metals that can be extracted by heating their oxides with carbon, and write simple word equations for these reactions

   ⓘ *Technical details not required*

4. understand that when a metal oxide loses oxygen it is reduced, while the carbon gains oxygen and is oxidised

5. understand that some metals are so reactive that their oxides cannot be reduced by carbon

6. write word equations when given appropriate information

7. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products

   ⓘ *In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*

8. **balance unbalanced symbol equations**

9. **write balanced equations, including the state symbols (s), (*l*), (g) and (aq), when given appropriate information**

10. recall the state symbols (s), (*l*), (g) and (aq) and understand their use in equations.

11. use the Periodic Table to obtain the relative atomic masses of elements

12. use relative atomic masses to calculate relative formula masses

13. calculate the mass of an element in the gram formula mass of a compound

14. **calculate the mass of the metal that can be extracted from a mineral given its formula or an equation**

15. describe electrolysis as the decomposition of an electrolyte with an electric current

16. understand that electrolytes include molten ionic compounds

17. describe what happens to the ions when an ionic crystal melts

18. understand that, during electrolysis, metals form at the negative electrode and non-metals form at the positive electrode

19. describe the extraction of aluminium from aluminium oxide by electrolysis

C5.4 How can we extract useful metals from minerals?

20. understand that during electrolysis of molten aluminium oxide, positively charged aluminium ions gain electrons from the negative electrode to become neutral atoms

21. understand that during electrolysis of molten aluminium oxide, negatively charged oxide ions lose electrons to the positive electrode to become neutral atoms which then combine to form oxygen molecules

22. use ionic theory to explain the changes taking place during the electrolysis of a molten salt to account for the conductivity of the molten salt and the changes at the electrodes

23. understand that the uses of metals are related to their properties (limited to strength, malleability, melting point and electrical conductivity)

24. explain the physical properties of high strength and high melting point of metals in terms of a giant structure held together by strong bonds (metallic bonding)

25. understand that in a metal crystal there are positively charged ions, held closely together by a sea of electrons that are free to move, and use this to explain the physical properties of metals, including malleability and conductivity

26. evaluate, given appropriate information, the impacts on the environment that can arise from the extraction, use and disposal of metals.

3.4.3 Module C6: Chemical synthesis

Overview

Synthesis provides many of the chemicals that people need for food processing, health care, cleaning and decorating, modern sporting materials and many other products. The chemical industry today is developing new processes for manufacturing these chemicals more efficiently and with less impact on the environment.

In this context, the module explores related questions that chemists have to answer: 'How much?' and 'How fast?' in the context of the chemical industry. Quantitative work includes the calculation of yields from chemical equations and the measurement of rates of reaction.

A further development of ionic theory shows how chemists use this theory to account for the characteristic behaviours of acids and alkalis. Energy level diagrams are used to describe the exothermic and endothermic nature of chemical reactions.

Topics
C6.1 Chemicals and why we need them
The scale and importance of the chemical industry; acids, alkalis and their reactions Neutralisation explained in terms of ions
C6.2 Planning, carrying out and controlling a chemical synthesis
Planning chemical syntheses Procedures for making pure inorganic products safely Comparing alternative routes to the same product Calculating reacting quantities and yields Measuring purity by simple titration Controlling the rate of change

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations to find percentage yield
- use ideas of ratios in the context of formulae of ionic compounds
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use an equation for calculating the rate of a reaction
- use ideas about correlation in the context of rates of reaction
- balance equations
- calculate reacting masses and yield.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- reactions of acids
- reactions of alkalis
- exothermic and endothermic reactions
- titration experiments
- rate of reaction experiments
- synthesis of a salt.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- logging and storing data, and displaying data in a variety of formats for analysis.

Use of ICT in teaching and learning can include:

- video clips to illustrate the manufacture of chemicals on a large-scale in industry
- using sensors and data loggers to monitor neutralisation reactions and the rates of chemical changes.

Module C6: Chemical synthesis – Ideas about Science

Module C6 provides opportunities to develop candidates' understanding of these Ideas about Science

1	Data: their importance and limitations Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2	Cause-effect explanations Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**

Module C6: Chemical synthesis

C6.1 Chemicals and why we need them

1. understand the importance of chemical synthesis to provide food additives, fertilisers, dyestuffs, paints, pigments and pharmaceuticals

2. interpret information about the sectors, scale and importance of chemical synthesis in industry and in laboratories

3. recall the formulae of the following chemicals: chlorine gas, hydrogen gas, nitrogen gas, oxygen gas, hydrochloric acid, nitric acid, sulfuric acid, sodium hydroxide, sodium chloride, sodium carbonate, sodium nitrate, sodium sulfate, potassium chloride, magnesium oxide, magnesium hydroxide, magnesium carbonate, magnesium chloride, magnesium sulfate, calcium carbonate, calcium chloride and calcium sulfate

4. **work out the formulae of ionic compounds given the charges on the ions**

5. **work out the charge on one ion given the formula of a salt and the charge on the other ion**

6. recall the main hazard symbols and be able to give the safety precautions for handling hazardous chemicals (limited to explosive, harmful, toxic, corrosive, oxidizing, and highly flammable)

7. recall examples of pure acidic compounds that are solids (citric and tartaric acids), liquids (sulfuric, nitric and ethanoic acids) or gases (hydrogen chloride)

8. recall that common alkalis include the hydroxides of sodium, potassium and calcium

9. recall the pH scale

10. recall the use of litmus paper, universal indicator and pH meters to detect acidity and alkalinity, and the use of universal indicator and pH meters to measure pH

11. recall the characteristic reactions of acids that produce salts, to include the reactions with metals and their oxides, hydroxides and carbonates

12. write word equations when given appropriate information

13. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products

    ⓘ *In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*

14. **balance unbalanced symbol equations**

15. **write balanced equations, including the state symbols (s), (*l*), (g) and (aq), to describe the characteristic reactions of acids and other reactions when given appropriate information**

16. recall the state symbols (s), (*l*), (g) and (aq) and understand their use in equations

17. recall that the reaction of an acid with an alkali to form a salt is a neutralisation reaction

C6.1 Chemicals and why we need them

18. explain that acidic compounds produce aqueous hydrogen ions, $H^+(aq)$, when they dissolve in water
19. explain that alkaline compounds produce aqueous hydroxide ions, $OH^-(aq)$, when they dissolve in water
20. write down the name of the salt produced given the names of the acid and alkali
21. **write down the formula of the salt produced given the formulae of the acid and alkali**
22. explain that during a neutralisation reaction, the hydrogen ions from the acid react with hydroxide ions from the alkali to make water:

    $$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

23. understand the terms endothermic and exothermic
24. use and interpret simple energy level diagrams for endothermic and exothermic reactions
25. understand the importance of the energy change during a reaction to the management and control of a chemical reaction.

Module C6: Chemical synthesis

C6.2 Planning, carrying out and controlling a chemical synthesis

1. identify the stages in a given chemical synthesis of an inorganic compound (limited to acid-alkali reactions), including:
    - a. choosing the reaction or series of reactions to make the required product
    - b. carrying out a risk assessment
    - **c. working out the quantities of reactants to use**
    - d. carrying out the reaction in suitable apparatus in the right conditions (such as temperature, concentration)
    - e. separating the product from the reaction mixture (limited to filtration)
    - f. purifying the product (limited to evaporation, crystallisation and drying in an oven or desiccator)
    - g. measuring the yield and checking the purity of the product (by titration)
2. understand the purpose of these techniques: dissolving, crystallisation, filtration, evaporation, drying in an oven or desiccator
3. understand the importance of purifying chemicals and checking their purity
4. understand that a balanced equation for a chemical reaction shows the relative numbers of atoms and molecules of reactants and products taking part in the reaction
5. understand that the relative atomic mass of an element shows the mass of its atom relative to the mass of other atoms
6. use the Periodic Table to obtain the relative atomic masses of elements
7. calculate the relative formula mass of a compound using the formula and the relative atomic masses of the atoms it contains
8. substitute relative formula masses and data into a given mathematical formula to calculate reacting masses and/or products from a chemical reaction
9. **calculate the masses of reactants and products from balanced equations**
10. calculate percentage yields given the actual and the theoretical yield
11. describe how to carry out an acid-alkali titration accurately, when starting with a solution or a solid to be dissolved to make up a solution

    ⓘ *Making up of standard solutions is not required*
12. substitute results in a given mathematical formula to interpret titration results quantitatively
13. understand why it is important to control the rate of a chemical reaction (to include safety and economic factors)
14. explain what is meant by the term ‘rate of chemical reaction’

C6.2 Planning, carrying out and controlling a chemical synthesis

15. describe methods for following the rate of a reaction (for example, by collecting a gas, weighing the reaction mixture or observing the formation or loss of a colour or precipitate)
16. interpret results from experiments that investigate rates of reactions
17. understand how reaction rates vary with the size of solid particles, the concentration of solutions of chemicals and the temperature of the reaction mixture

    ⓘ *A qualitative treatment only is expected*

18. understand that catalysts speed up chemical reactions while not being used up in the reaction
19. interpret information about the control of rates of reaction in chemical synthesis
20. use simple ideas about collisions to explain how chemical reactions take place
21. use simple collision theory and ideas about collision frequency to explain how rates of reaction depend on the size of solid particles and on the concentration of solutions of dissolved chemicals.

    ⓘ *The effect of temperature on collision frequency is not considered since activation energy has a greater influence*

3.5 Summary of Chemistry A Unit A173: *Module C7*

Unit A173 is the third unit for GCSE Chemistry A. It assesses the content of Module C7 together with **any** of the Ideas about Science.

Unit A173 includes additional content to enhance progression and to give a greater understanding of the subjects concerned. This unit continues the emphasis on 'science for the scientist' in preparation for further study, and provides a stimulating bridge to advanced level studies in science.

Ideas about Science in Unit A173

Module C7 presents learning opportunities for a number of the Ideas about Science. The start of the module details the particular Ideas about Science that can be introduced or developed within the contexts covered in the module. Specific examples of contexts within which Ideas about Science can be taught are given in the OCR scheme of work for GCSE Chemistry A (published separately).

However, it is not intended that understanding and application of Ideas about Science should be limited to the context in which they are taught; they should be applicable to any appropriate scientific context.

Accordingly, questions in Unit A173 can assess any of the Ideas about Science (summarised in Appendix B), and these Ideas about Science may be assessed in the context of any of the learning outcomes covered in Module C7.

In summary, the Ideas about Science that can be assessed in Unit A173, within **any** of the scientific contexts introduced by Module C7, are:

Data: their importance and limitations
IaS 1.1 – 1.6
Cause-effect explanations
IaS 2.1 – 2.7
Developing scientific explanations
IaS 3.1 – 3.4
The scientific community
IaS 4.1 – 4.4
Risk
IaS 5.1 – 5.7
Making decisions about science and technology
IaS 6.1 – 6.6

3.5.1 Module C7: Further Chemistry

Overview

The five topics in this longer module introduce new chemical ideas while illustrating important features of the applications of chemistry and exploring Ideas about Science from IaS1: Data and their limitations, IaS3: Developing explanations, and IaS6: Making decisions about science and technology.

The module starts with an introduction to green chemistry and describes how the chemical industry is reinventing processes so that the manufacture of bulk and fine chemicals is more sustainable. The theme of green chemistry runs through the module, presenting several opportunities to see how the principles are applied in real life.

The second topic covers introductory organic chemistry taking alcohols and carboxylic acids as the main examples. This builds on the coverage of hydrocarbon molecules in Modules C1 and C2.

The third and fourth topics lay the foundations for more advanced study of physical chemistry by exploring chemical concepts on a molecular scale including the connection between energy changes and bond breaking, as well as the notion of dynamic equilibrium.

The fifth topic introduces concepts of valid analytical measurements in contexts where the results of analysis matter. The two main analytical methods featured are chromatography and volumetric analysis.

Topics
C7.1 Green chemistry
The chemical industry The characteristics of green chemistry
C7.2 Alcohols, carboxylic acids and esters
Organic molecules and functional groups Alcohols Carboxylic acids Esters
C7.3 Energy changes in chemistry
Why are there energy changes during chemical reactions?
C7.4 Reversible reactions and equilibria
Introducing dynamic equilibrium
C7.5 Analysis
Analytical procedures Chromatography Quantitative analysis by titration

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations to find percentage yield and atom economy
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use an equation to calculate Rf values in chromatography
- use an equation to calculate concentration using appropriate units for physical quantities
- calculate reacting masses
- extract information from charts, graphs and tables including comparing data about nitrogen fixation processes
- balance equations
- calculate energy changes using bond energies.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- reactions of alkanes, alcohols, and carboxylic acids
- synthesis of an ester
- exothermic and endothermic reactions
- reversible reactions
- chromatography
- acid alkali titrations
- experiments to investigate catalysts.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- modelling the structures of molecules
- the integral role of ICT in chemical instrumentation.

Use of ICT in teaching and learning can include:

- using modelling software to explore the shapes of organic molecules
- video clips to illustrate the manufacture of chemicals on large and small scales
- video clips to illustrate gas chromatography and other analytical techniques
- using the internet to research current developments in green chemistry.

Module C7: Further Chemistry – Ideas about Science		
Module C7 provides opportunities to develop candidates' understanding of these Ideas about Science		
1	**Data: their importance and limitations**	
	Candidates should understand that:	A candidate who understands this can, for example:
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

3	Developing scientific explanations	
	Candidates should understand that:	A candidate who understands this can, for example:
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
6	**Making decisions about science and technology**	
	Candidates should understand that:	A candidate who understands this can, for example:
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.2	• scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	• identify, and suggest, examples of unintended impacts of human activity on the environment • explain the idea of sustainability, and apply it to specific situations • use data (for example, from a Life Cycle Assessment) to compare the sustainability of alternative products or processes.

Module C7: Further Chemistry

C7.1 Green chemistry

The chemical industry

1. understand and use the terms ‘bulk’ (made on a large scale) and ‘fine’ (made on a small scale) in the context of the chemical industry
2. recall examples of chemicals made on a large scale (ammonia, sulfuric acid, sodium hydroxide, phosphoric acid) and examples of chemicals made on a small scale (drugs, food additives, fragrances)
3. interpret information about the work done by people who make chemicals

   ⓘ *Candidates are not expected to recall any specific details*
4. understand that the development of new chemical products or processes requires an extensive programme of research and development (for example, catalysts for new processes)
5. recall that governments have strict regulations to control chemical processes as well as the storage and transport of chemicals to protect people and the environment

What are the characteristics of green chemistry?

6. understand that the production of useful chemicals involves several stages to include:
   a. the preparation of feedstocks
   b. synthesis
   c. separation of products
   d. handling of by-products and wastes
   e. the monitoring of purity
7. understand that sustainability of any chemical process depends on:
   a. whether or not the feedstock is renewable
   b. the atom economy
   c. the nature and amount of by-products or wastes and what happens to them
   d. the energy inputs or outputs
   e. the environmental impact
   f. the health and safety risks
   g. the social and economic benefits
8. understand the term activation energy in terms of the energy needed to break bonds to start a reaction
9. understand that a catalyst provides an alternative route for a reaction with a lower activation energy
10. understand that some industrial processes use enzyme catalysts, and the restrictions this places on the conditions that are used
11. use the Periodic Table to obtain the relative atomic masses of elements and use these to calculate relative formula masses
12. **calculate the masses of reactants and products from balanced equations.**

Module C7: Further Chemistry

C7.2 Alcohols, carboxylic acids and esters

Organic molecules and functional groups

1. recall that there is a family of hydrocarbons called alkanes
2. recall the names and molecular formulae of the alkanes: methane, ethane, propane and butane
3. translate between molecular, structural and ball-and-stick representations of simple organic molecules
4. understand that alkanes burn in plenty of air to give carbon dioxide and water
5. understand that alkanes are unreactive towards aqueous reagents because they contain only C—C and C—H bonds, which are difficult to break and therefore unreactive
6. recall that in saturated compounds, such as alkanes, all the carbon to carbon bonds are single, C—C, but that in unsaturated compounds there are carbon to carbon double bonds, C=C
7. represent chemical reactions by word equations
8. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of ‘formulas’ of ionic compounds, in reactants and products

   ⓘ *In this context, ‘formula’ is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*
9. **represent chemical reactions by balanced equations, including state symbols**

Alcohols

10. recall the names, molecular formulae and structural formulae of methanol and ethanol
11. recall two uses of methanol and two uses of ethanol
12. recognise the formulae of alcohols
13. understand that the characteristic properties of alcohols are due to the presence of the –OH functional group
14. recall how ethanol compares in its physical properties with water and with alkanes
15. understand that alcohols burn in air to produce carbon dioxide and water because of the presence of a hydrocarbon chain
16. **recall the reaction of alcohols with sodium and how this compares with the reactions of water and alkanes with sodium**
17. understand why there is a limit to the concentration of ethanol solution that can be made by fermentation
18. understand how ethanol solution can be concentrated by distillation and that this can be used to make products such as whisky and brandy
19. understand the optimum conditions for making ethanol by fermentation of sugar with yeast, taking into consideration temperature and pH
20. understand how genetically modified E. coli bacteria can be used to convert waste biomass from a range of sources into ethanol and recall the optimum conditions for the process

C7.2 Alcohols, carboxylic acids and esters

21. recall in outline the synthetic route for converting ethane (from oil or natural gas) into ethanol (via ethene)
22. interpret data about the different processes involved in the production of ethanol, and evaluate their sustainability

Carboxylic acids

23. understand that the characteristic properties of carboxylic acids are due to the presence of the –COOH functional group
24. recall the names, molecular formulae and structural formulae of methanoic acid and ethanoic acid
25. recognise the formulae of carboxylic acids
26. recall that many carboxylic acids have unpleasant smells and tastes and are responsible for the smell of sweaty socks and the taste of rancid butter
27. understand that carboxylic acids show the characteristic reactions of acids with metals, alkalis and carbonates
28. recall that vinegar is a dilute solution of ethanoic acid
29. understand that carboxylic acids are called weak acids because they are less reactive than strong acids such as hydrochloric acid, sulfuric acid and nitric acid
30. understand that dilute solutions of weak acids have higher pH values than dilute solutions of strong acids

Esters

31. understand that carboxylic acids react with alcohols, in the presence of a strong acid catalyst, to produce esters
32. recall that esters have distinctive smells
33. recall that esters are responsible for the smells and flavours of fruits
34. recall the use of esters as food flavourings, solvents and plasticizers, and in perfumes
35. **understand the procedure for making an ester (such as ethyl ethanoate) from a carboxylic acid and an alcohol**
36. **understand the techniques used to make a liquid ester, limited to:**
    a. **heating under reflux**
    b. **distillation**
    c. **purification by treatment with reagents in a tap funnel**
    d. **drying**
37. recall that fats are esters of glycerol and fatty acids
38. recall that living organisms make fats and oils as an energy store
39. recall that animal fats are mostly saturated molecules and that vegetable oils are mostly unsaturated molecules.

Module C7: Further Chemistry

C7.3 Energy changes in chemistry

Why are there energy changes during chemical reactions?

1. understand the terms exothermic and endothermic
2. use and interpret energy level diagrams for exothermic and endothermic reactions
3. understand that energy is needed to break chemical bonds and that energy is given out when chemical bonds form
4. **use given data on the energy needed to break covalent bonds to estimate the overall energy change in simple examples (for example, the formation of steam or hydrogen halides from their elements)**
5. understand the term activation energy in terms of the energy needed to break bonds to start a reaction.

Module C7: Further Chemistry

C7.4 Reversible reactions and equilibria

Introducing dynamic equilibrium

1. understand that some chemical reactions are reversible and are shown by the symbol $\rightleftharpoons$
2. understand that reversible reactions can reach a state of equilibrium
3. **understand the dynamic equilibrium explanation for chemical equilibrium**
4. understand why fixing nitrogen by the Haber process is important
5. recall that the feedstocks of nitrogen and hydrogen for the Haber process are made from air, natural gas and steam

   ⓘ *Candidates do not need to know the details of the processes involved*
6. in the context of the Haber process:
   a. understand that the reaction between hydrogen and nitrogen to form ammonia is a reversible reaction
   b. understand how the yield of ammonia is increased by recycling unreacted hydrogen and nitrogen
   c. explain the effect of changing temperature and pressure on the yield of ammonia at equilibrium
   d. understand that the gases do not stay in the reactor long enough to reach equilibrium
   e. understand that a catalyst is used to increase the rate of reaction in the Haber process
   f. understand that the efficiency of the process can be improved by using a different catalyst
   g. explain how the conditions used for the process are a compromise to produce an economically viable yield of ammonia
7. understand that some living organisms ‘fix’ nitrogen at room temperature and pressure using enzymes as catalysts
8. understand why chemists are interested in producing new catalysts that mimic natural enzymes
9. understand the impact on the environment of the large scale manufacture of ammonia and the widespread use of fertilisers made from it
10. interpret data about nitrogen fixation processes and evaluate their sustainability.

Module C7: Further Chemistry

C7.5 Analysis

Analytical procedures

1. understand the difference between qualitative and quantitative methods of analysis
2. understand that an analysis must be carried out on a sample that represents the bulk of the material under test
3. recall that many analytical methods are based on samples in solution
4. understand the need for standard procedures for the collection, storage and preparation of samples for analysis

Chromatography

5. understand that in chromatography, substances are separated by movement of a mobile phase through a stationary phase
6. understand and use the terms aqueous and non-aqueous as applied to solvents
7. understand that for each component in a sample there is a dynamic equilibrium between the stationary and mobile phases
8. understand how a separation by chromatography depends on the distribution of the components in the sample between the mobile and stationary phases
9. understand the use of standard reference materials in chromatography
10. describe and compare paper and thin-layer chromatography
11. use the formula:

$$Rf = \frac{\text{distance travelled by solute}}{\text{distance travelled by solvent}}$$

    and understand the use of Rf values

12. understand the use of locating agents in paper and thin-layer chromatography
13. recall in outline the procedure for separating a mixture by gas chromatography (gc)
14. understand the term retention time as applied to gc
15. interpret print-outs from gc analyses, limited to retention times and peak heights

C7.5 Analysis

Quantitative analysis by titration

16. understand the main stages of a quantitative analysis:
    a. measuring out accurately a specific mass or volume of the sample
    b. working with replicate samples
    c. dissolving the samples quantitatively
    d. measuring a property of the solution quantitatively
    e. calculating a value from the measurements (IaS 1.4)
    f. estimating the degree of uncertainty in the results (IaS 1.5–1.6)
17. understand that concentrations of solutions can be measured in g/dm^3
18. recall the procedure for making up a standard solution
19. **calculate the concentration of a given volume of solution given the mass of solute**
20. **calculate the mass of solute in a given volume of solution with a specified concentration**
21. recall the procedure for carrying out an acid-base titration using a pipette and burette
22. substitute results in a given formula to interpret titration results quantitatively
23. **use the balanced equation and relative formula masses to interpret the results of a titration**
24. use values from a series of titrations to assess the degree of uncertainty in a calculated value.

4 Assessment of GCSE Chemistry A

4.1 Overview of the assessment in GCSE Chemistry A

GCSE Chemistry A J244	
Unit A171: *Modules C1, C2, C3*	
25% of the total GCSE 1 hr written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses modules C1, C2 and C3 • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A172: *Modules C4, C5, C6*	
25% of the total GCSE 1 hr written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses modules C4, C5 and C6 • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A173: *Module C7*	
25% of the total GCSE 1 hr written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses module C7 • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A174: *Controlled assessment*	
25% of the total GCSE Controlled assessment Approximately 4.5–6 hours 64 marks	This unit: • comprises a Practical Investigation • is assessed by teachers, internally standardised and then externally moderated by OCR • assesses the quality of written communication.

4.2 Tiers

All written papers are offered in Foundation Tier and Higher Tier. Foundation Tier papers assess grades G to C and Higher Tier papers assess Grades D to A*. An allowed grade E may be awarded on the Higher Tier components.

In Units A171, A172 and A173 candidates are entered for an option in either the Foundation Tier or the Higher Tier. Unit A174 (controlled assessment) is not tiered.

Candidates may enter for either the Foundation Tier or Higher Tier in each of the externally assessed units. So a candidate may take, for example, A171/F and A172/H.

4.3 Assessment objectives (AOs)

Candidates are expected to demonstrate their ability to:

AO1	recall, select and communicate their knowledge and understanding of chemistry;
AO2	apply skills, knowledge and understanding of chemistry in practical and other contexts;
AO3	analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence.

4.3.1 AO weightings – GCSE Chemistry A

The relationship between the units and the assessment objectives of the scheme of assessment is shown in the following grid:

Unit	% of GCSE			Total
	AO1	AO2	AO3	
Units A171–A173	30	34	11	75
Unit A174: Controlled assessment	2	5	18	25
Total	32	39	29	100

4.4 Grading and awarding grades

GCSE results are awarded on the scale A* to G. Units are awarded a* to g. Grades are indicated on certificates. However, results for candidates who fail to achieve the minimum grade (G or g) will be recorded as *unclassified* (U or u) and this is **not** certificated.

GCSEs are unitised schemes. Candidates can take units across several different series provided the terminal rules are satisfied. They can also re-sit units.

When working out candidates' overall grades OCR needs to be able to compare performance on the same unit in different series when different grade boundaries have been set, and between different units. OCR uses a Uniform Mark Scale to enable this to be done.

A candidate's uniform mark for each unit is calculated from the candidate's raw marks on that unit. The raw mark boundary marks are converted to the equivalent uniform mark boundary. Marks between grade boundaries are converted on a pro rata basis.

When unit results are issued, the candidate's unit grade and uniform mark are given. The uniform mark is shown out of the maximum uniform mark for the unit, eg 60/100.

The uniform mark grade boundaries for each of the assessments are shown below:

(GCSE) Unit Weighting	Maximum Unit Uniform Mark	Unit Grade								
		a*	a	b	c	d	e	f	g	u
25%	100	90	80	70	60	50	40	30	20	0

The written papers will have a total weighting of 75% and controlled assessment a weighting of 25%.

Higher tier candidates who fail to gain a 'd' grade may achieve an "allowed e". Higher tier candidates who miss the allowed grade 'e' will be given a uniform mark in the range f–u but will be graded as 'u'.

Candidate's uniform marks for each unit will be combined to give a total uniform mark for the specification. The candidate's overall grade will be determined by the total uniform mark.

The following table shows the minimum total mark for each overall grade:

Qualification	Max Uniform Mark	Qualification Grade								
		A*	A	B	C	D	E	F	G	U
J244	400	360	320	280	240	200	160	120	80	0

A candidate's uniform mark for each paper will be combined with the uniform mark for the controlled assessment to give a total uniform mark for the specification. The candidate's grade will be determined by the total uniform mark.

4.5 Grade descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded will depend in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of the assessment may be balanced by better performance in others.

The grade descriptors have been produced by the regulatory authorities in collaboration with the awarding bodies.

4.5.1 Grade F

Candidates recall, select and communicate limited knowledge and understanding of chemistry. They show a limited understanding that scientific advances may have ethical implications, benefits and risks. They recognise simple inter-relationships between chemistry and society. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.

They apply skills, including limited communication, mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They recognise and use hypotheses, evidence and explanations and can explain straightforward models of phenomena, events and processes. They use a limited range of methods, sources of information and data to address straightforward scientific questions, problems and hypotheses.

Candidates interpret and evaluate limited quantitative and qualitative data and information from a narrow range of sources. They can draw elementary conclusions having collected limited evidence.

4.5.2 Grade C

Candidates recall, select and communicate secure knowledge and understanding of chemistry. They demonstrate understanding of the nature of chemistry, its laws, principles and its applications and the relationship between chemistry and society. They understand that scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.

They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They show understanding of the relationships between hypotheses, evidence, theories and explanations and use models, including mathematical models, to describe abstract ideas, phenomena, events and processes. They use a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and test hypotheses.

Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They draw conclusions based on the available evidence.

4.5.3 Grade A

Candidates recall, select and communicate precise knowledge and detailed understanding of chemistry. They demonstrate a comprehensive understanding of the nature of chemistry, its laws, principles and applications and the relationship between chemistry and society. They understand the relationships between scientific advances, their ethical implications and the benefits and risks associated with them. They use scientific and technical knowledge, terminology and conventions appropriately and consistently, showing a detailed understanding of scale in terms of time, size and space.

They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models, including mathematical models, to explain abstract ideas, phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.

Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations, taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.

4.6 Quality of written communication

Quality of written communication (QWC) is assessed in all units and is integrated into the marking criteria.

Candidates are expected to:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
- present information in a form that suits its purpose
- use a suitable structure and style of writing.

Questions assessing quality of written communication will be indicated by the icon of a pencil (✐).

Controlled assessment in GCSE Chemistry A

This section provides general guidance on controlled assessment: what controlled assessment tasks are, when and how they are available, how to plan and manage controlled assessment and what controls must be applied throughout the process. More specific guidance and support is provided in the *'Guide to controlled assessment for GCSE Twenty First Century Science'*, which will be available on the OCR website from Spring 2011.

5.1 Introduction to controlled assessment tasks

All controlled assessment tasks are set by OCR and will be available for submission only in June examination series. Each year a choice of two tasks will be offered, based upon Modules C1 – C7; one of these two tasks will be based on Modules C4 – C6.

Each task will be valid for submission in a single examination series only, but may be undertaken at any point between release of the task by OCR and the examination series for which the task must be submitted. Centres must ensure that candidates undertake a task that is valid for submission in the year in which the candidate intends to submit it. The series in which each task can be submitted will be clearly marked on the front cover of the task. Tasks will not be valid for submission in any examination series other than that indicated.

Every year, two new controlled assessment tasks will be made available on OCR Interchange from 1 June, two years ahead of the examination series for which the tasks are to be submitted. These will be removed upon expiry. Guidance on how to access controlled assessment tasks from OCR Interchange is available on the OCR website: www.ocr.org.uk.

It is not necessary for all candidates from a centre to carry out the same task from the choice of two provided. Staff at each centre can choose whether:

- all candidates from the centre complete the same task
- all candidates in any teaching group carry out the same task, but different groups use different tasks
- candidates complete tasks on an individual basis.

The number of tasks attempted is at the discretion of the centre, but the results of only one complete task may be submitted.

5.2 Nature of controlled assessment tasks

5.2.1 Introduction to skills assessment

The controlled assessment for GCSE Chemistry A comprises one element: a practical investigation.

Investigations are central to the nature of science as an evidence-based activity and practical investigations provide an effective and valid assessment instrument for a course which is both a basis for further studies and for possible future careers in science. The ability of a candidate to formulate a hypothesis and to explain patterns in results will be related to their knowledge and understanding of the topic.

Controlled assessment tasks for GCSE Chemistry A practical investigations require candidates to:

- develop hypotheses and plan practical ways to test them, including risk assessment
- manage risks when carrying out practical work
- collect, process, analyse and interpret primary and secondary data including the use of appropriate technology to draw evidence-based conclusions
- review methodology to assess fitness for purpose
- review hypotheses in the light of outcomes.

Practical investigations therefore draw together the skills of predicting and planning, and collecting, interpreting, evaluating and reviewing primary and secondary data within the context of a whole investigation. Candidates should be familiar with these requirements before starting any controlled assessment task.

It is expected that candidates will be involved in a variety of practical work during the course that will prepare them for this assessment. This should include developing their abilities to handle equipment and carry out practical procedures safely, illustrating science principles with real experiences and learning how to carry out and evaluate investigations.

In addition, candidates' abilities to devise and evaluate suitable methods, to decide on suitable data ranges and to offer explanations will be closely linked to their understanding of some Ideas about Science, particularly:

- IaS1: Data: their importance and limitations
- IaS2: Cause-effect explanations
- IaS3: Developing scientific explanations
- IaS5: Risk.

Candidates should be encouraged to use ideas and vocabulary related to these Ideas about Science in their reports and it is therefore important that candidates are familiar with these ideas before attempting the investigation. Ideas about Science are detailed in Appendix B.

The tasks to be used for the controlled assessment that are set by OCR will be presented in a way which leaves some freedom for each centre to vary the approach as appropriate, to allow for candidates of different abilities and interests, or for differences in the materials, equipment and facilities at different centres.

The tasks provided will be open-ended and investigative in nature. The information provided with each task will include:

- Information for candidates (1): an introduction to the topic of the investigation, to be issued to candidates at the start of the task, placing the work into an appropriate wider context
- Information for candidates (2): secondary data for analysis, to be issued to candidates only on completion of the data collection part of their practical investigation
- Information for teachers: an overview of the investigation including notes on possible approaches and assessment issues and guidance for technicians.

At the start of a controlled assessment, candidates will use the information provided to plan how to collect data, including any preliminary work required, and to develop a testable hypothesis before carrying out the investigation. After collecting primary data and interpreting and evaluating the results, candidates will be expected to engage with relevant secondary data to develop and evaluate their conclusions further and review their original hypothesis. Sources of secondary data can include experimental results from other candidates in the class or school, as well as text books and web sites on the internet. In addition, OCR will provide some secondary data relevant to the task set for each practical investigation.

The completed work will be presented for assessment as a written report.

5.2.2 Summary of tasks in Unit A174

Assessment Task	Task Marks	Weighting
Practical investigation	64	25%

5.3 Planning and managing controlled assessment

Controlled assessment tasks will be available up to two years ahead of the examination series for which they are valid, to allow planning time. It is anticipated that candidates will spend a total of about 4.5–6 hours in producing the work for this unit. Candidates should be allowed sufficient time to complete the task.

When supervising tasks, teachers are expected to:

- exercise continuing supervision of work in order to monitor progress and to prevent plagiarism
- provide guidance on the use of information from other sources to ensure that confidentiality and intellectual property rights are maintained
- exercise continuing supervision of practical work to ensure essential compliance with Health and Safety requirements
- ensure that the work is completed in accordance with the specification requirements and can be assessed in accordance with the specified marking criteria and procedures.

Teachers must not provide templates, model answers or feedback on drafts. Candidates must produce their own individual responses to each stage and work independently to produce the report on the final stage (Analysis, evaluation and review).

Suggested steps and timings are included below, with guidance on regulatory controls at each stage of the process. Teachers must ensure that control requirements indicated below are met throughout the process.

5.3.1 Research and planning, and collecting data

- Strategy: research and planning **1.5 – 2 hours**

  In the research and planning stage, a limited level of control is required. This means that candidates can undertake this part of the process without direct teacher supervision and away from the centre, as required. This may also include collection of secondary data where this informs the planning of the work. Candidates are also able to work in collaboration during this stage. During the research phase candidates can be given support and guidance. Teachers can explain the task, advise on how the task could be approached, advise on resources and alert the candidate to key things that must be included in their final piece of work. However, each candidate must develop their own individual response.

- Collecting data **1.5 – 2 hours**

  In the data collection stage, a limited level of control is required. Candidates will carry out practical work under direct teacher supervision to collect primary data. They may work in collaboration during this stage but all candidates must be actively involved and develop their own, individual response in determining how best to collect and record primary data.

  Secondary data may also be collected during this stage to support or extend the conclusions to the investigation. However, it is not permitted to base the assessment solely on secondary data or (computer) simulations, or on data recorded by candidates whilst watching demonstrations.

  The OCR-provided secondary data, *Information for candidates (2)*, should be given to candidates **only** after collection of primary data is completed. This can be used in addition to secondary data collection by the candidate, if appropriate. Time should be allowed for further collection of secondary data following the issue of *Information for candidates (2)*.

5.3.2 Analysis, evaluation and review

- Analysis, evaluation and review **1.5 – 2 hours**

  The report for this stage is produced in the centre under conditions of high control, which means that candidates work individually to complete their reports under direct teacher supervision. Teachers must be able to authenticate the work and there must be acknowledgement and referencing of any sources used. If writing up is carried out over several sessions, work must be collected in between each session, including any electronic data storage such as USB memory sticks and rewritable CDs.

5.3.3 Presentation of the final piece of work

Candidates must observe certain procedures in the production of controlled assessment tasks.

- Tables, graphs and spreadsheets may be produced using appropriate ICT. These should be inserted into the final report at the appropriate place.
- Any copied material must be suitably acknowledged.
- Quotations must be clearly marked and a reference provided wherever possible.
- Work submitted for moderation by OCR must be marked with the:
  - centre number
  - centre name
  - candidate number
  - candidate name
  - unit code and title
  - controlled assessment task title.

Work submitted on paper for moderation must be secured by treasury tags. Work submitted in digital format (CD or online) must be in a suitable file structure as detailed in Appendix A at the end of this specification.

5.4 Marking and moderating controlled assessment

All controlled assessment units are marked by centre assessor(s) using OCR marking criteria and guidance.

This corresponds to a medium level of control.

5.4.1 Applying the marking criteria

The starting point for marking the tasks is the marking criteria (see section 5.4.5 Marking criteria for controlled assessment tasks). These identify levels of performance for the skills, knowledge and understanding that the candidate is required to demonstrate. Guidance for each specific task will be provided in the 'Information for teachers' for each task. Before the start of the course, and for use at INSET training events, OCR will provide exemplification through real or simulated candidate work which will help to clarify the level of achievement that assessors should be looking for when awarding marks.

5.4.2 Using the hierarchical marking criteria

A standard method of marking is used for the controlled assessment tasks for Twenty First Century Science GCSE Chemistry A, based on a grid of hierarchical marking criteria. The marking criteria indicate levels of response and are generic, so can be used for marking any OCR-issued practical investigation. They define the performance for the skills, knowledge and understanding that the candidate is expected to demonstrate at each level. For each task set by OCR, more specific guidance will also be given in the *Information for teachers* on applying the marking criteria in the context of the task.

Candidates' progress through a task is assessed in five strands, each of which corresponds to a different type of performance by the candidate. Three of the five strands include two different aspects of the work. Thus, marking is based on a total of 8 aspects, each of which is shown as a different row in the grid of marking criteria.

For each aspect, a hierarchical set of four marking criteria shows typical performance for candidates working at 1–2, 3–4, 5–6 and 7–8 marks. This provides a level of response mark scheme where achievement is divided into four non-overlapping bands, each covering a range of two marks.

Award of marks in each row of the grid is based on the professional judgement of the teacher and is hierarchical. This means that each of the criteria is considered in turn, working up from the lowest band to the highest band that is fully matched by the candidate's performance. Once a band has been reached which is not fully matched by the work seen, no higher bands can be considered.

Within each two-mark band, the higher mark is available where the performance fully matches the criterion for that mark band (and all preceding, lower mark bands). The lower mark is awarded where the candidate has partially, but not fully, matched this criterion and has exceeded the criteria in the preceding, lower mark bands.

Where there is no evidence of engagement with an aspect of the work, or if the response is not sufficient to merit award of one mark, a mark of zero is awarded for the aspect.

This method of marking can be used even where there is wide variation in performance between different aspects of the work. Weak performance on one aspect need not limit marks in other aspects.

In Strand A, two alternative routes to credit are provided. One row of criteria is used for investigations where the candidate uses graphical display or charts to reveal patterns in the data. The other row is used where the candidate has used statistical or algebraic methods to identify patterns. Only the row which gives the highest mark is counted.

The level awarded in each aspect is recorded on a marking grid, which also serves as a cover sheet if the work is called for moderation.

The total for the assessment is the sum of all the aspect marks, giving a maximum possible mark of 64.

5.4.3 Annotation of candidates' work

Each piece of internally assessed work should show how the marks have been awarded in relation to the marking criteria.

The writing of comments on candidates' work provides a means of dialogue and feedback between teacher and candidate and a means of communication between teachers during internal standardisation.

5.4.4 Overview of marking criteria for controlled assessment tasks

The five strands in the marking criteria are designed to match five main stages in the investigation. However, candidates do not always follow this sequence strictly when writing their investigation reports, and positive achievement should be credited in the appropriate strand wherever it is found in the report.

Strand	Aspect	Notes
S strategy	S(a) – formulating a hypothesis or prediction	Candidates review factors that might affect their results (this may include preliminary tests of these effects) and use their scientific knowledge to choose an effect to study, based on a prediction or testable hypothesis (IaS3). Responses in this aspect will be in extended writing and should be assessed for quality of written communication of the content.
	S(b) – design of techniques and choice of equipment	Candidates test different experimental methods or apparatus, and justify the choices they make (IaS1). They show awareness of safe working practices and the hazards associated with materials (IaS5, IaS1–3). At the highest level, a full risk assessment is included.
C collecting data	C – range and quality of data	Candidates make decisions about the amount of data to be collected, the range of values covered, and effective checking for reproducibility (IaS1).
A analysis	A – revealing patterns in data	To allow access to a wider range of activities, this strand has two alternative sets of criteria. One is for the quality of graphical display. The alternative row can be used to award credit for statistical or numerical analysis of data, eg species distribution surveys.
E evaluation	E(a) – evaluation of apparatus and procedures	Candidates show awareness of any limitations imposed by the apparatus or techniques used and suggest improvements to the method.
	E(b) – evaluation of primary data	Candidates consider carefully the reproducibility of their data, recognise outliers and treat them appropriately (IaS1).

Strand	Aspect	Notes
R review	R(a) – collection and use of secondary data	Candidates collect secondary data, which can be considered together with their own primary data, to give a broader basis for confirmation, adaptation or extension of the initial hypothesis or prediction.
	R(b) – reviewing confidence in the hypothesis	Candidates make an overall review of the evidence in relation to the underlying scientific theory and consider how well it supports the hypothesis, and what extra work might help to improve confidence in the hypothesis (IaS2 and IaS3). Quality of written communication should be taken into account in assessing this aspect of the work.

5.4.5 Marking criteria for controlled assessment tasks

Marking criteria are to be applied hierarchically (see section 5.4.2).

Strand/ Aspect	0	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks	AOs
S a	*	Make a prediction to test, but without any justification. The response may be simplistic, with frequent errors of spelling, punctuation or grammar and have little or no use of scientific vocabulary.	Suggest a testable prediction and justify it by reference to common sense or previous experience. Some relevant scientific terms are used, but spelling, punctuation and grammar are of variable quality.	Consider major factors and refer to scientific knowledge to make a testable hypothesis about how one factor will affect the outcome. Information is effectively organised with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	After consideration of all relevant factors, select one and propose a testable hypothesis and quantitative prediction about how it will affect the outcomes. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.	AO1: 2 marks AO2: 4 marks AO3: 2 marks
S b	*	Follow a given technique, but with very limited precision or accuracy. Make an appropriate comment about safe working.	Select and use basic equipment to collect a limited amount of data. Correctly identify hazards associated with the procedures used.	Select and use techniques and equipment appropriate for the range of data required, and explain the ranges chosen. Identify any significant risks and suggest some precautions.	Justify the choice of equipment and technique to achieve data which is precise and valid. Complete a full and appropriate risk assessment, identifying ways of minimising risks associated with the work.	AO2: 4 marks AO3: 4 marks
C	*	Record a very limited amount of data (eg isolated individual data points with no clear pattern), covering only part of the range of relevant cases/situations, with no checking for repeatability. Data is generally of low quality.	Record an adequate amount or range of data, allowing some errors in units or labelling, and with little checking for repeatability. Data is of variable quality, with some operator error apparent.	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality.	Choose an appropriate range of values to test across the range, with regular repeats and appropriate handling of any outliers. Checks or preliminary work are included to confirm or adapt the range and number of measurements to ensure data of high quality.	AO1: 1 mark AO2: 3 marks AO3: 4 marks

Strand/ Aspect	0	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks	AOs
A	*	Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line of best fit, or construct complex charts or diagrams eg species distribution maps.	Indicate the spread of data (eg through scatter graphs or range bars) or give clear keys for displays involving multiple data-sets.	AO3: 8 marks
		Select individual results as a basis for conclusions.	Carry out simple calculations eg correct calculation of averages from repeated readings.	Use mathematical comparisons between results to support a conclusion.	Use complex processing to reveal patterns in the data eg statistical methods, use of inverse relationships, or calculation of gradient of graphs.	
E a	*	Make relevant comments about problems encountered whilst collecting the data.	Describe the limitations imposed by the techniques and equipment used.	Suggest (in outline) improvements to apparatus or techniques, or alternative ways to collect the data; or explain why the method used gives data of sufficient quality to allow a conclusion.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement; or explain fully why no further improvement could reasonably be achieved.	AO3: 8 marks
E b	*	Make a claim for accuracy or repeatability, but without appropriate reference to the data.	Correctly identify individual results which are beyond the range of experimental error (are outliers), or justify a claim that there are no outliers.	Use the general pattern of results or degree of scatter between repeats as a basis for assessing accuracy and repeatability and explain how this assessment is made.	Consider critically the repeatability of the evidence, accounting for any outliers.	AO3: 8 marks
R a	*	Compare own experimental results with at least one piece of secondary data and make basic comments on similarities and/or differences. Secondary data collected is limited in amount and not always relevant to the investigation.	Identify in detail similarities and differences between the secondary data and primary data. Secondary data collected is relevant to the investigation and sources are referenced, although these may be incomplete.	Describe and explain the extent to which the secondary data supports, extends and/or undermines the primary data, and identify any areas of incompleteness. A range of relevant secondary data is collected from several fully referenced sources.	Assess the levels of confidence that can be placed on the available data, and explain the reasons for making these assessments. Comment on the importance of any similarities or differences.	AO1: 1 mark AO2: 1 mark AO3: 6 marks

Strand/ Aspect	0	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks	AOs
R b	*	Correctly state whether or not the original prediction or hypothesis is supported, with reference only to common sense or previous experience. The response is simplistic, with frequent errors in spelling, punctuation or grammar and has little or no use of scientific vocabulary.	Comment on whether trends or correlations in the data support the prediction or hypothesis and suggest why by reference to appropriate science. Some relevant scientific terms are used correctly, but spelling, punctuation and grammar are of variable quality.	Explain the extent to which the hypothesis can account for the pattern(s) shown in the data. Use relevant science knowledge to conclude whether the hypothesis has been supported or to suggest how it should be modified to account for the data more completely. Information is organised effectively with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	Give a detailed account of what extra data could be collected to increase confidence in the hypothesis. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.	AO1: 2 marks AO3: 6 marks

* No response, or response not sufficient for award of 1 mark

5.4.6 Assessment objectives (AOs)

Each of the aspects to be assessed addresses one or more of the assessment objectives and these are shown in the marking criteria. The overall balance is shown in the table below:

Assessment Objective	TOTAL
AO1: Recall, select and communicate their knowledge and understanding of chemistry	6
AO2: Apply skills, knowledge and understanding of chemistry in practical and other contexts	12
AO3: Analyse and evaluate evidence, make reasoned judgments and draw conclusions based on evidence	46
TOTAL	64

5.4.7 Authentication of work

Teachers must be confident that the work they mark is the candidate's own. This does not mean that a candidate must be supervised throughout the completion of all work but the teacher must exercise sufficient supervision, or introduce sufficient checks, to be in a position to judge the authenticity of the candidate's work.

Wherever possible, the teacher should discuss work-in-progress with candidates. This will not only ensure that work is underway in a planned and timely manner but will also provide opportunities for assessors to check authenticity of the work and provide general feedback.

Candidates must not plagiarise. Plagiarism is the submission of another's work as one's own and/or failure to acknowledge the source correctly. Plagiarism is considered to be malpractice and could lead to the candidate being disqualified. Plagiarism sometimes occurs innocently when candidates are unaware of the need to reference or acknowledge their sources. It is therefore important that centres ensure that candidates understand that the work they submit must be their own and that they understand the meaning of plagiarism and what penalties may be applied. Candidates may refer to research, quotations or evidence but they must list their sources. The rewards from acknowledging sources, and the credit they will gain from doing so, should be emphasised to candidates as well as the potential risks of failing to acknowledge such material.

Both candidates and teachers must declare that the work is the candidate's own:

- **Each candidate** must sign a declaration before submitting their work to their teacher. A candidate authentication statement that can be used is available to download from the OCR website. These statements should be retained within the centre until all enquiries about results, malpractice and appeals issues have been resolved. **A mark of zero must be recorded if a candidate cannot confirm the authenticity of their work.**
- **Teachers** are required to declare that the work submitted for internal assessment is the candidate's own work by sending the moderator a centre authentication form (CCS160) for each unit at the same time as the marks. If a centre fails to provide evidence of authentication, **we will set the mark for that candidate(s) to Pending (Q) for that component until authentication can be provided.**

5.5 Internal standardisation

It is important that all internal assessors of this controlled assessment work to common standards. Centres must ensure that the internal standardisation of marks across assessors and teaching groups takes place using an appropriate procedure.

This can be done in a number of ways. In the first year, reference material and OCR training meetings will provide a basis for centres' own standardisation. In subsequent years, this, or centres' own archive material, may be used. Centres are advised to hold preliminary meetings of staff involved to compare standards through cross-marking a small sample of work. After most marking has been completed, a further meeting at which work is exchanged and discussed will enable final adjustments to be made.

5.6 Submitting marks and authentication

All work for controlled assessment is marked by the teacher and internally standardised by the centre. Marks are then submitted to OCR **and** your moderator: refer to the OCR website for submission dates of the marks to OCR.

There should be clear evidence that work has been attempted and some work produced. If a candidate submits no work for an internally assessed component, then the candidate should be indicated as being absent from that component. If a candidate completes any work at all for an internally assessed component, then the work should be assessed according to the internal assessment objectives and marking instructions and the appropriate mark awarded, which may be zero.

The centre authentication form (CCS160) must be sent to the moderator with the marks.

5.7 Submitting samples of candidate work

5.7.1 Sample requests

Once you have submitted your marks, your exams officer will receive an email requesting a moderation sample. Samples will include work from across the range of attainment of the candidates' work.

The sample of work which is presented to the Moderator for moderation must show how the marks have been awarded in relation to the marking criteria defined in Section 5.4.5. Each candidate's work should have a cover sheet attached to it with a summary of the marks awarded for the task.

When making your entries, the entry option specifies how the sample for each unit is to be submitted. For each of these units, all candidate work must be submitted using the **same entry option**. It is not possible for centres to offer both options for a unit within the same series. You can choose different options for different units. Please see Section 8.2.1 for entry codes.

5.7.2 Submitting moderation samples via post

The sample of candidate work must be posted to the moderator within three days of receiving the request. You should use one of the labels provided to send the candidate work.

We would advise you to keep evidence of work submitted to the moderator, eg copies of written work or photographs of practical work. You should also obtain a certificate of posting for all work that is posted to the moderator.

5.7.3 Submitting the moderation samples via the OCR Repository

The OCR Repository, which is accessed via Interchange, is a system which has been created to enable centres to submit candidate work electronically for moderation. It allows centres to upload work for several candidates at once but does not function as an e-portfolio for candidates.

OCR GCSE Chemistry A Unit A174 can be submitted via the OCR Repository.

Once you receive your sample request, you should upload the work to the OCR Repository within three days of receiving the request. Instructions for how to upload files to OCR using the OCR Repository can be found on the OCR website and in the *Guide to controlled assessment for GCSE Twenty First Century Science,* which will be available on the OCR website from Spring 2011.

It is the centre's responsibility to ensure that any work submitted to OCR electronically is virus-free.

5.8 External moderation

The purpose of moderation is to ensure that the standard of the award of marks for work is the same for each centre and that each teacher has applied the standards appropriately across the range of candidates within the centre.

At this stage, if necessary, centres may be required to provide an additional sample of candidate work (if marks are found to be in the wrong order) or carry out some re-marking. If you receive such a request, please ensure that you respond as quickly as possible to ensure that your candidates' results are not delayed.

6.1 Free support and training from OCR

OCR recognises that the introduction of the new specifications and controlled assessment will bring challenges for implementation and teaching.

Working in close consultation with teachers, publishers and other experts, centres can expect a high level of support, services and resources for OCR qualifications.

Essential FREE support materials including:

- New OCR GCSE Sciences website www.gcse-science.com to access information and support materials quickly and easily
- Specimen assessment materials and mark schemes
- Guide to controlled assessment
- Sample controlled assessment materials
- Exemplar candidate work
- Teacher's handbook
- Sample schemes of work and lesson plans
- Guide to curriculum planning
- Frequently asked questions

Essential FREE support services including:

- Free INSET training – for information visit www.gcse-science.com
- Interchange – a completely secure, free website to help centres reduce administrative tasks at exam time
- E-alerts – register now for regular updates at www.ocr.org.uk/2011signup
- Active Results – detailed item level analysis of candidate results
- Answers@OCR – a free online service providing answers to frequently asked questions about GCSE science

6.2 OCR endorsed resources

OCR works with publishers to ensure centres can access a choice of quality, 'Official Publisher Partner' and 'Approved Publication,' resources, endorsed by OCR for use with individual specifications.

You can be confident that resources branded with 'Official Publisher Partner' or 'Approved publication' logos have undergone OCR's thorough quality assurance process and are endorsed for use with the relevant specification.

These endorsements do not mean that the materials are the only suitable resources available or necessary to achieve an OCR qualification. All responsibility for the content of the published resources rests with the publisher.

6.2.1 Publisher partner

We have been working closely with Oxford University Press, our publisher partner for OCR GCSE Twenty First Century Science 2011, to help ensure their new resources are available when you need them and match the new specifications.

Oxford University Press is working with our science team, the Nuffield Foundation and University of York Science Education Group to publish new editions of the popular Twenty First Century Science resources. These resources are lively, engaging and make science relevant to every student.

The second edition of these resources is packed with up to date sciences, as well as the familiar topics you enjoy teaching including step by step guidance for answering all types of exam questions, extended response questions and support for the new Controlled Assessment.

To order an Evaluation Pack, or for further details, please visit the Oxford University Press website at www.oxfordsecondary.co.uk/twentyfirstcenturyscience.

6.2.2 Endorsed publishers

Other endorsed resources available for this specification include OCR GCSE Twenty First Century Science from Collins.

Collins is working with a team of experienced authors to provide resources which will help you deliver the new OCR GCSE Twenty First Century Science specifications. The Science, Additional Science and Separate Science components build on each other so your department can buy as needed and use them with all students taking different 2011 GCSE science routes.

Reduce planning time – the student books, teacher packs, homework activities, interactive books and assessment package are fully integrated and matched to the Collins GCSE Twenty First Century scheme of work so you can get started straight away.

For further details and to order an Evaluation Pack visit www.collinseducation.com/gcsescience2011

6.3 Training

6.3.1 Get Ready... introducing the new specification

If you would like an overview of the new OCR Science specifications, we have half day 'Get ready' courses running in three locations. For more information and to book online visit www.ocreventbooker.org.uk using **course code OSCP3**.

6.3.2 Get Started...towards successful delivery of the new specification

Our 'Get Started' courses will look at the new specification in more depth, with emphasis on first delivery. The courses planned for summer 2011 will focus on controlled assessment. For more information about our full range of OCR GCSE Science courses visit www.ocr.org.uk/science2011/training

6.4 OCR support services

6.4.1 Active Results

Active Results is available to all centres offering OCR's GCSE Chemistry A specifications.

activeresults

Active Results is a free results analysis service to help teachers review the performance of individual candidates or whole schools.

Devised specifically for the UK market, data can be analysed using filters on several categories such as gender and other demographic information, as well as providing breakdowns of results by question and topic.

Active Results allows you to look in greater detail at your results:

- Richer and more granular data will be made available to centres including question level data available from e-marking
- You can identify the strengths and weaknesses of individual candidates and your centre's cohort as a whole
- Our systems have been developed in close consultation with teachers so that the technology delivers what you need.

Further information on Active Results can be found on the OCR website.

6.4.2 OCR Interchange

OCR Interchange has been developed to help you to carry out day-to-day administration functions online, quickly and easily. The site allows you to register and enter candidates online. In addition, you can gain immediate and free access to candidate information at your convenience. Sign up at https://interchange.ocr.org.uk.

7 Access to GCSE Chemistry A

7.1 Disability Discrimination Act (DDA) information relating to GCSE Chemistry A

GCSEs often require assessment of a broad range of competencies. This is because they are general qualifications and, as such, prepare candidates for a wide range of occupations and higher level courses.

The revised GCSE qualifications and subject criteria were reviewed by the regulators to identify whether any of the competencies required by the subject presented a potential barrier to any disabled candidates. If this was the case, the situation was reviewed again to ensure that such competencies were included only where essential to the subject. The findings of this process were discussed with disability groups and with disabled people.

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments and to demonstrate what they know and can do. For this reason, very few candidates will have a complete barrier to the assessment. Information on reasonable adjustments is found in *Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations* produced by the Joint Council www.jcq.org.uk.

Candidates who are unable to access part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award based on the parts of the assessment they have taken.

The access arrangements permissible for use in this specification are in line with QCDA's GCSE subject criteria equalities review and are as follows:

	Yes/No	Type of Assessment
Readers	Yes	All assessments
Scribers	Yes	All assessments
Practical assistants	Yes	All controlled assessments. The practical assistant may assist with assessed practical experiments under instruction from the candidate.
Word processors	Yes	All assessments
Transcripts	Yes	All assessments
BSL interpreters	Yes	All assessments
Oral language modifiers	Yes	All assessments
MQ papers	Yes	All assessments
Extra time	Yes	All assessments

7.2 Arrangements for candidates with particular requirements

All candidates with a demonstrable need may be eligible for access arrangements to enable them to show what they know and can do. The criteria for eligibility for access arrangements can be found in the JCQ document *Access Arrangements, Reasonable Adjustments and Special Consideration.*

Candidates who have been fully prepared for the assessment but who have been affected by adverse circumstances beyond their control at the time of the examination may be eligible for special consideration. Centres should consult the JCQ document *Access Arrangements, Reasonable Adjustments and Special Consideration.*

Administration of GCSE Chemistry A

8

8.1 Availability of assessment

There are two examination series each year, in January and June. GCSE Physics A units will be assessed from January 2012. Assessment availability and unit weighting can be summarised as follows:

	Unit A171 (25%)	Unit A172 (25%)	Unit A173 (25%)	Unit A174 (25%)	Certification availability
January 2012	✓				–
June 2012	✓	✓			–
January 2013	✓	✓			–
June 2013	✓	✓	✓	✓	✓*
January 2014	✓	✓	✓		✓*
June 2014	✓	✓	✓	✓	✓*

GCSE certification is available for the first time in June 2013 for GCSE Chemistry A, and each January and June thereafter.

*Centres are reminded that at least 40% of the assessment must be taken in the examination series in which the qualification is certificated. This can be any combination of assessment units, including written papers and controlled assessment units.

8.2 Making entries

Centres must be registered with OCR in order to make any entries, including estimated entries. We recommend that centres apply to OCR to become a registered centre well in advance of making their first entries.

Submitting entries accurately and on time is critical to the successful delivery of OCR's services to centres. Entries received after the advertised deadlines can ultimately jeopardise the final production and delivery of results. Therefore, please make sure that you are aware of the entry deadlines, which are available on the OCR website.

8.2.1 Making unit entries

Centres must have made an entry for a unit in order for OCR to supply the appropriate forms and/or moderator details for controlled assessment.

It is essential that unit entry codes are quoted in all correspondence with OCR.

Unit entry code	Component code	Assessment method	Unit title
A171 F	01	Written paper	Unit A171: *Modules C1, C2 and C3* (Foundation Tier)
A171 H	02	Written paper	Unit A171: *Modules C1, C2 and C3* (Higher Tier)
A172 F	01	Written paper	Unit A172: *Modules C4, C5 and C6* (Foundation Tier)
A172 H	02	Written paper	Unit A172: *Modules C4, C5 and C6* (Higher Tier)
A173 F	01	Written paper	Unit A173: *Module C7* (Foundation Tier)
A173 H	02	Written paper	Unit A173: *Module C7* (Higher Tier)

Controlled assessment unit

For the controlled assessment Unit A174, candidates must be entered for either the OCR Repository option or the postal moderation option. Centres must enter all of their candidates for ONE of the options. It is not possible for centres to offer both components within the same series.

Unit entry code	Component code	Assessment method	Unit title
A174 A	01	Moderated via OCR Repository	Controlled assessment
A174 B	02	Moderated via postal moderation	Controlled assessment

8.2.2 Qualification entries

Candidates must enter for qualification certification separately from unit assessment(s). If a certification entry is **not** made, no overall grade can be awarded.

Candidates may enter for:

- GCSE certification code J244.

A candidate who has completed all the units required for the qualification must enter for certification in the same examination series in which the terminal rules are satisfied.

GCSE certification is available for the first time in June 2013 for GCSE Chemistry A, and each January and June thereafter.

8.3 Terminal rule

Candidates must take at least 40% of the overall assessment in the same series they enter for the qualification certification.

Guidance on the terminal rule can be found on the OCR website.

8.4 Unit and qualification re-sits

Candidates may re-sit each unit once before entering for certification for a GCSE. The better result for each unit will count towards the final qualification, **provided that the terminal rule is satisfied.**

However, candidates may enter for the qualification an unlimited number of times.

Please refer to the Admin Guide on the OCR website for more information.

8.5 Enquiries about results

Under certain circumstances, a centre may wish to query the result issued to one or more candidates. Enquiries about results for GCSE units must be made immediately following the series in which the relevant unit was taken (by the Enquiries about Results deadline).

Please refer to the JCQ *Post-Results Services* booklet and the OCR Admin Guide for further guidance about action on the release of results. Copies of the latest versions of these documents can be obtained from the OCR website.

8.6 Shelf-life of units

Individual unit results, prior to certification of the qualification, have a shelf-life limited only by that of the qualification.

8.7 Prohibited qualifications and classification code

Every specification is assigned a national classification code indicating the subject area to which it belongs. The classification code for this specification is 1110.

Centres should be aware that candidates who enter for more than one GCSE qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Performance Tables.

Centres may wish to advise candidates that, if they take two specifications with the same classification code, schools and colleges are very likely to take the view that they have achieved only one of the two GCSEs. The same view may be taken if candidates take two GCSE specifications that have different classification codes but have significant overlap of content. Candidates who have any doubts about their subject combinations should seek advice, for example from their centre or the institution to which they wish to progress.

9 Other information about GCSE Chemistry A

9.1 Overlap with other qualifications

This specification has been developed alongside GCSE Science A, GCSE Additional Science A, GCSE Biology A, GCSE Physics A and GCSE Additional Applied Science.

Modules 1–3 of this specification are also included in GCSE Science A. Modules 4–6 of this specification are also included in GCSE Additional Science A.

Aspects of the controlled assessment of skills are common across GCSE Additional Science A, GCSE Biology A, GCSE Chemistry A and GCSE Physics A.

9.2 Progression from this qualification

GCSE qualifications are general qualifications which enable candidates to progress directly to employment, or to proceed to further qualifications.

Progression to further study from GCSE will depend upon the number and nature of the grades achieved. Broadly, candidates who are awarded mainly Grades D to G at GCSE could either strengthen their base through further study of qualifications at Level 1 within the National Qualifications Framework or could proceed to Level 2. Candidates who are awarded mainly Grades A* to C at GCSE would be well prepared for study at Level 3 within the National Qualifications Framework.

9.3 Avoidance of bias

OCR has taken great care in preparation of this specification and assessment materials to avoid bias of any kind.

9.4 Code of Practice/Common criteria requirements/Subject criteria

This specification complies in all respects with the current GCSE, GCE, Principal Learning and Project Code of Practice as available on the Ofqual website, *The Statutory Regulation of External Qualifications 2004*, and the subject criteria for GCSE Chemistry.

9.5 Language

This specification and associated assessment materials are in English only.

9.6 Spiritual, moral, ethical, social, legislative, economic and cultural issues

This specification offers opportunities which can contribute to an understanding of these issues in the following topics.

The table below gives some examples which could be used when teaching the course.

Issue	Opportunities for teaching issues during the course
Moral issues The commitment of scientists to publish their findings and subject their ideas to testing by others.	Practical investigation: reviewing the strategy and procedures.
Ethical issues The ethical implications of selected scientific issues.	C7: Green chemistry
Economical issues The range of factors which have to be considered when weighing the costs and benefits of scientific activity.	C2: The technical, economic and social issues that have to be taken into account when designing a material object. C6: Evaluating the costs and benefits associated with chemical manufacturing.
Cultural issues Scientific explanations which give insight into the local and global environment.	C1: The origins of pollutants and what happens to them in the atmosphere. C5: Insight into the chemical nature of natural changes in the lithosphere, hydrosphere, atmosphere and biosphere.

9.7 Sustainable development, health and safety considerations and European developments, consistent with international agreements

This specification supports these issues, consistent with current EU agreements, as outlined below.

The specification incorporates specific modules on health and welfare and the environment within its content. These modules encourage candidates to develop environmental responsibility based upon a sound understanding of the principle of sustainable development.

9.8 Key Skills

This specification provides opportunities for the development of the Key Skills of *Communication, Application of Number, Information Technology, Working with Others, Improving Own Learning and Performance* and *Problem Solving* at Levels 1 and/or 2. However, the extent to which this evidence fulfils the Key Skills criteria at these levels will be totally dependent on the style of teaching and learning adopted for each unit.

The following table indicates where opportunities may exist for at least some coverage of the various Key Skills criteria at Levels 1 and/or 2 for each unit.

Unit	C		AoN		IT		WwO		IoLP		PS	
	1	2	1	2	1	2	1	2	1	2	1	2
A171	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A172	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A173	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A174	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Detailed opportunities for generating Key Skills evidence through this specification are posted on the OCR website (www.ocr.org.uk). A summary document for Key Skills Coordinators showing ways in which opportunities for Key Skills arise within GCSE courses has been published.

9.9 ICT

In order to play a full part in modern society, candidates need to be confident and effective users of ICT. This specification provides candidates with a wide range of appropriate opportunities to use ICT in order to further their study of chemistry.

Opportunities for ICT include:

- using video clips to provide the context for topics studied and to illustrate the practical importance of the scientific ideas
- gathering information from the internet and software libraries
- gathering data using sensors linked to data-loggers or directly to computers
- using spreadsheets and other software to process data
- using animations and simulations to visualise scientific ideas
- using modelling software to explore theories
- using software to present ideas and information on paper and on screen

Particular opportunities for the use of ICT appear in the introductions to each of the modules.

9.10 Citizenship

From September 2002, the National Curriculum for England at Key Stage 4 includes a mandatory programme of study for Citizenship.

GCSE Chemistry A is designed as a science education for future citizens which not only covers aspects of the Citizenship programme of study but also extends beyond that programme by dealing with important aspects of science which all people encounter in their everyday lives.

A Appendix A: Guidance for the production of electronic controlled assessment

Structure for evidence

A controlled assessment portfolio is a collection of folders and files containing the candidate's evidence. Folders should be organised in a structured way so that the evidence can be accessed easily by a teacher or moderator. This structure is commonly known as a folder tree. It would be helpful if the location of particular evidence is made clear by naming each file and folder appropriately and by use of an index called 'Home Page'.

There should be a top level folder detailing the candidate's centre number, candidate number, surname and forename, together with the unit code A174, so that the portfolio is clearly identified as the work of one candidate.

Each candidate produces an assignment for controlled assessment. The evidence should be contained within a separate folder within the portfolio. This folder may contain separate files.

Each candidate's controlled assessment portfolio should be stored in a secure area on the centre's network. Prior to submitting the controlled assessment portfolio to OCR, the centre should add a folder to the folder tree containing controlled assessment and summary forms.

Data formats for evidence

In order to minimise software and hardware compatibility issues it will be necessary to save candidates' work using an appropriate file format.

Candidates must use formats appropriate to the evidence that they are providing and appropriate to viewing for assessment and moderation. Open file formats or proprietary formats for which a downloadable reader or player is available are acceptable. Where this is not available, the file format is not acceptable.

Electronic controlled assessment is designed to give candidates an opportunity to demonstrate what they know, understand and can do using current technology. Candidates do not gain marks for using more sophisticated formats or for using a range of formats. A candidate who chooses to use only word documents will not be disadvantaged by that choice.

Evidence submitted is likely to be in the form of word processed documents, PowerPoint presentations, digital photos and digital video.

To ensure compatibility, all files submitted must be in the formats listed below. Where new formats become available that might be acceptable, OCR will provide further guidance. OCR advises against changing the file format that the document was originally created in. It is the centre's responsibility to ensure that the electronic portfolios submitted for moderation are accessible to the moderator and fully represent the evidence available for each candidate.

Accepted file formats

Movie formats for digital video evidence
MPEG (*.mpg)
QuickTime movie (*.mov)
Macromedia Shockwave (*.aam)
Macromedia Shockwave (*.dcr)
Flash (*.swf)
Windows Media File (*.wmf)
MPEG Video Layer 4 (*.mp4)

Audio or sound formats
MPEG Audio Layer 3 (*.mp3)

Graphics formats including photographic evidence
JPEG (*.jpg)
Graphics file (*.pcx)
MS bitmap (*.bmp)
GIF images (*.gif)

Animation formats
Macromedia Flash (*.fla)

Structured markup formats
XML (*.xml)

Text formats
Comma Separated Values (.csv)
PDF (.pdf)
Rich text format (.rtf)
Text document (.txt)

Microsoft Office suite
PowerPoint (.ppt)
Word (.doc)
Excel (.xls)
Visio (.vsd)
Project (.mpp)

B Appendix B: Ideas About Science

The specifications within the Twenty First Century Science suite are unique in having interpreted and extrapolated the principles of 'How Science Works' into a series of 'Ideas about Science'. It is intended that the Ideas about Science will ensure students understand how scientific knowledge is obtained, how it is reported in the world outside the classroom, and the impacts of scientific knowledge on society.

GCSE Chemistry A aims to develop students' understanding of the Ideas about Science alongside their growing understanding of scientific ideas and explanations of the behaviour of the natural world.

Why are Ideas about Science important?

In order to make sense of the scientific ideas that students encounter in lessons and read or hear about outside of school, they need to develop an understanding of science itself – of how scientific knowledge is obtained, the kinds of evidence and reasoning behind it, its strengths and limitations, and how far we can therefore rely on it. They also need opportunities to reflect on the impacts of scientific knowledge on society, and how we respond individually and collectively to the new ideas, artefacts and processes that science makes possible.

Reports of scientific claims, inventions and discoveries are prolific in the media of the twenty first century, and an understanding of the Ideas about Science will ensure that students are well-equipped to critically evaluate the science stories they read and hear.

The kind of understanding of science that we would wish students to have by the end of their school science education might be summarised as follows:

How science works

The aim of science is to find explanations for the behaviour of the natural world. There is no single 'method of science' that leads automatically to scientific knowledge. Scientists do, however, have characteristic ways of working. In particular, data from observations and measurements are of central importance. All data, however, have to be interpreted, and this is influenced by the ideas we bring to it. Scientific explanations do not 'emerge' automatically from data. Proposing an explanation involves creative thinking. So, it is quite possible (and may be quite reasonable) for different people to arrive at different explanations for the same data.

Causes and effects

Scientists often look for cause-effect explanations. 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.

Theories, explanations and predictions

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 theory might propose a model involving objects (and their behaviour) that cannot be observed direction, to account for what we observe. Or it might define quantities and ways of measuring them, and state some mathematical relationships between them.

A scientific explanation of a specific event or phenomenon is often based on applying a scientific theory (or theories) to the situation in question.

A proposed scientific explanation (whether it is a very general scientific theory or a more specific explanation) is tested by comparing predictions based on it with observations or measurements. If these agree, it increases our confidence that the explanation might be correct. This can never be conclusively proved, but accumulating evidence can bring us to the point where it is hard to imagine any other possible explanation. If prediction and data disagree, then one or other must be wrong. Data can never be relied on completely because observations may be incorrect and all measurements are subject to uncertainty, arising from the inevitable limitations of the measuring equipment or the person using it. If we believe the data are accurate, then the prediction must be wrong, lowering our confidence in the proposed explanation.

Science and scientists

The scientific community has established robust procedures for testing and checking the claims of individual scientists, and reaching an agreed view. Scientists report their findings to other scientists at conferences and in peer-reviewed journals. Claims are not accepted until they have survived the critical scrutiny of the scientific community. In some areas of enquiry, it has proved possible to eliminate all the explanations we can think of but one – which then becomes the accepted explanation (until, if ever, a better one is proposed).

Where possible, scientists choose to study simple situations in order to gain understanding. This, however, can make it difficult to apply this understanding to complex, real-world situations. So there can be legitimate disagreements about scientific explanations of particular phenomena or events, even though there is no dispute about the fundamental scientific knowledge involved.

Science and society

The application of scientific knowledge, in new technologies, materials and devices, greatly enhances our lives, but can also have unintended and undesirable side-effects. Often we need to weigh up the benefits against the disadvantages – and also consider who gains and who loses. An application of science may have social, economic and political implications, and sometimes also ethical ones. Personal and social decisions require an understanding of the science involved, but also involve knowledge and values that go beyond science

How can Ideas about Science be developed in teaching?

Within this Appendix all of the Ideas about Science are listed together, in an order that shows clearly how they relate to one another and build up the understanding of science that we would like students to develop.

In addition to this Appendix, specific Ideas about Science are identified at the start of each module within the specification, to indicate that there are good opportunities within the content of the module to introduce and develop them. The OCR scheme of work for GCSE Chemistry A (published separately) will also highlight teaching opportunities for specific Ideas about Science.

What are the Ideas about Science?

The following pages set out in detail the Ideas about Science and what candidates should be able to do to demonstrate their understanding of them. The statements in the left-hand column specify the understandings candidates are expected to develop; the entries in the right-hand column are suggestions about some ways in which evidence of understanding can be demonstrated.

1 Data: their importance and limitations

Data are the starting point for scientific enquiry – and the means of testing scientific explanations. But data can never be trusted completely, and scientists need ways of evaluating how good their data are.

	Candidates should understand that:	A candidate who understands this can, for example:
1.1	• data are crucial to science. The search for explanations starts from data; and data are collected to test proposed explanations.	• use data rather than opinion if asked to justify an explanation • outline how a proposed scientific explanation has been (or might be) tested, referring appropriately to the role of data.
1.2	• we can never be sure that a measurement tells us the true value of the quantity being measured.	• suggest reasons why a given measurement may not be the true value of the quantity being measured.
1.3	• if we make several measurements of any quantity, these are likely to vary.	• suggest reasons why several measurements of the same quantity may give different values • when asked to evaluate data, make reference to its repeatability **and/or reproducibility.**
1.4	• the mean of several repeat measurements is a good estimate of the true value of the quantity being measured.	• calculate the mean of a set of repeated measurements • from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value • explain why repeating measurements leads to a better estimate of the quantity.
1.5	• from a set of repeated measurements of a quantity, it is possible to estimate a range within which the true value probably lies.	• from a set of repeated measurements of a quantity, make a sensible suggestion about the range within which the true value probably lies **and explain this** • **when discussing the evidence that a quantity measured under two different conditions has (or has not) changed, make appropriate reference both to the difference in means and to the variation within each set of measurements.**
1.6	• if a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect. If possible, it should be checked. If not, it should be used unless there is a specific reason to doubt its accuracy.	• identify any outliers in a set of data • treat an outlier as data unless there is a reason for doubting its accuracy • **discuss and defend the decision to discard or to retain an outlier.**

2 Cause-effect explanations

Scientists look for patterns in data, as a means of identifying correlations that might suggest possible cause-effect links – for which an explanation might then be sought.

	Candidates should understand that:	A candidate who understands this can, for example:
2.1	• it is often useful to think about processes in terms of factors which may affect an outcome (or input variables which may affect an outcome variable).	• in a given context, identify the outcome and factors that may affect it • in a given context, suggest how an outcome might alter when a factor is changed.
2.2	• to investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	• identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive design feature, or the fact that they are not as a design flaw • explain why it is necessary to control all the factors that might affect the outcome other than the one being investigated.
2.3	• if an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	• suggest and explain an example from everyday life of a correlation between a factor and an outcome • identify where a correlation exists when data are presented as text, as a graph, or in a table. ⓘ *Examples may include both positive and negative correlations, but candidates will not be expected to know these terms.*
2.4	• a correlation between a factor and an outcome does not necessarily mean that the factor causes the outcome; both might, for example, be caused by some other factor.	• use the ideas of correlation and cause when discussing data and show awareness that a correlation does not necessarily indicate a causal link • identify, and suggest from everyday experience, examples of correlations between a factor and an outcome where the factor is (or is not) a plausible cause of the outcome • explain why an observed correlation between a given factor and outcome does not necessarily mean that the factor causes the outcome.
2.5	• in some situations, a factor alters the chance (or probability) of an outcome, but does not invariably lead to it. We also call this a correlation.	• suggest factors that might increase the chance of a particular outcome in a given situation, but do not invariably lead to it • explain why individual cases do not provide convincing evidence for or against a correlation.

	Candidates should understand that:	A candidate who understands this can, for example:
2.6	• to investigate a claim that a factor increases the chance (or probability) of an outcome, scientists compare samples (eg groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples, the more confident we can be about any conclusions drawn.	• discuss whether given data suggest that a given factor does/does not increase the chance of a given outcome • evaluate critically the design of a study to test if a given factor increases the chance of a given outcome, by commenting on sample size and how well the samples are matched.
2.7	• **even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.**	• **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.**

3 Developing scientific explanations

The aim of science is to develop good explanations for natural phenomena. Initially, an explanation is a hypothesis that might account for the available data. As more evidence becomes available, it may become an accepted explanation or theory. Scientific explanations and theories do not 'emerge' automatically from data, and cannot be deduced from the data. Proposing an explanation or theory involves creative thinking. It can then be tested – by comparing its predictions with data from observations or measurements.

	Candidates should understand that:	A candidate who understands this can, for example:
3.1	• scientific hypotheses, explanations and theories are not simply summaries of the available data. They are based on data but are distinct from them.	• in a given account of scientific work, identify statements which report data and statements of explanatory ideas (hypotheses, explanations, theories) • recognise that an explanation may be incorrect even if the data agree with it.
3.2	• an explanation cannot simply be deduced from data, but has to be thought up creatively to account for the data.	• identify where creative thinking is involved in the development of an explanation.
3.3	• a scientific explanation should account for most (ideally all) of the data already known. It may explain a range of phenomena not previously thought to be linked. It should also enable predictions to be made about new situations or examples.	• recognise data or observations that are accounted for by, or conflict with, an explanation • give good reasons for accepting or rejecting a proposed scientific explanation • identify the better of two given scientific explanations for a phenomenon, and give reasons for the choice.
3.4	• scientific explanations are tested by comparing predictions based on them with data from observations or experiments.	• draw valid conclusions about the implications of given data for a given scientific explanation, in particular: — understand that agreement between a prediction and an observation increases confidence in the explanation on which the prediction is based but does not prove it is correct — understand that disagreement between a prediction and an observation indicates that one or other is wrong, and decreases our confidence in the explanation on which the prediction is based.

4 The scientific community

Findings reported by an individual scientist or group are carefully checked by the scientific community before being accepted as scientific knowledge.

	Candidates should understand that:	A candidate who understands this can, for example:
4.1	• scientists report their claims to other scientists through conferences and journals. Scientific claims are only accepted once they have been evaluated critically by other scientists.	• describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists • recognise that there is less confidence in new scientific claims that have not yet been evaluated by the scientific community than there is in well-established ones.
4.2	• scientists are usually sceptical about claims that cannot be repeated by anyone else, and about unexpected findings until they have been replicated (by themselves) or reproduced (by someone else).	• identify the fact that a finding has not been reproduced by another scientist as a reason for questioning a scientific claim • explain why scientists see this as important.
4.3	• if explanations cannot be deduced from the available data, 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 judgments.	• show awareness that the same data might be interpreted, quite reasonably, in more than one way • suggest plausible reasons why scientists in a given situation disagree(d).
4.4	• an accepted scientific explanation is rarely abandoned just because some new data disagree with its predictions. It usually survives until a better explanation is available.	• discuss the likely consequences of new data that disagree with the predictions of an accepted explanation • **suggest reasons why scientists should not give up an accepted explanation immediately if new data appear to conflict with it.**

5 Risk

Every activity involves some risk. Assessing and comparing the risks of an activity, and relating these to the benefits we gain from it, are important in decision making.

	Candidates should understand that:	A candidate who understands this can, for example:
5.1	• everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	• explain why it is impossible for anything to be completely safe • identify examples of risks which arise from a new scientific or technological advance • suggest ways of reducing a given risk.
5.2	• we can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.	• interpret and discuss information on the size of risks, presented in different ways.
5.3	• to make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.	• discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.
5.4	• to make a decision about a course of action, we need to take account of both its risks and benefits, to the different individuals or groups involved.	• identify risks and benefits in a given situation, to the different individuals and groups involved • discuss a course of action, with reference to its risks and benefits, taking account of who benefits and who takes the risks • suggest benefits of activities that are known to have risk.
5.5	• 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.	• offer reasons for people's willingness (or reluctance) to accept the risk of a given activity.
5.6	• **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).**	• **distinguish between perceived and calculated risk, when discussing personal choices** • **suggest reasons for given examples of differences between perceived and measured risk.**
5.7	• governments and public bodies may have to assess what level of risk is acceptable in a particular situation. This decision may be controversial, especially if those most at risk are not those who benefit.	• discuss the public regulation of risk, **and explain why it may in some situations be controversial.**

6 Making decisions about science and technology

To make sound decisions about the applications of scientific knowledge, we have to weigh up the benefits and costs of new processes and devices. Sometimes these decisions also raise ethical issues. Society has developed ways of managing these issues, though new developments can pose new challenges to these.

	Candidates should understand that:	A candidate who understands this can, for example:
6.1	• science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	• in a particular context, identify the groups affected and the main benefits and costs of a course of action for each group • **suggest reasons why different decisions on the same issue might be appropriate in view of differences in social and economic context.**
6.2	• scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	• identify, and suggest, examples of unintended impacts of human activity on the environment • explain the idea of sustainability, and apply it to specific situations • use data (for example, from a Life Cycle Assessment) to compare the sustainability of alternative products or processes.
6.3	• in many areas of scientific work, the development and application of scientific knowledge are subject to official regulations.	• in contexts where this is appropriate, show awareness of, **and discuss**, the official regulation of scientific research and the application of scientific knowledge.
6.4	• some questions, such as those involving values, cannot be answered by science.	• distinguish questions which could in principle be answered using a scientific approach, from those which could not.
6.5	• some forms of scientific research, and some applications of scientific knowledge, have ethical implications. People may disagree about what should be done (or permitted).	• where an ethical issue is involved: — say clearly what this issue is — summarise different views that may be held.
6.6	• in discussions of ethical issues, one common argument is that the right decision is one which leads to the best outcome for the greatest number of people involved. Another is that certain actions are considered right or wrong whatever the consequences.	• in a given context, identify, **and develop**, arguments based on the ideas that: — the right decision is the one which leads to the best outcome for the greatest number of people involved — certain actions are considered right or wrong whatever the consequences.

Appendix C: Mathematics skills for GCSE science qualifications

C

Candidates are permitted to use calculators in all assessments.

Candidates should be able to:

- understand number, size and scale and the quantitative relationship between units
- understand when and how to use estimation
- carry out calculations involving +, – , ×, ÷, either singly or in combination, decimals, fractions, percentages and positive whole number powers
- provide answers to calculations to an appropriate number of significant figures
- understand and use the symbols =, <, >, ~
- understand and use direct proportion and simple ratios
- calculate arithmetic means
- understand and use common measures and simple compound measures such as speed
- plot and draw graphs (line graphs, bar charts, pie charts, scatter graphs, histograms), selecting appropriate scales for the axes
- substitute numerical values into simple formulae and equations using appropriate units
- translate information between graphical and numeric form
- extract and interpret information from charts, graphs and tables
- understand the idea of probability
- calculate area, perimeter and volume of simple shapes.

In addition, higher tier candidates should be able to:

- interpret, order and calculate with numbers written in standard form
- carry out calculations involving negative powers (only –1 for rate)
- change the subject of an equation
- understand and use inverse proportion
- understand and use percentiles and deciles.

D Appendix D: Physical quantities and units

It is expected that candidates will show an understanding of the physical quantities and corresponding SI units listed below, and will be able to use them in quantitative work and calculations. Whenever they are required for such questions, units will be provided and, where necessary, explained.

Fundamental physical quantities

Physical quantity	Unit(s)
length	metre (m); kilometre (km); centimetre (cm); millimetre (mm); nanometre (nm)
mass	kilogram (kg); gram (g); milligram (mg)
time	second (s); millisecond (ms) ; year (a); million years (Ma); billion years (Ga)
temperature	degree Celsius (°C); kelvin (K)
current	ampere (A); milliampere (mA)

Derived physical quantities and units

Physical quantity	Unit(s)
area	cm^2; m^2
volume	cm^3; dm^3; m^3; litre (l); millilitre (ml)
density	kg/m^3; g/cm^3
speed, velocity	m/s; km/h
acceleration	m/s^2
momentum	kg m/s
force	newton (N)
pressure	N/m^2; pascal (Pa)
gravitational field strength	N/kg
energy	joule (J); kilojoule (kJ); megajoule (MJ); kilowatt hour (kWh); megawatt hour (MWh)
power	watt (W); kilowatt (kW); megawatt (MW)
frequency	hertz (Hz); kilohertz (kHz)
information	bytes (B); kilobytes (kB); megabytes (MB)
potential difference	volt (V)
resistance	ohm (Ω)
radiation dose	sievert (Sv)
distance (in astronomy)	light-year (ly); parsec (pc)
power of a lens	dioptre (D)

Prefixes for units

nano (n)	one thousand millionth	0.000000001	× 10^{-9}
micro (μ)	one millionth	0.000001	× 10^{-6}
milli (m)	one thousandth	0.001	× 10^{-3}
kilo (k)	× one thousand	1000	× 10^{3}
mega (M)	× one million	1 000 000	× 10^{6}
giga (G)	× one thousand million	1 000 000 000	× 10^{9}
tera (T)	× one million million	1 000 000 000 000	× 10^{12}

E Appendix E: Health and safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for GCSE, this is likely to be the local education authority or the governing body. Employees, ie teachers and lecturers, have a duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment.

For members, the CLEAPSS® guide, *Managing Risk Assessment in Science** offers detailed advice. Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X.

Topics in Safety, 3rd edition, 2001, ASE ISBN 0 86357 316 9;

Safeguards in the School Laboratory, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;

CLEAPSS® *Hazcards,* 2007 edition and later updates*;

CLEAPSS® *Laboratory Handbook**;

Hazardous Chemicals, A Manual for Science Education, 1997, SSERC Limited

ISBN 0 9531776 0 2

Where an employer has adopted these or other publications as the basis of their 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 candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, 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, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, 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® (or, in Scotland, SSERC).

*These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications CD-ROM issued annually to members. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk. In Scotland, SSERC (www.sserc.org.uk) has a similar role to CLEAPSS® and there are some reciprocal arrangements.

Appendix F: Periodic table

F

Key

Key
relative atomic mass **atomic symbol** name atomic (proton) number

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

***** *The lanthanoids (atomic numbers 58-71) and the actinoids (atomic numbers 90-103) have been omitted.*

The relative atomic masses of copper and chlorine have not been rounded to the nearest whole number.

G Appendix G: Qualitative analysis

Tests for ions with a positive charge

ion	test	observation
calcium Ca^{2+}	add dilute sodium hydroxide	a white precipitate forms; the precipitate does not dissolve in excess sodium hydroxide
copper Cu^{2+}	add dilute sodium hydroxide	a light blue precipitate forms; the precipitate does not dissolve in excess sodium hydroxide
iron(II) Fe^{2+}	add dilute sodium hydroxide	a green precipitate forms; the precipitate does not dissolve in excess sodium hydroxide
iron(III) Fe^{3+}	add dilute sodium hydroxide	a red-brown precipitate forms; the precipitate does not dissolve in excess sodium hydroxide
zinc Zn^{2+}	add dilute sodium hydroxide	a white precipitate forms; the precipitate dissolves in excess sodium hydroxide

Tests for ions with a negative charge

ion	test	observation
carbonate CO_3^{2-}	add dilute acid	the solution effervesces; carbon dioxide gas is produced (the gas turns lime water from colourless to milky)
chloride Cl^-	add dilute nitric acid, then add silver nitrate	a white precipitate forms
bromide Br^-	add dilute nitric acid, then add silver nitrate	a cream precipitate forms
iodide I^-	add dilute nitric acid, then add silver nitrate	a yellow precipitate forms
sulfate SO_4^{2-}	add dilute acid, then add barium chloride or barium nitrate	a white precipitate forms

YOUR CHECKLIST

OUR AIM IS TO PROVIDE YOU WITH ALL THE INFORMATION AND SUPPORT YOU NEED TO DELIVER OUR SPECIFICATIONS.

- ✓ Bookmark **www.gcse-science.com**
- ✓ Be among the first to hear about support materials and resources as they become available. Register for email updates at **www.ocr.org.uk/updates**
- ✓ Book your INSET training place online at **www.ocr.org.uk/eventbooker**
- ✓ Find out about controlled assessment support at **www.ocr.org.uk/science2011/support**
- ✓ Learn more about Active Results at **www.ocr.org.uk/activeresults**
- ✓ Join our social network community for teachers at **www.social.ocr.org.uk**

NEED MORE HELP?

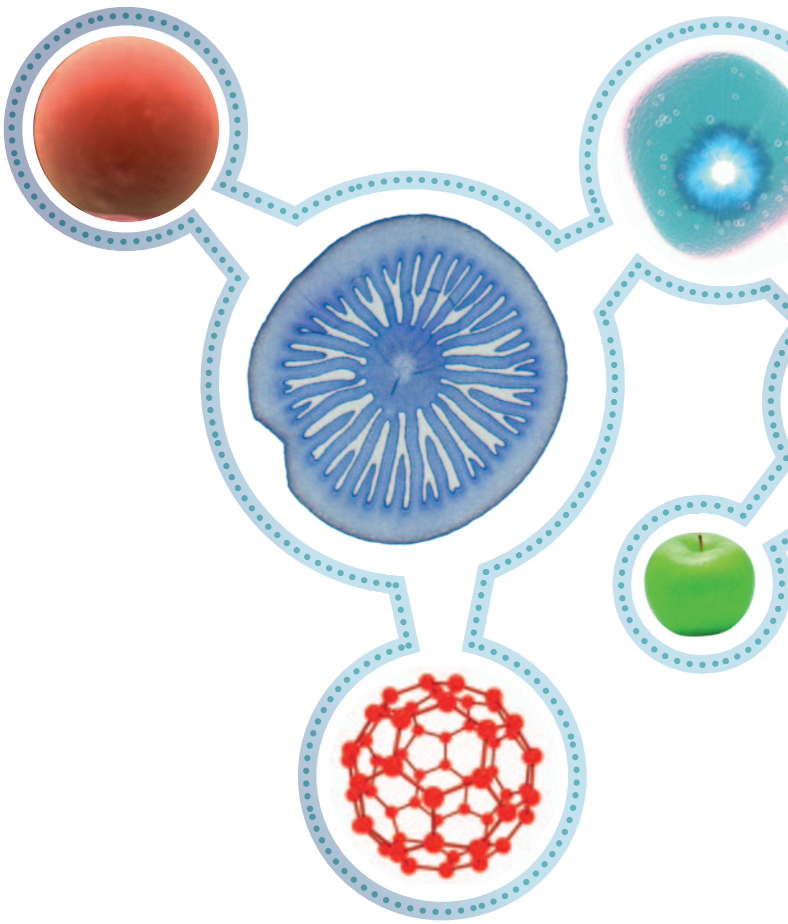
Here's how to contact us for specialist advice

Phone:	01223 553998
Email:	science@ocr.org.uk
Online:	http://answers.ocr.org.uk
Fax:	01223 552627
Post:	Customer Contact Centre, OCR, Progress House, Westwood Business Park, Coventry CV4 8JQ

WHAT TO DO NEXT

1) Sign up to teach – let us know you will be teaching this specification to ensure you receive all the support and examination materials you need. Simply complete the online form at **www.ocr.org.uk/science/signup**

2) Become an approved OCR centre – if your centre is completely new to OCR and has not previously used us for any examinations, visit **www.ocr.org.uk/centreapproval** to become an approved OCR centre.



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