TWENTY FIRST CENTURY SCIENCE SUITE

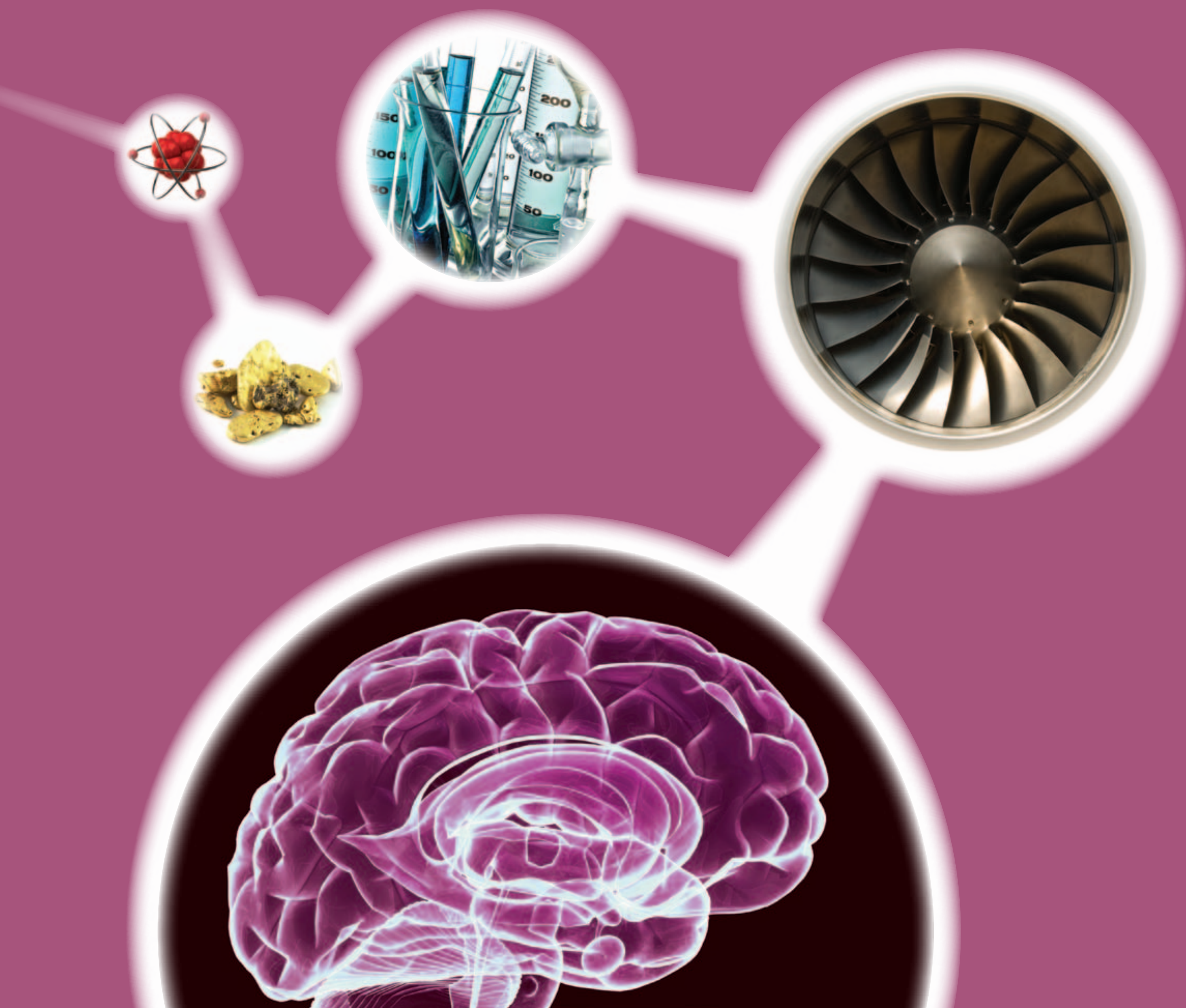
GCSE ADDITIONAL SCIENCE A

ACCREDITED SPECIFICATION

J242

VERSION 2

MAY 2012



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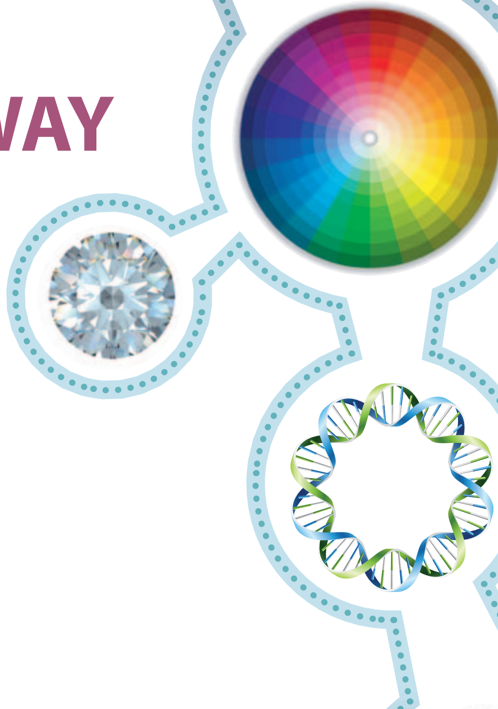
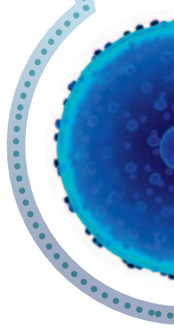
SUPPORTING YOU ALL THE WAY



Our aim is to help you at every stage and we work in close consultation with teachers and other experts, to provide a practical package of high quality resources and support.

Our support materials are designed to save you time while you prepare for and teach our new specifications. In response to what you have told us we are offering detailed guidance on key topics and controlled assessment.



Our essential FREE support includes:

Materials

- Specimen assessment materials and mark schemes
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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.

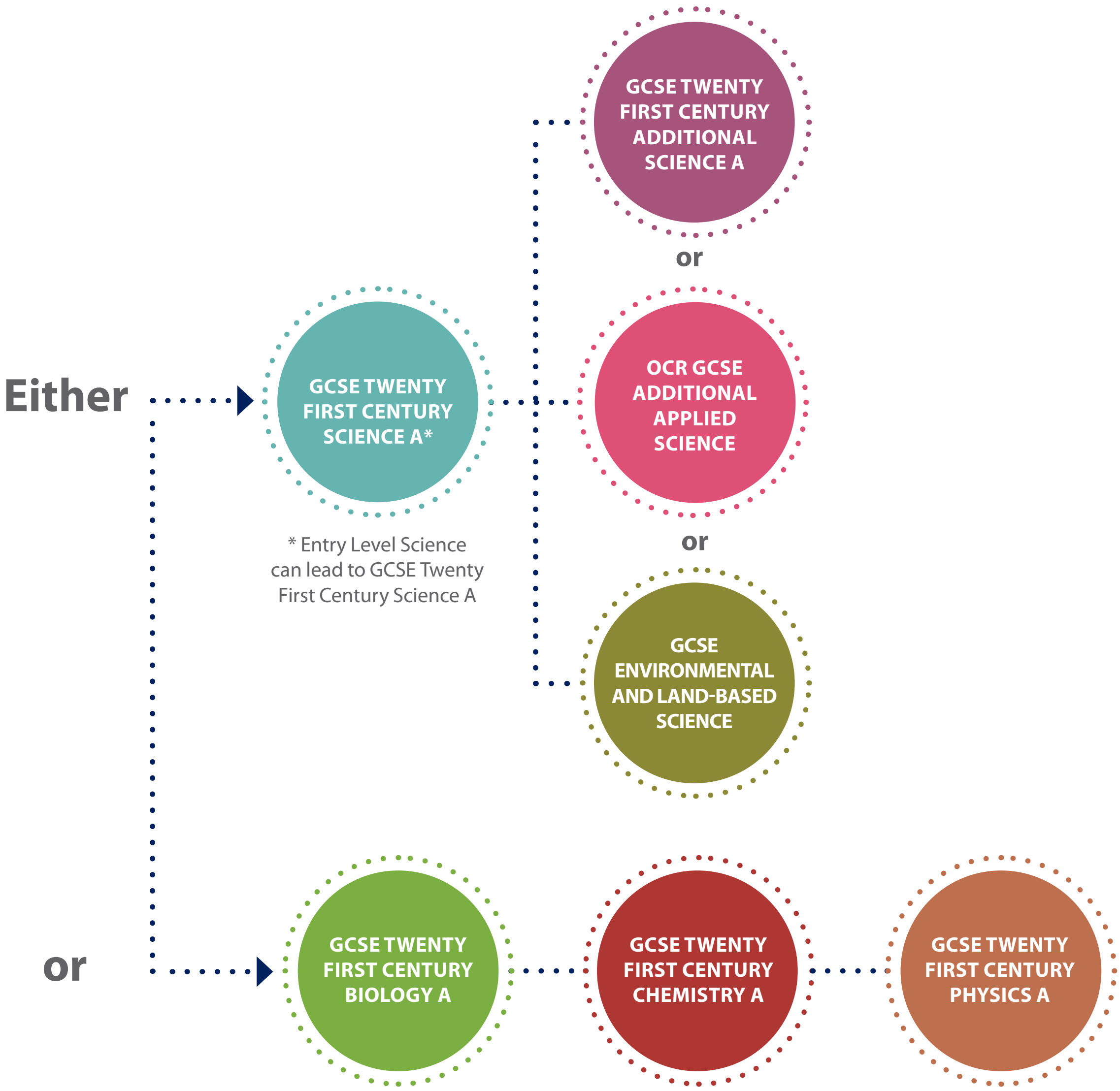
Our Twenty First Century Science suite:

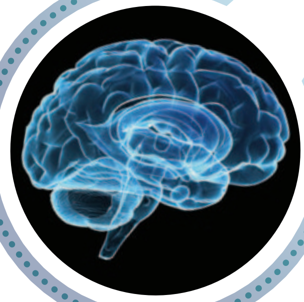
- is engaging to study and motivating for you to teach
- will help your students engage with the course rather than just study it
- gives you the flexibility to choose a delivery style to engage students.

KEY FEATURES

- **How Science Works**, fully integrated into teaching and assessment.
- An **ideal foundation** for students to progress to more-advanced studies and science-related careers.
- A well regarded and proven **concept led** teaching approach to science.

POSSIBLE GCSE COMBINATIONS





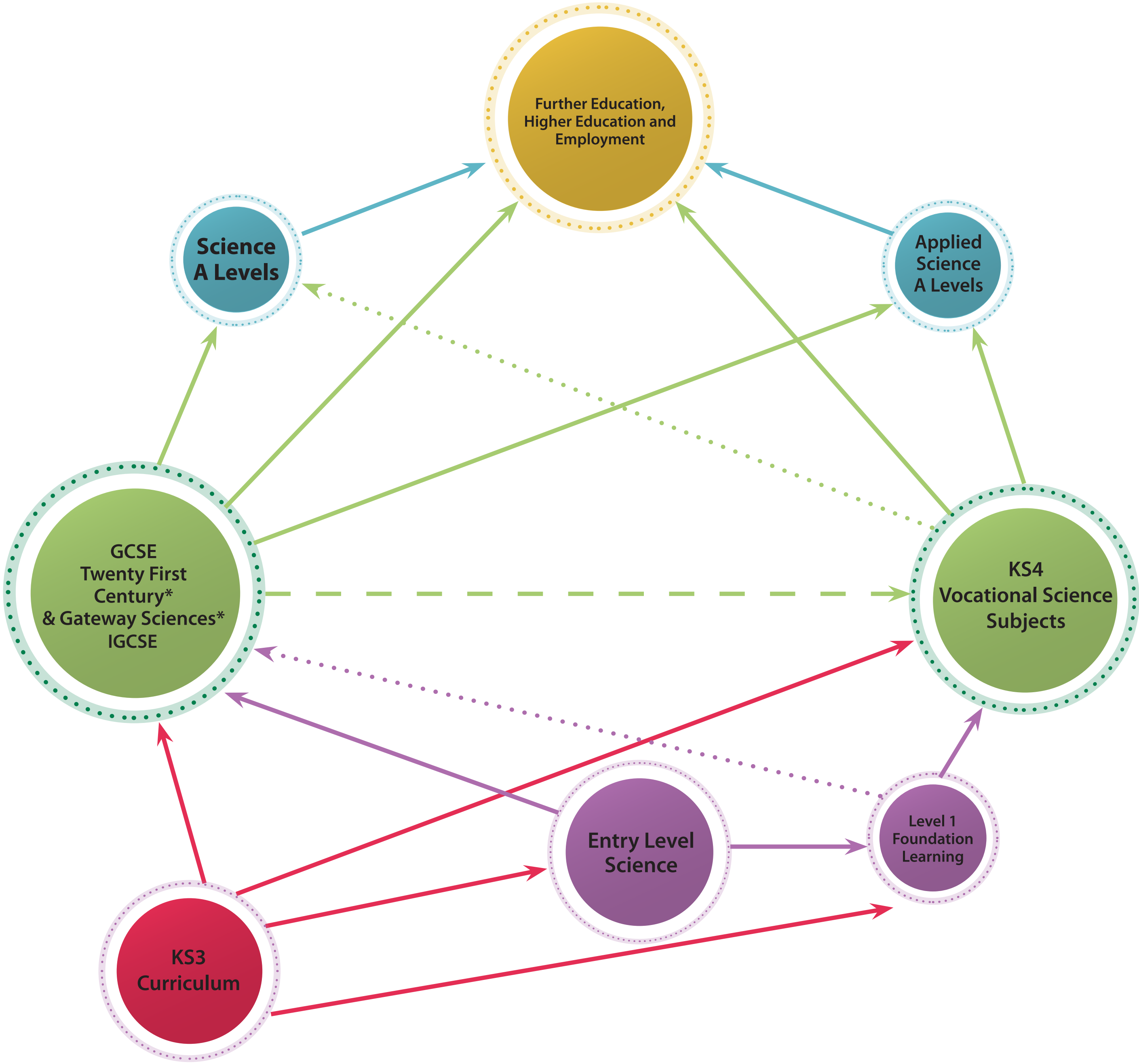
GCSE ADDITIONAL SCIENCE A

KEY FEATURES

GCSE Additional Science A uses different contexts to relate science concepts to their applications. Focusing on scientific explanations and models, it gives students an insight into how scientists help develop our understanding of ourselves and the world we live in. GCSE Additional Science A provides distinctive and relevant experience for learners who wish to progress to Level 3 qualifications.

COURSE OVERVIEW	ASSESSMENT OVERVIEW		
UNIT A162 (BIOLOGY A) *Module B4: The processes of life* *Module B5: Growth and development* *Module B6: Brain and mind*	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 (CHEMISTRY A) *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 A182 (PHYSICS A) *Module P4: Explaining motion* *Module P5: Electric circuits* *Module P6: Radioactive materials*	60 marks 1 hour written paper	**25%** of total GCSE	
UNIT A154 (ADDITIONAL SCIENCE A) *Controlled assessment*	64 marks Approx 6–7 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.

<table>
<tr><td>GCSE Science A (J241)</td><td>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 approaches.</td></tr>
<tr><td>GCSE Additional Science A (J242)</td><td>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.</td></tr>
<tr><td>GCSE Biology A (J243)</td><td rowspan="3">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.</td></tr>
<tr><td>GCSE Chemistry A (J244)</td></tr>
<tr><td>GCSE Physics A (J245)</td></tr>
</table>

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 Additional Science A

2.1 Overview of GCSE Additional Science A

Unit A162: *Biology A* Modules B4, B5, B6

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: *Chemistry A* 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 A182: *Physics A* Modules P4, P5, P6

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 A154: *Additional Science A* 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 GCSE Additional Science A?

	What stays the same?	What changes?
Structure	• Four units of assessment, comprising three externally assessed units and one internally assessed unit. • All four units have equal weightings of 25%. • Externally assessed units are tiered – Foundation and Higher Tier. • Internally assessed unit is controlled assessment.	• The course can only be assessed as linear. • Only one route to certification.
Content	• Content is divided into nine modules. • No changes to module content.	• All of the Ideas about Science provide the underlying context for all modules and units of assessment.
Assessment	• Modules externally assessed within written examination papers. • Modules assessed in particular units are unchanged. • Choice of controlled assessment tasks set by OCR valid for entry in a single examination series only. • Controlled assessment unit worth 25% and available in June series only. • Controlled assessment unit consists of a Case Study and Practical Data Analysis. • Quality of written communication (QWC) assessed in all units. • Externally assessed papers each 1 hour long, with a total of 60 marks divided between objective (up to 40%) and free-response style questions.	• New 100% terminal rule applies to science GCSEs. • No mixed science written papers – written papers correspond to biology, chemistry and physics. • All of the Ideas about Science may be assessed in <u>all</u> units. • All units, including written papers, available for assessment in June series only. • Certification in the same series in Twenty First Century Science A GCSE and Twenty First Century Biology A, Chemistry A or Physics A GCSEs is no longer possible.

2.3 Guided learning hours

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

2.4 Aims and learning outcomes

GCSE specifications in Additional Science should encourage learners to develop their knowledge about the living, material and physical worlds and provide insight into, and experience of, how science works. They should enable learners to engage with science and to make informed decisions about further study in science and related subjects and about career choices.

The aims of this specification are to enable candidates to:

- develop their knowledge and understanding of the material, physical and living worlds
- develop their understanding of the effects of science on society
- develop an understanding of the importance of scale in science
- develop and apply their knowledge and understanding of the nature of science and of the scientific process
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations
- develop their awareness of risk and the ability to assess potential risk in the context of potential benefits
- develop and apply their observational, practical, modelling, enquiry and problem-solving skills and understanding in laboratory, field and other learning environments
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions both qualitatively and quantitatively
- develop their skills in communication, mathematics and the use of technology in scientific contexts.

2.5 Prior learning

Candidates entering this course should have achieved a general educational level equivalent to National Curriculum Level 3, or an Entry 3 at Entry Level within the National Qualifications Framework.

3 Content of GCSE Additional Science A

3.1 Summary of content

GCSE Additional Science A course content gives emphasis and space to fundamental ideas in the sciences, ensures that appropriate skills are developed in preparation for further study, and provides a stimulating bridge to advanced levels in science. The emphasis of the course is on 'science for the scientist' and those aspects of 'How Science Works' that relate to the process of science.

A module defines the required teaching and learning outcomes.

The specification content is displayed as nine modules. The titles of these nine modules are listed in the table on the next page.

Each module is designed to be taught in approximately **half a term**, in 10% of the candidates' curriculum time.

Content of GCSE Additional Science A

Module B4: The processes of life	*Module B5: Growth and development*	*Module B6: Brain and mind*
• How do chemical reactions take place in living things? • How do plants make food? • How do living organisms obtain energy?	• How do organisms develop? • How does an organism produce new cells? • How do genes control growth and development within the cell?	• How do animals respond to changes in their environment? • How is information passed through the nervous system? • Can reflex responses be learned? • How do humans develop more complex behaviour?
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 P4: Explaining motion	***Module P5: Electric circuits***	***Module P6: Radioactive materials***
• How can we describe motion? • What are forces? • What is the connection between forces and motion? • How can we describe motion in terms of energy changes?	• Electric current – a flow of what? • What determines the size of the current in an electric circuit and the energy it transfers? • How do parallel and series circuits work? • How is mains electricity produced? How are voltages and currents induced? • How do electric motors work?	• Why are some materials radioactive? • How can radioactive materials be used and handled safely, including wastes?

3.2 Layout of specification content

The specification content is divided into nine modules that, together with the Ideas about Science (see Section 3.3), are assessed across three written papers (Units A162, A172 and A182) and one unit of controlled assessment (Unit A154).

Section 3.3 describes the Ideas about Science and what candidates will need to understand and be able to do. The Ideas about Science are assessed across all units.

Sections 3.4, 3.5 and 3.6 summarise the three written paper units, A162, A172 and A182, and the associated content that can be assessed within them. Within each of these sections, a brief summary of the unit precedes the detailed description of the modules that are assessed within that unit.

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

- a summary of the topics
- opportunities for mathematics
- opportunities for practical work
- opportunities for ICT
- examples of Ideas about Science for which there are particular opportunities for introduction or development.

Following the module overview, the module content is presented in detail.

Within the detailed content of each module, 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 coverage required.*

3.3 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 Additional Science 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 directly, 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 the 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 Section 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 Section, 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 Additional Science 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.

How are Ideas about Science assessed?

All Ideas about Science can be assessed in all units of assessment. Those that will only be assessed in Higher Tier papers are indicated in **bold**.

In order to assist with curriculum planning, Ideas about Science that could be linked to each module are suggested in the overview of each module (see Sections 3.4, 3.5 and 3.6). Taking all of the modules together, suggested links to **all** of the Ideas about Science are identified in this way. However, it is not intended that understanding and application of the Ideas about Science should be limited to any particular context, so these links are provided as suggestions only. There is freedom to develop links between modules and the Ideas about Science in any way, providing that all have been covered prior to assessment.

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 (e.g. 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 the 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.

3.4 Summary of Unit A162: *Biology A* Modules B4, B5, B6

Unit A162 is the unit within GCSE Additional Science A where the biology content is assessed. It assesses the content of *Modules B4, B5 and B6* together with the Ideas about Science.

3.4.1 Module B4: The processes of life

Overview

Biological processes that take place in cells involve chemical reactions catalysed by enzymes. Photosynthesis and respiration are examples of these processes, and these reactions take place in specialised structures within cells. The conditions for optimum enzyme action require temperature and pH to be controlled. Anaerobic respiration of microorganisms and yeast provides humans with useful products, including biogas, bread and alcohol.

The first topic considers some of the most fundamental chemical reactions that occur within cells and highlights the crucial role that enzymes play in these processes. The highly specific nature of enzymes is explored, along with sensitivity of enzymes to their environment. The lock and key model provides an accessible example of how models and analogy can enhance understanding of scientific processes.

The second topic focuses in more detail on photosynthesis and the processes plants utilise to take in and transport water and nutrients, necessary to produce the complex molecules required for plant growth.

The processes of plant growth are also fundamental to providing the glucose and complex sugars that many animal and microbial life forms depend upon for respiration. Respiration is explored in more detail in the third topic.

Topics
B4.1 How do chemical reactions take place in living things?
Reactions in cells Role of enzymes
B4.2 How do plants make food?
Photosynthesis Cell structures for photosynthesis Limiting factors
B4.3 How do living organisms obtain energy?
Aerobic respiration Anaerobic respiration Cell structures for respiration

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 using fractions and percentages
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use ideas about correlation.

Opportunities for practical work

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

- investigate how seed beetles are able to sense their surroundings
- investigate the effects of an enzyme on biological processes
- investigate the factors affecting photosynthesis
- use microscopes to look carefully at the structure of leaves
- investigate rates of diffusion in different media
- investigate the effect of solute concentration on potato cell water balance
- use soil tests to compare soils and composts
- use field work to investigate factors affecting the species of plants in different environmental conditions
- investigate the energy content of different foods
- use data logging to track temperature changes during respiration in peas
- investigate anaerobic respiration in yeast.

Opportunities for ICT

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

- molecular modelling to develop explanations of enzyme action.

Use of ICT in teaching and learning can include:

- animations to explain enzyme action and the effect of temperature on enzyme activity
- animations of diffusion, osmosis and active transport.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.1, 2.2

Module B4: The processes of life

B4.1 How do chemical reactions take place in living things?

1. understand that the basic processes of life carried out by all living things depend on chemical reactions within cells that require energy released by respiration
2. understand the role of photosynthesis in making food molecules and energy available to living organisms through food chains
3. describe photosynthesis as a series of chemical reactions that use energy from sunlight to build large food molecules in plant cells and some microorganisms (e.g. phytoplankton)
4. describe respiration as a series of chemical reactions that release energy by breaking down large food molecules in all living cells
5. recall that enzymes are proteins that speed up chemical reactions
6. recall that cells make enzymes according to the instructions carried in genes
7. understand that molecules have to be the correct shape to fit into the active site of the enzyme (the lock and key model)
8. understand that enzymes need a specific constant temperature to work at their optimum, and that they permanently stop working **(denature)** if the temperature is too high
9. **explain that enzyme activity at different temperatures is a balance between:**
    a. **increased rates of reaction as temperature increases**
    b. **changes to the active site at higher temperatures, including denaturing**

    ⓘ *Candidates are not expected to explain why rates of reaction increase with temperature*
10. recall that an enzyme works at its optimum at a specific pH
11. **explain the effect of pH on enzyme activity in terms of changes to the shape of the active site.**

Module B4: The processes of life

B4.2 How do plants make food?

1. recall the names of the reactants and products of photosynthesis, and use the word equation:

   light energy
   carbon dioxide + water → glucose + oxygen

2. recall the formulae of the reactants and products of photosynthesis, and use the symbol equation:

   light energy
   $$6CO_2 + 6H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + 6O_2$$

3. recall the main stages of photosynthesis:
   a. light energy absorbed by the green chemical chlorophyll
   b. energy used to bring about the reaction between carbon dioxide and water to produce glucose (a sugar)
   c. oxygen produced as a waste product
4. recall that glucose may be:
   a. converted into chemicals needed for growth of plant cells, for example cellulose, protein and chlorophyll
   b. converted into starch for storage
   c. used in respiration to release energy
5. recall the structure of a typical plant cell, limited to chloroplasts, cell membrane, nucleus, cytoplasm, mitochondria, vacuole and cell wall
6. understand the functions of the structures in a typical plant cell that have a role in photosynthesis, including:
   a. chloroplasts contain chlorophyll and the enzymes for the reactions in photosynthesis
   b. cell membrane allows gases and water to pass in and out of the cell freely while presenting a barrier to other chemicals
   c. nucleus contains DNA which carries the genetic code for making enzymes and other proteins used in the chemical reactions of photosynthesis
   d. cytoplasm where the enzymes and other proteins are made
7. recall that minerals taken up by plant roots are used to make some chemicals needed by cells, including nitrogen from nitrates to make proteins
8. understand that diffusion is the passive overall movement of molecules from a region of their higher concentration to a region of their lower concentration
9. recall that the movement of oxygen and carbon dioxide in and out of leaves during photosynthesis occurs by diffusion
10. understand that osmosis (a specific case of diffusion) is the overall movement of water from a dilute to a more concentrated solution through a partially permeable membrane
11. recall that the movement of water into plant roots occurs by osmosis
12. **understand that active transport is the overall movement of chemicals across a cell membrane requiring energy from respiration**
13. **recall that active transport is used in the absorption of nitrates by plant roots**

B4.2 How do plants make food?

14. understand that the rate of photosynthesis may be limited by:
    a. temperature
    b. carbon dioxide
    c. light intensity
15. interpret data on factors limiting the rate of photosynthesis
16. describe and explain techniques used in fieldwork to investigate the effect of light on plants, including:
    a. using a light meter
    b. using a quadrat
    c. using an identification key
17. understand how to take a transect.

Module B4: The processes of life

B4.3 How do living organisms obtain energy?

1. understand that all living organisms require energy released by respiration for some chemical reactions in cells, including chemical reactions involved in:
   a. movement
   b. synthesis of large molecules
   c. active transport
2. understand that synthesis of large molecules includes:
   a. synthesis of polymers required by plant cells such as starch and cellulose from glucose in plant cells
   b. synthesis of amino acids from glucose and nitrates, and then proteins from amino acids in plant, animal and microbial cells
3. recall that aerobic respiration takes place in animal and plant cells and some microorganisms, and requires oxygen
4. recall the names of the reactants and products of aerobic respiration and use the word equation:
   glucose + oxygen → carbon dioxide + water (+ energy released)
5. **recall the formulae of the reactants and products of aerobic respiration and use the symbol equation:**
   $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
6. recall that anaerobic respiration takes place in animal, plant and some microbial cells in conditions of low oxygen or absence of oxygen, to include:
   a. plant roots in waterlogged soil
   b. bacteria in puncture wounds
   c. human cells during vigorous exercise
7. recall the names of the reactants and products of anaerobic respiration in animal cells and some bacteria, and use the word equation:
   glucose → lactic acid (+ energy released)
8. recall the names of the reactants and products of anaerobic respiration in plant cells and some microorganisms including yeast, and use the word equation:
   glucose → ethanol + carbon dioxide (+ energy released)
9. understand that aerobic respiration releases more energy per glucose molecule than anaerobic respiration
10. recall the structure of typical animal and microbial cells (bacteria and yeast) limited to:
   a. nucleus
   b. cytoplasm
   c. cell membrane
   d. mitochondria (for animal and yeast cells)
   e. cell wall (for yeast and bacterial cells)
   f. circular DNA molecule (for bacterial cells)

B4.3	How do living organisms obtain energy?
11.	understand the functions of the structures in animal, plant, bacteria and yeast cells that have a role in respiration, including:
	a. mitochondria contain enzymes for the reactions in aerobic respiration (in animals, plants and yeast)
	b. cell membrane allows gases and water to pass in and out of the cell freely while presenting a barrier to other chemicals
	c. nucleus or circular DNA in bacteria contains DNA which carries the genetic code for making enzymes used in the chemical reactions of respiration
	d. cytoplasm where enzymes are made and which contains the enzymes used in anaerobic respiration
12.	describe examples of the applications of the anaerobic respiration of microorganisms, including the production of biogas and fermentation in bread making and alcohol production.

3.4.2 Module B5: Growth and development

Overview

Genetic technologies are at the cutting edge of contemporary science. Research into proteomics, stem cell technology and cellular growth control is at the forefront of modern medical science. Knowledge and understanding of these areas promise powerful applications to benefit both present and future generations.

The first topic explains plant and animal development, comparing and contrasting the development of unspecialised cells. The ability of plant meristems to regenerate whole plants is considered, including the effect of plant hormones on their development.

The second topic looks at how the structure of DNA allows cells to be accurately copied. Key stages in the cell cycle are identified, and cell division by mitosis and meiosis compared.

The final topic describes the process of protein synthesis, following the one-gene-one-protein hypothesis.

Topics
B5.1 How do organisms develop?
Embryo development; cell specialisation in plants and animals; plant growth responses
B5.2 How does an organism produce new cells?
Main processes of the cell cycle; comparisons of mitosis and meiosis
B5.3 How do genes control growth and development within the cell?
Structure of genetic code and mechanism for protein synthesis

Opportunities for mathematics

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

- develop a sense of scale in the context of DNA, cells and plants
- carry out calculations using fractions and percentages
- plot, draw and interpret graphs and charts from candidates' own and secondary data.

Opportunities for practical work

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

- use microscopes to look at a variety of plant and animal cells
- dissect and draw a broad bean
- take plant cuttings and investigate the effects of using hormone rooting powder
- investigate the effects of phototropism
- view germinating pollen
- extract DNA from plants.

Opportunities for ICT

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

- imaging cells and observing their growth and development.

Use of ICT in teaching and learning can include:

- animations to illustrate DNA structure, replication, and protein synthesis
- animations to illustrate cell division
- video clips to show stages in human development.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

IaS 3.1 – 3.4

Module B5: Growth and development

B5.1 How do organisms develop?

1. recall that cells in multicellular organisms can be specialised to do particular jobs
2. recall that groups of specialised cells are called tissues, and groups of tissues form organs
3. recall that a fertilised egg cell (zygote) divides by mitosis to form an embryo
4. recall that in a human embryo up to (and including) the eight cell stage, all the cells are identical (embryonic stem cells) and could produce any type of cell required by the organism
5. understand that after the eight cell stage, most of the embryo cells become specialised and form different types of tissue
6. understand that some cells (adult stem cells) remain unspecialised and can become specialised, at a later stage, to become many, but not all, types of cell required by the organism
7. understand that in plants, only cells within special regions called meristems are mitotically active
8. understand that the new cells produced from plant meristems are unspecialised and can develop into any kind of plant cell
9. understand that unspecialised plant cells can become specialised to form different types of tissue (including xylem and phloem) within organs (including flowers, leaves, stems and roots)
10. understand that the presence of meristems (as sources of unspecialised cells) allows the production of clones of a plant from cuttings, and that this may be done to reproduce a plant with desirable features
11. understand that a cut stem from a plant can develop roots and then grow into a complete plant which is a clone of the parent, and that rooting can be promoted by the presence of plant hormones **(auxins)**
12. understand that the growth and development of plants is also affected by the environment, e.g. phototropism
13. understand how phototropism increases the plant's chance of survival
14. **explain phototropism in terms of the effect of light on the distribution of auxin in a shoot tip.**

Module B5: Growth and development

B5.2 How does an organism produce new cells?

1. recall that cell division by mitosis produces two new cells that are genetically identical to each other and to the parent cell
2. describe the main processes of the cell cycle:
   a. cell growth during which:
      - numbers of organelles increase
      - the chromosomes are copied when the two strands of each DNA molecule separate and new strands form alongside them

   b. mitosis during which:
      - copies of the chromosomes separate
      - the nucleus divides

   ⓘ *Candidates are not expected to recall intermediate stages of mitosis*
3. recall that meiosis is a type of cell division that produces gametes
4. understand why, in meiosis, it is important that the cells produced only contain half the chromosome number of the parent cell

   ⓘ *Candidates are not expected to recall intermediate stages of meiosis*
5. understand that a zygote contains a set of chromosomes from each parent.

Module B5: Growth and development

B5.3 How do genes control growth and development within the cell?

1. recall that DNA has a double helix structure
2. recall that both strands of the DNA molecule are made up of four different bases which always pair up in the same way: A with T, and C with G
3. understand that the order of bases in a gene is the genetic code for the production of a protein
4. **explain how the order of bases in a gene is the code for building up amino acids in the correct order to make a particular protein**

   ⓘ *Candidates are not expected to recall details of nucleotide structure, transcription or translation*
5. recall that the genetic code is in the cell nucleus of animal and plant cells but proteins are produced in the cell cytoplasm
6. understand that genes do not leave the nucleus but a copy of the gene **(messenger RNA)** is produced to carry the genetic code to the cytoplasm
7. understand that although all body cells in an organism contain the same genes, many genes in a particular cell are not active (switched off) because the cell only produces the specific proteins it needs
8. understand that in specialised cells only the genes needed for the cell can be switched on, but in embryonic stem cells any gene can be switched on during development to produce any type of specialised cell
9. understand that adult stem cells and embryonic stem cells have the potential to produce cells needed to replace damaged tissues
10. understand that ethical decisions need to be taken when using embryonic stem cells and that this work is subject to Government regulation
11. **understand that, in carefully controlled conditions of mammalian cloning, it is possible to reactivate (switch on) inactive genes in the nucleus of a body cell to form cells of all tissue types.**

3.4.3 Module B6: Brain and mind

Overview

How the human brain functions remains largely unknown. Neuroscience is an area at the frontier of medical research, and has huge potential impact for an ageing population.

This module begins by looking at how, in order to survive, simple organisms respond to changes in their environment. The nervous system of multicellular animals is also considered.

The second topic considers how information is transmitted from receptor cells to effector cells, including a simple description of chemical transmission across synapses. The effects of drugs on synapses in the brain are explored (for example, Ecstasy).

Simple, conditioned and modified reflexes are introduced in the third topic, with reference to survival and adaptation.

The fourth topic takes a closer look at the brain, and how some neuron pathways become ‘preferred’ while other potential pathways remain available to allow for adaptation to new situations. This topic illustrates specialised areas of the brain, identifies methods scientists have used to map the cerebral cortex and introduces a basic understanding of memory.

Topics	
B6.1	How do animals respond to changes in their environment?
Co-ordination of responses to stimuli via the central nervous system	
B6.2	How is information passed through the nervous system?
Structure of neurons; transmission of electrical impulses, including synapses; effects of Ecstasy on synapse action	
B6.3	What can we learn through conditioning?
Simple reflex actions for survival; mechanism of a reflex arc; conditioned reflexes	
B6.4	How do humans develop more complex behaviour?
Formation of neuron pathways and learning through repetition; mapping brain function; models for understanding memory	

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
- plot, draw and interpret graphs and charts from candidates’ own and secondary data.

Opportunities for practical work

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

- investigate reflex behaviour of woodlice
- look at microscope slides of neurons
- research reflex behaviour in newborn babies and in other animals
- investigate receptor cells on the tongue
- measure the speed at which a nerve impulse travels
- investigate factors that affect reaction times
- measure the touch sensitivity of different areas of the body
- make a presentation about Pavlov and his work on conditioned reflexes
- investigate how practice of a skill improves performance
- investigate pupils' own learning
- investigate whether woodlice have a memory.

Opportunities for ICT

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

- observe and digitally record human and animal behaviour
- log, record and display physiological data.

Use of ICT in teaching and learning can include:

- video clips to illustrate patterns in the behaviour of living things
- animations to explain synapse function and the effects of drugs on synapses
- interactive animations on brain function
- using the internet to research behaviour and memory.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Making decisions about science and technology

IaS 6.5, 6.6

Module B6: Brain and mind

B6.1 How do animals respond to changes in their environment?

1. recall that a stimulus is a change in the environment of an organism
2. understand that simple reflexes produce rapid involuntary responses to stimuli
3. understand that the simplest animals rely on reflex actions for the majority of their behaviour
4. understand that these reflex actions help to ensure that the simplest animals respond to a stimulus in a way that is most likely to result in their survival, to include finding food and sheltering from predators
5. recall examples of simple reflexes in humans, to include newborn reflexes (e.g. stepping, grasping, sucking), pupil reflex, knee jerk and dropping a hot object
6. understand that nervous co-ordination, including simple reflexes, requires:
   a. receptors to detect stimuli
   b. processing centres to receive information and coordinate responses
   c. effectors to produce the response
7. understand that receptors and effectors can form part of complex organs, for example:
   a. light receptor cells in the retina of the eye
   b. hormone secreting cells in a gland
   c. muscle cells in a muscle
8. understand that nervous systems use electrical impulses for fast, short-lived responses including simple reflexes
9. recall that hormones are chemicals that are produced in glands, travel in the blood and bring about slower, longer-lasting responses, e.g. insulin and oestrogen
10. recall that the development of nervous and hormonal communication systems depended on the evolution of multicellular organisms.

Module B6: Brain and mind

B6.2 How is information passed through the nervous system?

1. recall that nervous systems are made up of neurons (nerve cells) linking receptor cells (e.g. in eyes, ears and skin) to effector cells (in muscles/glands)
2. recall that neurons transmit electrical impulses when stimulated
3. recall that an axon is a long extension of the cytoplasm in a neuron and is surrounded by a cell membrane
4. understand that some axons are surrounded by a fatty sheath, which insulates the neuron from neighbouring cells and increases the speed of transmission of a nerve impulse
5. recall that in humans and other vertebrates the central nervous system (CNS) is made up of the spinal cord and brain
6. recall that in the mammalian nervous system the CNS (brain and spinal cord) is connected to the body via the peripheral nervous system (PNS) (sensory and motor neurons)
7. understand that the CNS coordinates an animal's responses via:
   a. sensory neurons carrying impulses from receptors to the CNS
   b. motor neurons carrying impulses from the CNS to effectors
8. understand that within the CNS, impulses are passed from sensory neurons to motor neurons through relay neurons
9. describe the nervous pathway of a spinal reflex arc to include receptor, sensory neuron, relay neuron, spinal cord, motor neuron and effector
10. **understand that this arrangement of neurons into a fixed pathway allows reflex responses to be automatic and so very rapid, since no processing of information is required**
11. recall that there are gaps between adjacent neurons called synapses and that impulses are transmitted across them
12. **understand that at a synapse an impulse triggers the release of chemicals (transmitter substances) from the first neuron into the synapse, which diffuse across and bind to receptor molecules on the membrane of the next neuron**
13. **understand that only specific chemicals bind to the receptor molecules, initiating a nerve impulse in the next neuron**
14. recall that some toxins and drugs, including Ecstasy, beta blockers and Prozac, affect the transmission of impulses across synapses
15. **understand that Ecstasy (MDMA) blocks the sites in the brain's synapses where the transmitter substance, serotonin, is removed**
16. **understand that the effects of Ecstasy on the nervous system are due to the subsequent increase in serotonin concentration**
17. recall that the cerebral cortex is the part of our brain most concerned with intelligence, memory, language and consciousness
18. understand that scientists can map the regions of the brain to particular functions (including studies of patients with brain damage, studies in which different parts of the brain are stimulated electrically, and brain scans such as MRI, showing brain structure and activity).

Module B6: Brain and mind

B6.3 Can reflex responses be learned?

1. understand that a reflex response to a new stimulus can be learned by introducing the secondary (new) stimulus in association with the primary stimulus, and that this is called conditioning
2. describe and explain two examples of conditioning, including Pavlov’s dogs
3. **understand that in a conditioned reflex the final response (e.g. salivation) has no direct connection to the secondary stimulus (e.g. ringing of a bell)**
4. **understand that conditioned reflexes are a form of simple learning that can increase an animal’s chance of survival**
5. **recall that in some circumstances the brain can modify a reflex response via a neuron to the motor neuron of the reflex arc, for example keeping hold of a hot object.**

Module B6: Brain and mind

B6.4 How do humans develop more complex behaviour?

1. understand that the evolution of a larger brain gave early humans a better chance of survival
2. recall that mammals have a complex brain of billions of neurons that allows learning by experience, including social behaviour
3. understand that during development the interaction between mammals and their environment results in neuron pathways forming in the brain
4. understand that learning is the result of experience where:
    a. certain pathways in the brain become more likely to transmit impulses than others
    b. new neuron pathways form and other neuron pathways are lost
5. understand that this is why some skills may be learnt through repetition
6. **understand that the variety of potential pathways in the brain makes it possible for the animal to adapt to new situations**
7. **understand the implications of evidence suggesting that children may only acquire some skills at a particular age, to include language development in feral children**
8. describe memory as the storage and retrieval of information
9. recall that memory can be divided into short-term memory and long-term memory
10. understand that humans are more likely to remember information if:
    a. they can see a pattern in it (or impose a pattern on it)
    b. there is repetition of the information, especially over an extended period of time
    c. there is a strong stimulus associated with it, including colour, light, smell, or sound
11. understand how models can be used to describe memory (including the multi-store model) to include short-term memory, long-term memory, repetition, storage, retrieval and forgetting
12. understand that models are limited in explaining how memory works.

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

Unit A172 is the unit within GCSE Additional Science A where the chemistry content is assessed. It assesses the content of *Modules C4, C5 and C6* together with Ideas about Science.

3.5.1 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.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

IaS 3.1 – 3.4

The scientific community

IaS 4.1 – 4.4

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, toxic, corrosive, oxidizing, and highly flammable)

    ⓘ *See Appendix H for guidance on recent changes to hazard labelling*
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
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

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

3.5.2 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.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

IaS 3.1, 3.2

Risk

IaS 5.1

Making decisions about science and technology

IaS 6.1, 6.2, 6.5, 6.6

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
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)

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

3.5.3 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.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.1 – 2.3, 2.6, **2.7**

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, toxic, corrosive, oxidizing, and highly flammable)

   ⓘ *See Appendix H for guidance on recent changes to hazard labelling*
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
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

C6.1	Chemicals and why we need them
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’
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*

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

3.6 Summary of Unit A182: *Physics A Modules P4, P5, P6*

Unit A182 is the unit within GCSE Additional Science A where the physics content is assessed. It assesses the content of *Modules P4, P5 and P6* together with the Ideas about Science.

3.6.1 Module P4: Explaining motion

Overview

Simple but counterintuitive concepts of forces and motion, developed by Galileo and Newton, can transform young people's insight into everyday phenomena. These ideas also underpin an enormous range of modern applications, including spacecraft, urban mass transit systems, sports equipment and rides at theme parks.

This module starts by looking at how speed is measured and represented graphically and the idea of velocity (as distinct from speed).

The second topic introduces the idea of forces: identifying, describing and using forces to explain simple situations. This is further developed in the third topic where resultant forces and changes in momentum are described.

The final topic considers how we can explain motion in terms of energy changes.

Topics	
P4.1	How can we describe motion?
Calculation of speed	
Velocity	
Acceleration	
Graphical representations of speed and velocity	
P4.2	What are forces?
The identification of forces and 'partner' forces	
P4.3	What is the connection between forces and motion?
Resultant forces and change in momentum	
Relating momentum to road safety measures	
P4.4	How can we describe motion in terms of energy changes?
Work done	
Changes in energy	
GPE and KE	
Losses due to air resistance and friction	

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
- use ideas of proportion
- plot, draw and interpret graphs from candidates' own and secondary data
- use equations, including appropriate units for physical quantities
- 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:

- use data logging to investigate motion
- investigate the behaviour of colliding and 'exploding' objects
- investigate the effect of different combinations of surfaces on the frictional forces
- investigate the motion of objects in free fall and the effects of air resistance.

Opportunities for ICT

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

- computer programs that control the motion of spacecraft
- use of computers for collecting, storing and displaying data on forces in simulated vehicle collisions
- computer-enhanced use of radar to predict flight paths of aircraft.

Use of ICT in teaching and learning can include:

- video clips to provide contexts for learning about forces and motion
- animations to illustrate interactive force pairs in various situations
- animations to show the meaning of distance-time and other graphs
- sensors and data loggers to collect measurements of movement for analysis
- modelling software to analyse motion.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.1 – 2.6, **2.7**

Developing scientific explanations

IaS 3.1 – 3.4

Module P4: Explaining motion

P4.1 How can we describe motion?

1. apply the following equation to situations where an average speed is involved:

$$\text{speed (m/s)} = \frac{\text{distance travelled (m)}}{\text{time taken (s)}}$$

2. distinguish between average speed and instantaneous speed (in effect, an average over a short time interval) for examples of motion where speed is changing
3. **understand that the displacement of an object at a given moment is its net distance from its starting point together with an indication of direction**
4. draw and interpret a distance-time **(or displacement-time)** graph for an object that is:
   a. stationary
   b. moving at constant speed
   c. moving with increasing or decreasing speed
5. interpret a steeper gradient of a distance-time graph as a higher speed
6. **calculate a speed from the gradient of a straight section of a distance-time graph**
7. draw and interpret a speed-time graph for an object that is:
   a. stationary
   b. moving in a straight line with constant speed
   c. moving in a straight line with steadily increasing or decreasing speed (but no change of direction)
8. understand that in many everyday situations, acceleration is used to mean the change in speed of an object in a given time interval
9. recall that the instantaneous velocity of an object is its instantaneous speed together with an indication of the direction
10. **understand that the velocity of an object moving in a straight line is positive if it is moving in one direction and negative if it is moving in the opposite direction**
11. **draw and interpret a velocity-time graph for an object that is:**
    a. stationary
    b. moving in a straight line with constant speed
    c. moving in a straight line with steadily increasing or decreasing speed (including situations involving a change of direction)
12. **calculate the acceleration from the gradient of a velocity–time graph (or from a speed-time graph in situations where direction of motion is constant)**
13. calculate acceleration using the equation:

$$\text{acceleration (m/s}^2\text{)} = \frac{\text{change in velocity (m/s)}}{\text{time taken (s)}}$$

Module P4: Explaining motion

P4.2 What are forces?

1. recall that a force arises from an interaction between two objects
2. understand that when two objects interact, both always experience a force and that these two forces form an interaction pair
3. in simple everyday situations:
   a. identify forces arising from an interaction between two objects
   b. identify the 'partner' of a given force (i.e. the other force of the interaction pair)
   c. specify, for each force, the object which exerts it, and the object on which it acts
   d. use arrows to show the sizes and directions of forces acting
4. understand that the two forces in an interaction pair are equal in size and opposite in direction, and that they act on different objects
5. describe the interaction between two surfaces which slide (or tend to slide) relative to each other: each surface experiences a force in the direction that prevents (or tends to prevent) relative movement; this interaction is called friction
6. describe the interaction between an object and a horizontal surface it is resting on: the object pushes down on the surface, the surface pushes up on the object with an equal force, and this is called the reaction of the surface
7. recall that friction and the reaction of a surface arise in response to the action of an applied force, and their size matches the applied force up to a limit
8. use the ideas of friction and reaction to explain situations such as the driving force on vehicles **and walking**
9. use the idea of a pair of equal and opposite forces to explain in outline how rockets and jet engines produce a driving force.

Module P4: Explaining motion

P4.3 What is the connection between forces and motion?

1. interpret situations in which several forces act on an object
2. understand that the resultant force on an object is the sum of all the individual forces acting on it, taking their directions into account
3. understand that if a resultant force acts on an object, it causes a change of momentum in the direction of the force
4. use the definition:

momentum	=	mass	×	velocity
(kg m/s)		(kg)		(m/s)

5. understand that the size of the change of momentum of an object is proportional to the size of the resultant force acting on the object and to the time for which it acts:

change of momentum	=	resultant force	×	time for which it acts
(kg m/s)		(N)		(s)

6. understand how the horizontal motion of objects (like cars and bicycles) can be analysed in terms of a driving force (produced by the engine or the cyclist), and a counter force (due to friction and air resistance)
7. understand that for an object moving in a straight line, if the driving force is:
   a. greater than the counter force, the vehicle will speed up
   b. equal to the counter force, the vehicle will move at constant speed in a straight line
   c. smaller than the counter force, the vehicle will slow down
8. understand that, in situations involving a change in momentum (such as a collision), the longer the duration of the impact, the smaller the average force for a given change in momentum
9. use ideas about force and momentum to explain road safety measures, such as car seat-belts, crumple zones, air bags, and cycle and motorcycle helmets
10. understand how the vertical motion of objects (falling, or initially thrown upwards) can be analysed in terms of the forces acting (gravity, air resistance)
11. understand that, if the resultant force on an object is zero, its momentum does not change (if it is stationary, it stays at rest; if it is already moving, it continues at a constant velocity [a steady speed in a straight line]).

Module P4: Explaining motion

P4.4 How can we describe motion in terms of energy changes?

1. recall that the energy of a moving object is called its kinetic energy
2. recall that as an object is raised, its gravitational potential energy increases, and as it falls, its gravitational potential energy decreases
3. recall that when a force moves an object, it does work
4. use the equation:

   work done by a force (joules, J) = force (newtons, N) × distance moved in the direction of the force (metres, m)

5. understand that when work is done on an object, energy is transferred to the object and when work is done by an object, energy is transferred from the object to something else, according to the relationship:

   amount of energy transferred (joules, J) = work done (joules, J)

6. understand that when an object is lifted to a higher position above the ground, work is done by the lifting force; this increases the gravitational potential energy
7. use the equation:

   change in gravitational potential energy (joules, J) = weight (newtons, N) × vertical height difference (metres, m)

8. understand that when a force acting on an object makes its velocity increase, the force does work on the object and this results in an increase in its kinetic energy
9. understand that the greater the mass of an object and the faster it is moving, the greater its kinetic energy
10. use the equation:

    kinetic energy (joules, J) = ½ × mass (kilograms, kg) × $[\text{velocity}]^2$ ($[\text{metres per second}]^2$, $[\text{m/s}]^2$)

11. understand that if friction and air resistance can be ignored, an object's kinetic energy changes by an amount equal to the work done on it by an applied force
12. understand that air resistance or friction will cause the gain in an object's kinetic energy to be less than the work done on it by an applied force in the direction of motion, because some energy is dissipated through heating
13. recall that energy is always conserved in any event or process
14. calculate the gain in kinetic energy, **and the speed**, of an object that has fallen through a given height.

3.6.2 Module P5: Electric circuits

Overview

Known only by its effects, electricity provides an ideal vehicle to illustrate the use and power of scientific models. During the course of the 20th century, electrical engineers completely changed whole societies, by designing systems for electrical generation and distribution, and a whole range of electrical devices.

In this module, candidates learn how scientists visualise what is going on inside circuits and predict circuit behaviour. The idea of current as a flow of electrons is introduced in the first topic. In the second topic, useful models of charge moving through circuits driven by a voltage and against a resistance are introduced. A more general understanding of voltage as potential difference is developed in the third topic.

The concepts of current and voltage are further developed in the topic on generation of electricity. The final topic relates these concepts to power, and introduces the idea of efficiency of electrical appliances

ⓘ *Candidates will only be expected to consider situations in which the internal resistance of batteries or other electrical power supplies is negligible and can be ignored.*

Topics
P5.1 Electric current – a flow of what?
Electric current as a flow of charge
How the charge moves
P5.2 What determines the size of the current in an electric circuit and the energy it transfers?
Voltage
Current and resistance
Series and parallel circuits
P5.3 How do parallel and series circuits work?
Voltage and how it behaves in a series circuit
Current and how it behaves in a parallel circuit
P5.4 How is mains electricity produced? How are voltages and currents induced?
How generators work
Transformers
Alternating current and direct current
P5.5 How do electric motors work?
How motors work and some uses

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 using fractions and percentages
- use ideas of proportion
- use ideas of ratios in the context of transformers
- use equations, including appropriate units for physical quantities
- plot, draw and interpret graphs from candidates' own and secondary data
- 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:

- investigating the behaviour of electric circuits
- making both model generators and motors and investigating factors affecting their behaviour
- investigating the behaviour of transformers.

Opportunities for ICT

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

- studying electric fields between charged particles and surfaces
- using computer simulations to construct virtual circuits and test their behaviour.

Use of ICT in teaching and learning can include:

- modelling software to explore electric circuit theory
- animations to illustrate models of electric current as flowing charges.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.1 – 2.6, **2.7**

Module P5: Electric circuits

P5.1 Electric current – a flow of what?

1. explain that when two objects are rubbed together they become charged, because electrons are transferred from one object to the other
2. recall that objects with similar charges repel, and objects with opposite charges attract
3. explain simple electrostatic effects in terms of attraction and repulsion of charges
4. recall that electrons are negatively charged
5. recall that electric current is a flow of charge
6. recall that electric current is measured in amperes
7. understand that in an electric circuit the metal conductors (the components and wires) contain many charges that are free to move
8. understand that when a circuit is made, the battery causes these free charges to move, and that they are not used up but flow in a continuous loop
9. recall that in metallic conductors an electric current is a movement of free electrons that are present throughout such materials
10. understand that in metal conductors there are lots of charges free to move but in an insulator there are few charges free to move.
11. describe how an ammeter should be connected in a circuit to measure the flow of current at a chosen point.

Module P5: Electric circuits

P5.2 What determines the size of the current in an electric circuit and the energy it transfers?

1. recall that the larger the voltage of the battery in a given circuit, the bigger the current
2. recall that components (for example, resistors, lamps, motors) resist the flow of charge through them
3. recall that the larger the resistance in a given circuit, the smaller the current will be
4. recall that the resistance of connecting wires is so small that it can usually be ignored
5. understand that when electric charge flows through a component (or device), work is done by the power supply, and energy is transferred from it to the component and/or its surroundings
6. recall that power (in watts, W) is a measure of the rate at which an electrical power supply transfers energy to an appliance or device and/or its surroundings
7. use the equation:

   $$\underset{\text{(watts, W)}}{\text{power}} = \underset{\text{(volts, V)}}{\text{voltage}} \times \underset{\text{(amperes, A)}}{\text{current}}$$

8. recall that resistors get hotter when there is an electric current through them, **and understand that this heating effect is caused by collisions between the moving charges and stationary ions in the wire**
9. recall that this heating effect makes a lamp filament hot enough to glow
10. describe how the resistance of an LDR varies with light intensity
11. describe how the resistance of a thermistor (ntc only) varies with temperature
12. recognise and use the electrical symbols for a cell, power supply, filament lamp, switch, LDR, fixed and variable resistor, thermistor, ammeter and voltmeter
13. understand that two (or more) resistors in series have more resistance than either one on its own, because the battery has to move charges through both of them
14. understand that two (or more) resistors in parallel provide more paths for charges to move along than either resistor on its own, so the total resistance is less
15. use the equation:

   $$\text{resistance (ohms, }\Omega) = \frac{\text{voltage (volts, V)}}{\text{current (amperes, A)}}$$

16. describe in words, or using a sketch graph, how the current through a component varies with voltage across it when the resistance stays constant.

Module P5: Electric circuits

P5.3 How do parallel and series circuits work?

1. describe how a voltmeter should be connected to measure the potential difference between any two chosen points
2. recall that the voltage across a battery (measured in V) provides a measure of the 'push' of the battery on the charges in the circuit
3. recall that potential difference is another term for voltage
4. relate the potential difference between two points in the circuit to the work done on, or by, a given amount of charge as it moves between these points
5. describe the effect on potential difference and current of adding further identical batteries in series **and in parallel** with an original single one
6. understand that when two **(or more)** components are connected in series to a battery:
   a. the current through each component is the same
   b. the potential differences across the components add up to the potential difference across the battery **(because the work done on each unit of charge by the battery must equal the work done by it on the circuit components)**
   c. the potential difference is largest across the component with the greatest resistance, **because more work is done by the charge moving through a large resistance than through a small one**
   d. a change in the resistance of one component (variable resistor, LDR or thermistor) will result in a change in the potential differences across all the components
7. understand that when several components are connected in parallel directly to a battery:
   a. the potential difference across each component is equal to the potential difference of the battery
   b. the current through each component is the same as if it were the only component present
   c. the total current from (and back to) the battery is the sum of the currents through each of the parallel components
   d. the current is largest through the component with the smallest resistance, **because the same battery voltage causes a larger current to flow through a smaller resistance than through a bigger one.**

Module P5: Electric circuits

P5.4 How is mains electricity produced? How are voltages and currents induced?

1. recall that mains electricity is produced by generators
2. recall that generators produce a voltage by a process called electromagnetic induction
3. understand that when a magnet is moving into a coil of wire a voltage is induced across the ends of the coil
4. understand that if the magnet is moving out of the coil, or the other pole of the magnet is moving into it, there is a voltage induced in the opposite direction
5. understand that if the ends of the coil are connected to make a closed circuit, a current will flow round the circuit
6. understand that a changing magnetic field caused by changes in the current in one coil of wire can induce a voltage in a neighbouring coil
7. describe the construction of a transformer as two coils of wire wound on an iron core
8. **understand that a changing current in one coil of a transformer will cause a changing magnetic field in the iron core, which in turn will induce a changing potential difference across the other transformer coil**
9. recall that a transformer can change the size of an alternating voltage
10. **use the equation:**

$$\frac{\textbf{voltage across primary coil}}{\textbf{voltage across secondary coil}} = \frac{\textbf{number of turns in primary coil}}{\textbf{number of turns in secondary coil}}$$

11. describe how, in a generator, a magnet or electromagnet is rotated within a coil of wire to induce a voltage across the ends of the coil
12. understand that the size of this induced voltage can be increased by:
    a. increasing the speed of rotation of the magnet or electromagnet
    b. increasing the strength of its magnetic field
    c. increasing the number of turns on the coil
    d. placing an iron core inside the coil
13. **describe how the induced voltage across the coil of an a.c. generator (and hence the current in an external circuit) changes during each revolution of the magnet or electromagnet**
14. understand that when the current is always in the same direction, it is a direct current (d.c.), e.g. the current from a battery
15. recall that mains electricity is an a.c. supply
16. **understand that a.c. is used because it is easier to generate than d.c., and is easier and simpler to distribute over long distances**
17. recall that the mains domestic supply in the UK is 230 volts.

Module P5: Electric circuits

P5.5 How do electric motors work?

1. understand that a current-carrying wire or coil can exert a force on a permanent magnet, or on another current-carrying wire or coil nearby
2. understand that a current-carrying wire, if placed in a magnetic field whose lines of force are at right-angles to the wire, experiences a force at right angles to both the current direction and the lines of force of the field
3. recall that a current-carrying wire that is parallel to the lines of force of a magnetic field experiences no force
4. explain how the motor effect can result in a turning force on a rectangular current-carrying coil placed in a uniform magnetic field
5. understand that the motor effect can be used to produce continuous rotation of the coil, by using a commutator to ensure that the direction of the current in the coil is reversed at an appropriate point in each revolution
6. explain the role and use of motors in devices including domestic appliances, hard disc drives, DVD players and electric motor vehicles.

3.6.3 Module P6: Radioactive materials

Overview

The terms ‘radiation’ and ‘radioactivity’ are often interchangeable in the public mind. Because of its invisibility, radiation is commonly feared. A more objective evaluation of risks and benefits is encouraged through developing an understanding of the many practical uses of radioactive materials.

The module begins by considering the evidence of a nuclear model of the atom, including Rutherford’s alpha particle scattering experiment. This topic then uses ideas about fusion and nuclear energy to introduce Einstein’s equation. The properties of alpha, beta and gamma radiation are investigated and ideas about half-life are developed.

The properties of ionising radiation lead to a consideration of some of its many uses and also risks, including nuclear fission.

Through the use of radioactive material in the health sector, candidates learn about its harmful effect on living cells and how it can be handled safely. In the context of health risks associated with irradiation and/or contamination by radioactive material, they also learn about the interpretation of data on risk.

Topics
P6.1 Why are some materials radioactive?
Structure of the atom
Nuclear fusion
Alpha, beta and gamma radiation
Half-life
P6.2 How can radioactive materials be used and handled safely, including wastes?
Background radiation
Uses of radiation
Nuclear fission and nuclear power stations

Opportunities for mathematics

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

- develop a sense of scale in the context of the size of the constituents of an atom
- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations using fractions in half-life calculations
- plot, draw and interpret graphs and charts from candidates’ own and secondary data
- 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:

- investigations of the properties of ionising radiations
- half-life of radioactive materials
- modelling half-life, using ICT or dice throwing.

Opportunities for ICT

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

- computer tomography used with gamma imaging
- the role of computers in remote handling of highly radioactive waste.

Use of ICT in teaching and learning can include:

- data logging to show decay of protactinium
- animations to illustrate atomic structure and decay
- video clips to illustrate key ideas of risk in the context of radioactive materials
- animations to illustrate key processes in power stations.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

IaS 1.1 – 1.6

Cause-effect explanations

IaS 2.1 – 2.6, **2.7**

Risk

IaS 5.1 – 5.5, **5.6**, 5.7

Making decisions about science and technology

IaS 6.1, 6.3, 6.4

Module P6: Radioactive materials

P6.1 Why are some materials radioactive?

1. recall that some elements emit ionising radiation all the time and are called radioactive
2. understand that radioactive elements are naturally found in the environment, contributing to background radiation
3. understand that an atom has a nucleus, made of protons and neutrons, which is surrounded by electrons
4. understand that the results of the Rutherford-Geiger-Marsden alpha particle scattering experiment provided evidence that a gold atom contains a small, massive, positive region (the nucleus)
5. **understand that protons and neutrons are held together in the nucleus by a strong force which balances the repulsive electrostatic force between the protons**
6. understand that, if brought close enough together, hydrogen nuclei can fuse into helium nuclei releasing energy, and that this is called nuclear fusion
7. **understand that Einstein's equation $E = mc^2$ is used to calculate the energy released during nuclear fusion and fission (where E is the energy produced, m is the mass lost and c is the speed of light in a vacuum)**

   energy = mass × [speed]^2
   (joules, J) (kilograms, kg) ([metres per second]^2, [m/s]^2)
8. **understand that every atom of any element has the same number of protons but the number of neutrons may differ, and that forms of the same element with different numbers of neutrons are called isotopes**
9. understand that the behaviour of radioactive materials cannot be changed by chemical or physical processes
10. recall that three types of ionising radiation (alpha, beta and gamma) are emitted by radioactive materials **and that alpha particles consist of two protons and two neutrons, and that beta particles are identical to electrons**
11. recall the penetration properties of each type of radiation
12. **describe radioactive materials in terms of the instability of the nucleus, radiation emitted and the element left behind**
13. **complete nuclear equations for alpha and beta decay**
14. understand that, over time, the activity of radioactive sources decreases
15. understand the meaning of the term half-life
16. understand that radioactive elements have a wide range of half-life values
17. **carry out simple calculations involving half-life.**

Module P6: Radioactive materials

P6.2 How can radioactive materials be used and handled safely, including wastes?

1. understand that ionising radiation can damage living cells and these may be killed or may become cancerous
2. understand that ionising radiation is able to break molecules into bits (called ions), **which can then take part in other chemical reactions**
3. recall **and explain** how ionising radiation can be used:
    a. to treat cancer
    b. to sterilise surgical instruments
    c. to sterilise food
    d. as a tracer in the body
4. recall that radiation dose (in sieverts) (based on both amount and type of radiation) is a measure of the possible harm done to your body
5. interpret given data on risk related to radiation dose
6. understand that radioactive materials expose people to risk by irradiation and contamination
7. understand that we are irradiated and contaminated by radioactive materials all the time and recall the main sources of this background radiation
8. relate ideas about half-life and background radiation to the time taken for a radioactive source to become safe
9. recall categories of people who are regularly exposed to risk of radiation and that their exposure is carefully monitored, including radiographers and workers in nuclear power stations
10. understand that a nuclear fuel is one in which energy is released by changes in the nucleus
11. **know that in nuclear fission, a neutron splits a large and unstable nucleus (limited to uranium and plutonium) into two smaller parts, roughly equal in size, releasing more neutrons**
12. recall that the amount of energy released during nuclear fission is much greater than that released in a chemical reaction involving a similar mass of material
13. **understand how the nuclear fission process in nuclear power stations is controlled, and use the terms chain reaction, fuel rod, control rod and coolant**
14. understand that nuclear power stations produce radioactive waste
15. understand that nuclear wastes are categorised as high level, intermediate level and low level, and relate this to disposal methods.

Assessment of GCSE Additional Science A

4.1 Overview of the assessment in GCSE Additional Science A

For GCSE Additional Science A candidates must take units A162, A172, A182 and A154.B

GCSE Additional Science A J242	
Unit A162: *Biology A Modules B4, B5, B6*	
25% of the total GCSE 1 hour written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses *Modules B4, B5 and B6* • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A172: *Chemistry A Modules C4, C5, C6*	
25% of the total GCSE 1 hour 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 A182: *Physics A Modules P4, P5, P6*	
25% of the total GCSE 1 hour written paper 60 marks	This question paper: • is offered in Foundation and Higher Tiers • assesses *Modules P4, P5 and P6* • uses both objective style and free response questions (there is no choice of questions) • assesses the quality of written communication.
Unit A154: *Additional Science A Controlled assessment*	
25% of the total GCSE Controlled assessment Approximately 4.5–6 hours 64 marks	This unit: • comprises a Practical Investigation task • 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 A162, A172 and A182, candidates are entered for an option in either the Foundation Tier or the Higher Tier. Unit A154 (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, A162/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 science
AO2	Apply skills, knowledge and understanding of science 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 Additional Science A

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

Unit	% of GCSE			
	AO1	AO2	AO3	Total
Units A162, A172 and A182	30	34	11	75
Unit A154: 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.

Most GCSEs are unitised schemes. 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 mark 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, e.g. 60/100.

The specification is graded on a Uniform Mark Scale. The uniform mark thresholds 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% F	69	–	–	–	60	50	40	30	20	0
25% H	100	90	80	70	60	50	45	–	–	0
25%	100	90	80	70	60	50	40	30	20	0

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 graded as 'u'.

A candidate's uniform marks for each unit are aggregated and grades for the specification are generated on the following scale:

Qualification	Max Uniform Mark	Qualification Grade								
		A*	A	B	C	D	E	F	G	U
J242	400	360	320	280	240	200	160	120	80	0

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

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 their limited knowledge and understanding of science. They have a limited understanding that scientific advances may have ethical implications, benefits and risks. They recognise simple inter-relationships between science 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 and technological skills, knowledge and understanding in practical and some other contexts. They show limited understanding of the nature of science and its applications. They can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas.

Candidates interpret and evaluate some qualitative and quantitative data and information from a limited 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 science. They demonstrate understanding of the nature of science, its laws, its applications and the influences of society on science and science on society. They understand how 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 and technological skills, knowledge and understanding in a range of practical and other contexts. They recognise, understand and use straightforward links between hypotheses, evidence, theories, and explanations. They use models to explain phenomena, events and processes. Using appropriate methods, sources of information and data, they apply their skills to answer 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 develop arguments with supporting explanations. They draw conclusions consistent with the available evidence.

4.5.3 Grade A

Candidates recall, select and communicate precise knowledge and detailed understanding of science and its applications, and of the effects and risks of scientific developments and its applications on society, industry, the economy and the environment. They demonstrate a clear understanding of why and how scientific applications, technologies and techniques change over time and the need for regulation and monitoring. They use terminology and conventions appropriately and consistently.

They apply appropriate skills, including communication, mathematical and technological skills, knowledge and understanding effectively to a wide range of practical contexts and to explain applications of science. They apply a comprehensive understanding of practical methods, processes and protocols to plan and justify a range of appropriate methods to solve practical problems. They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding in a wide range of practical contexts. They follow procedures and protocols consistently, evaluating and managing risk and working accurately and safely.

Candidates analyse and interpret critically a broad range of quantitative and qualitative information. They reflect on the limitations of the methods, procedures and protocols they have used and the data they have collected and evaluate information systematically to develop reports and findings. They make reasoned judgements consistent with the evidence to develop substantiated conclusions.

4.6 Quality of written communication

Quality of written communication is assessed in all units and is integrated in 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 an appropriate style of writing and, where applicable, specialist terminology.

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

5 Controlled assessment in GCSE Additional Science 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 support can be found on the OCR website.

Teaching and Learning

Controlled assessment is designed to be an integral part of teaching and learning. There are many opportunities in teaching and learning to develop skills and use a variety of appropriate materials and equipment. These opportunities allow students to practise a wide range of tasks, and teachers can discuss and comment on performance as appropriate.

When all necessary teaching and learning has taken place and teachers feel that candidates are ready for assessment, candidates can be given the appropriate controlled assessment task.

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 six tasks will be offered; two for each subject area of biology, chemistry and physics. These will correspond to the same tasks available for submission for Biology A (Unit A164), Chemistry A (Unit A174) and Physics A (Unit A184). Within each subject area, one of the tasks will always be based on the Additional Science A Modules B4–B6, C4–C6 and P4–P6.

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 each task. Tasks will not be valid for submission in any examination series other than that indicated.

Every year, six 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 six 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 Additional Science 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 Additional Science 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 Section 3.3.

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 A154

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 collected 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 the following procedures when producing their final piece of work for the 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 tasks 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. Some further guidance for each specific task will be provided, if appropriate, 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 Additional Science 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, further guidance on applying the marking criteria in the context of the task may also be given in the *Information for teachers*, if appropriate.

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. However, the requirements of the hierarchical marking criteria can be satisfied by crossing from one row to the next to demonstrate continuous progression through this strand.

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, and coversheet, provides a means of communication between teachers during internal standardisation and with the moderator if the work forms part of the moderation sample.

5.4.4 Overview of marking criteria for controlled assessment tasks

The five strands in the mark scheme 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 primary data	Candidates make decisions about the amount of data to be collected, the range of values covered, and effective checking for repeatability (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, e.g. 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 repeatability of their data, recognise outliers and treat them appropriately (IaS1).
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 (e.g. 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 e.g. species distribution maps.	Indicate the spread of data (e.g. 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 e.g. 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 e.g. 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

* 0 marks = no response or no response worthy of credit.

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 science.	6
AO2: Apply skills, knowledge and understanding of science 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 the 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, e.g. 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 is a secure website for centres to upload candidate work and for assessors to access this work digitally. Centres can use the OCR Repository for uploading marked candidate work for moderation.

Centres can access the OCR Repository via OCR Interchange, find their candidate entries in their area of the Repository, and use the Repository to upload files (singly or in bulk) for access by their moderator.

The OCR Repository allows candidates to send evidence in electronic file types that would normally be difficult to submit through postal moderation; for example multimedia or other interactive unit submissions.

The OCR GCSE Additional Science A unit A154 can be submitted electronically to the OCR Repository via Interchange: please check Section 8.2.1 for unit entry codes for the OCR Repository.

There are three ways to load files to the OCR Repository:

1. Centres can load multiple files against multiple candidates by clicking on 'Upload candidate files' in the Candidates tab of the Candidate Overview screen.

2. Centres can load multiple files against a specific candidate by clicking on 'Upload files' in the Candidate Details screen.

3. Centres can load multiple administration files by clicking on 'Upload admin files' in the Administration tab of the Candidate Overview screen.

The OCR Repository is seen as a faster, greener and more convenient means of providing work for assessment. It is part of a wider programme bringing digital technology to the assessment process, the aim of which is to provide simpler and easier administration for centres.

Instructions for how to upload files to OCR using the OCR Repository can be found on OCR Interchange.

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.

Support for GCSE Additional Science A

6.1 Free support and training from OCR

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:

- specimen assessment materials and mark schemes
- guide to controlled assessment
- sample controlled assessment materials
- exemplar candidate work and marking commentaries
- teachers' handbook
- sample schemes of work and lesson plans
- guide to curriculum planning.

Essential support services including:

- INSET training – for information visit www.gcse-science.com
- Interchange – a completely secure, free website to help centres reduce administrative tasks at exam time
- 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, 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 science, 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 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 Science 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

OCR will offer a range of support activities for all practitioners throughout the lifetime of the qualification to ensure they have the relevant knowledge and skills to deliver the qualification.

Please see Event Booker for further information.

6.4 OCR support services

6.4.1 Active Results

Active Results is available to all centres offering the OCR GCSE Additional Science A specification.

activeresults

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

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 in a number of ways:

- 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 on the OCR website.

7 Equality and inclusion in GCSE Additional Science A

7.1 Equality Act information relating to GCSE Additional Science A

GCSEs often require assessment of a broad range of competences. 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 qualification and subject criteria were reviewed by the regulators in order to identify whether any of the competences 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 competences 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 *Access Arrangements, Reasonable Adjustments and Special Consideration* 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 Ofqual's GCSE subject criteria equalities review and are as follows:

	Yes/No	Type of Assessment
Readers	Yes	All assessments
Scribes	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
Oral language modifiers	Yes	All assessments
BSL signers	Yes	All assessments
Modified question papers	Yes	All assessments
Extra time	Yes	All assessments

7.2 Arrangements for candidates with particular requirements (including Special Consideration)

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. As above, centres should consult the JCQ document *Access Arrangements, Reasonable Adjustments and Special Consideration.*

8 Administration of GCSE Additional Science A

In December 2011 the GCSE qualification criteria were changed by Ofqual. As a result, all GCSE qualifications have been updated to comply with the new regulations.

The most significant change for all GCSE qualifications is that, from 2014, unitised specifications must require that 100% of the assessment is terminal.

Please note that there are no changes to the terminal rule and re-sit rules for the January 2013 and June 2013 examination series:

- at least 40% of the assessment must be taken in the examination series in which the qualification is certificated
- candidates may re-sit each unit once before certification, i.e. each candidate can have two attempts at a unit before certification.

For full information on the assessment availability and rules that apply in the January 2013 and June 2013 examination series, please refer to the previous version of this specification GCSE Additional Science A (March 2011) available on the website.

The sections below explain in more detail the rules that apply from the June 2014 examination series onwards.

8.1 Availability of assessment from 2014

There is one examination series available each year in June (all units are available each year in June).

GCSE Additional Science A certification is available in June 2014 and each June thereafter.

	Unit A162	Unit A172	Unit A182	Unit A154	Certification availability
June 2014	✓	✓	✓	✓	✓
June 2015	✓	✓	✓	✓	✓

8.2 Certification rules

For GCSE Additional Science A, from June 2014 onwards, a 100% terminal rule applies. Candidates must enter for all their units in the series in which the qualification is certificated.

8.3 Rules for re-taking a qualification

Candidates may enter for the qualification an unlimited number of times.

Where a candidate re-takes a qualification, **all** units must be re-entered and all externally assessed units must be re-taken in the same series as the qualification is re-certificated. The new results for these units will be used to calculate the new qualification grade. Any results previously achieved cannot be re-used.

For the controlled assessment unit, candidates who are re-taking a qualification can choose either to re-take that controlled assessment unit or to carry forward the result for that unit that was used towards the previous certification of the same qualification.

- Where a candidate decides to re-take the controlled assessment, the new result will be the one used to calculate the new qualification grade. Any results previously achieved cannot be re-used.

- Where a candidate decides to carry forward a result for controlled assessment, they must be entered for the controlled assessment unit in the re-take series using the entry code for the carry forward option (see section 8.4).

8.4 Making entries

8.4.1 Making unit entries

Centres must be approved to offer OCR qualifications before they can make any entries, including estimated entries. It is recommended that centres apply to OCR to become an approved centre well in advance of making their first entries. Centres must have made an entry for a unit in order for OCR to supply the appropriate forms and administrative materials.

It is essential that correct unit entry codes are used when making unit entries.

For the externally assessed units A162, A172 and A182 candidates must be entered for either component 01 (Foundation Tier) or 02 (Higher Tier) using the appropriate unit entry code from the table below. It is not possible for a candidate to take both components for a particular unit within the same series; however, different units may be taken at different tiers.

For the controlled assessment unit, centres can decide whether they want to submit candidates' work for moderation through the OCR Repository or by post. Candidates submitting controlled assessment must be entered for the appropriate unit entry code from the table below. Candidates who are re-taking the qualification and who want to carry forward the controlled assessment should be entered using the unit entry code for the carry forward option.

Centres should note that controlled assessment tasks can still be completed at a time which is appropriate to the centre/candidate. However, where tasks change from year to year, centres would have to ensure that candidates had completed the correct task(s) for the year of entry.

Unit entry code	Component code	Assessment method	Unit titles
A162F	01	Written Paper	Unit A162: *Biology A Modules B4, B5 and B6* (Foundation Tier)
A162H	02	Written Paper	Unit A162: *Biology A Modules B4, B5 and B6* (Higher Tier)
A172F	01	Written Paper	Unit A172: *Chemistry A Modules C4, C5 and C6* (Foundation Tier)
A172H	02	Written Paper	Unit A172: *Chemistry A Modules C4, C5 and C6* (Higher Tier)
A182F	01	Written Paper	Unit A182: *Physics A Modules P4, P5 and P6* (Foundation Tier)
A182H	02	Written Paper	Unit A182: *Physics A Modules P4, P5 and P6* (Higher Tier)
A154A	01	Moderated via OCR Repository	Unit A154: *Additional Science A Controlled assessment*
A154B	02	Moderated via postal moderation	Unit A154: *Additional Science A Controlled assessment*
A154C	80	Carried forward	Unit A154: *Additional Science A Controlled assessment*

8.4.2 Certification entries

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

Centres must enter candidates for:

- GCSE Additional Science A certification code J242.

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 and by the relevant enquiries about results deadline for that series.

Please refer to the JCQ *Post-Results Services* booklet and the OCR *Admin Guide: 14–19 Qualifications* for further guidance on Enquiries about results and deadlines. Copies of the latest versions of these documents can be obtained from the OCR website at www.ocr.org.uk.

8.6 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 1320.

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, 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, either from their centre or from the institution to which they wish to progress.

Other information about GCSE Additional Science A

9.1 Overlap with other qualifications

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

This specification includes the content of Modules 4–6 of GCSE Biology A, GCSE Chemistry A and GCSE Physics 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 either 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. Special focus is given to the 9 strands of the Equality Act with the aim of ensuring both direct and indirect discrimination is avoided.

9.4 Regulatory requirements

This specification complies in all respects with the current: *General Conditions of Recognition; GCSE, GCE, Principal Learning and Project Code of Practice; GCSE Controlled Assessment regulations* and the *GCSE subject criteria for Science.* All documents are available on the Ofqual website.

9.5 Language

This specification and associated assessment materials are in English only. Only answers written in English will be assessed.

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 the issues during the course
Spiritual issues Scientific explanations which give insight into human nature.	B6: Insight into the ability of human beings to survive under extreme conditions. B6: The study of higher functions of the human brain – intelligence, memory, language and consciousness.
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.
Social issues Scientific explanations which give insight into everyday experiences.	P4: Theories of forces and motion and their implications for human safety in motor vehicles and other forms of transport. P5: Models for the behaviour of electric circuits and their practical importance for the generation of electricity.
Economic issues The range of factors which have to be considered when weighing the costs and benefits of scientific activity.	C6: Evaluating the costs and benefits associated with chemical manufacturing.
Cultural issues Scientific explanations which give insight into the local and global environment.	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 on 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 and Communication 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		ICT		WwO		IOLP		PS	
	1	2	1	2	1	2	1	2	1	2	1	2
A162	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A172	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A182	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A154	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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 science.

Opportunities for ICT include:

- using videos 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 Additional Science 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 A154, 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: Mathematics skills for GCSE science qualifications

Candidates are permitted to use calculators in all assessments.

Candidates should be able to:

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

In addition, Higher Tier candidates should be able to:

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

Appendix C: 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	$\times 10^{-9}$
micro (μ)	one millionth	0.000001	$\times 10^{-6}$
milli (m)	one thousandth	0.001	$\times 10^{-3}$
kilo (k)	× one thousand	1000	$\times 10^{3}$
mega (M)	× one million	1 000 000	$\times 10^{6}$
giga (G)	× one thousand million	1 000 000 000	$\times 10^{9}$
tera (T)	× one million million	1 000 000 000 000	$\times 10^{12}$

Appendix D: 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, i.e. 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 microorganisms 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.

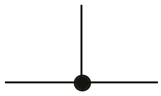
Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes 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.

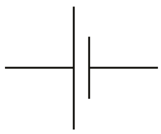
Appendix E: Electrical symbols

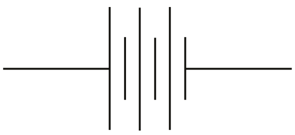
junction of conductors



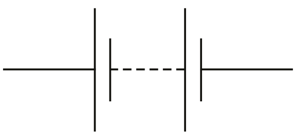
switch

primary or secondary cell



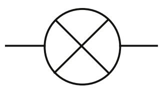


battery of cells or

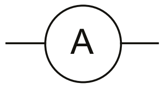


power supply

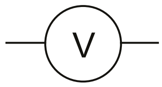
lamp



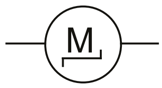
ammeter

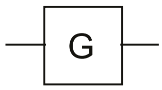


switch



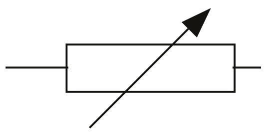
motor

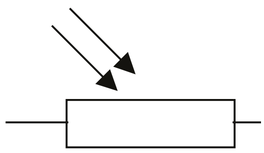




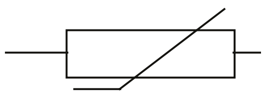
fixed resistor

variable resistor





thermistor



Appendix F: Periodic table

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

Appendix H: Hazard labelling

Specification statements C4.1.18 and C6.1.6 require candidates to recall the chemical hazard symbols associated with chemicals that can be explosive, toxic, corrosive, oxidizing and highly flammable.

Teachers and technicians will be familiar with the square symbols with orange backgrounds, as defined in EEC Directive 67/548/EEC. However, this Directive will be repealed on 1 June 2015 and the symbols will no longer be used after that date.

A new set of diamond-shaped hazard symbols with white backgrounds is being introduced in Europe, in accordance with the *United Nations Globally Harmonized System of Classification and Labelling of Chemicals* (the "GHS"). The GHS has been adopted in Europe under the *Regulation on the Classification, Labelling and Packaging of Substances and Mixtures* (the "CLP").

The period up to 1 June 2015 is considered to be a transitional period in which both systems of labelling will be in use. Hence, students are likely to see both sets of symbols on chemical bottles and chemical safety data sheets during the lifetime of this specification.

How does this affect teaching and assessment?

Under the new GHS / CLP system, suppliers are required to label chemicals with an appropriate symbol, signal word, hazard statement(s) and precautionary statement(s).

Guidance for teachers and technicians have been issued by CLEAPSS in the leaflet *'An introduction to GHS / CLP chemical hazard labelling'*, available free at:

www.cleapss.org.uk/attachments/article/0/GL%20101%20GHS%20CLP%20labelling.pdf?Secondary/Science/Guidance%20Leaflets/

Under the new GHS / CLP system, the familiar '**X**' symbol associated with chemicals that can be harmful or irritant will no longer be used. These chemicals will be labelled with other symbols appropriate to the nature of the hazard, along with appropriate signal word, hazard statement(s) and precautionary statement(s).

Students should be familiar with both systems of hazard labelling, and should be able to recognise during assessment the symbols used under both systems (limited to explosive, toxic, corrosive, oxidizing and highly flammable hazards), as shown below.

Hazard symbols under EEC Directive 67/548/EEC


Explosive

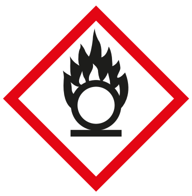

Toxic


Corrosive


Oxidizing


Highly flammable

Hazard symbols under the GHS / CLP system



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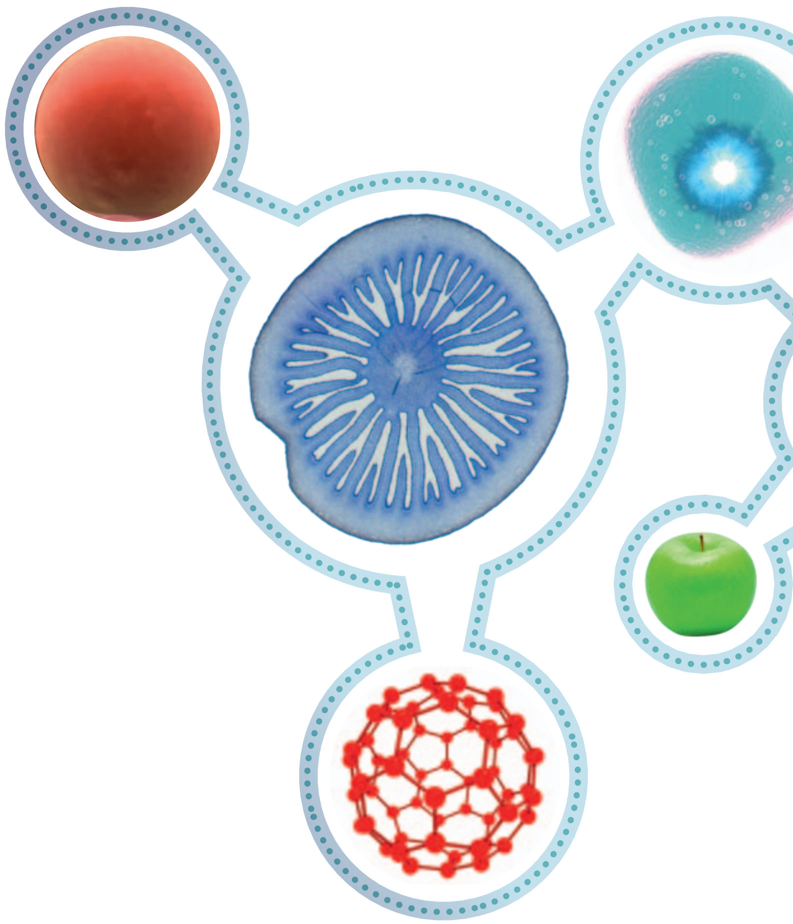

GENERAL QUALIFICATIONS
Telephone 01223 553998
Facsimile 01223 552627

science@ocr.org.uk
1 Hills Road, Cambridge CB1 2EU