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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Secondary Education

Additional Science 4463
2009

Material accompanying this Specification

- The Teachers' Guide

SPECIFICATION

This specification will be published annually on the AQA Website (www.aqa.org.uk). If there are any changes to the specification centres will be notified in print as well as on the Website. The version on the Website is the definitive version of the specification.

Vertical black lines indicate a significant change to the previous version of this specification.

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Background Information

1 Revision of GCSE Sciences – an Outcome of the DfES 14–19 Strategy

Following the publication of the DfES '14–19: opportunity and excellence' policy document, changes to the key stage 4 National Curriculum for England have been announced. One change is a new programme of study for KS4 Science (published autumn 2004), and the consequent rewriting by QCA of the GCSE Criteria for Science. Further details of this are given in Section 1.1. Another change relevant to GCSE Science is a requirement to provide work-related learning for all students. This is described in the QCA document 'Changes to the key stage 4 curriculum – guidance for implementation from September 2004', and is discussed in Section 1.2. These changes have together necessitated the redevelopment of GCSE Science specifications by all awarding bodies for first teaching from September 2006.

1.1 Changes to the GCSE Criteria for Science

The new programme of study has been incorporated by QCA into the GCSE Criteria for Science. The revised Criteria outline the common characteristics and subject content for science GCSEs developed by all awarding bodies for first teaching from September 2006. The main points are as follows.

- Importance is attached to the knowledge, skills and understanding of how science works in the world at large as well as in the laboratory (referred to as the procedural content in this specification).
- This is set in the context of knowing and understanding a body of scientific facts (referred to as the substantive content).
- In the programme of study, procedural and substantive content are given equal emphasis.
- There is a new single award GCSE Science incorporating all of the content in the programme of study.
- There is a new single award GCSE Additional Science, which together with GCSE Science allows progression to post-16 science courses.
- Alternative progression routes are available in the form of single award separate sciences (GCSE Biology, GCSE Chemistry and GCSE Physics), and an applied science route leading to a new single award GCSE Additional Applied Science.

- There is provision for students wishing to follow an applied route from the outset of KS4 through a revised double award GCSE Applied Science.
- Taken together, the three separate sciences cover the requirement to teach the new programme of study, as does the revised double award GCSE Applied Science.
- Through these new specifications the opportunity exists for candidates to study GCSE Science and one or more of the separate science GCSE courses.

In parallel with the GCSE developments, a new Entry Level Certificate specification for Science is being produced. This covers the breadth of the programme of study but in less depth than required for GCSE Science.

Further details of the suite of specifications developed by AQA to meet these requirements are given in Section 4.2.

1.2 Changes to the KS4 Curriculum

Requirement to teach programme of study

The revised programme of study for KS4 Science has been designed by QCA as a small core of content relevant to all students. It is a statutory requirement to teach the programme of study to all students at maintained schools. Since the start of teaching of the new specifications (September 2006), it has no longer been possible to disapply KS4 students from this requirement for the purposes of extended work-related learning.

Work-related learning

The removal of the provision for disapplication is linked to the statutory requirement for work-related learning for all students which was introduced in September 2004. With the greater emphasis in the revised programme of study on 'How Science Works', science teachers are enabled, if they wish, to make a larger contribution to work-related learning through the teaching of science.

1.3 Other Regulatory Requirements

Key Skills

All GCSE specifications must identify, as appropriate to the subject, opportunities for generating evidence for the Key Skills of Application of Number, Communication, Information and Communication Technology, Working with Others, Improving Own Learning and Performance, and Problem Solving. Details for this specification are given in Section 14.

ICT

The subject content of all GCSEs must require candidates to make effective use of ICT and provide, where appropriate, assessment opportunities for ICT. In science in the wider world, ICT plays a crucial role, and teaching and learning in the GCSE Sciences should reflect this. Details of how the teaching of this specification can encourage the application and development of ICT skills are given in Section 9.3. However, ICT skills are not assessed by any component of this specification.

Communication

All GCSE specifications must ensure that the assessment arrangements require that, when they produce extended written material, candidates have to:

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

Further details for this specification are given in Section 7.4.

Citizenship

Since 2002, students in England have been required to study Citizenship as a National Curriculum subject. Each GCSE specification must signpost, where appropriate, opportunities for developing citizenship knowledge, skills and understanding. Further details for this specification are given in Section 15.5.

Other issues

All specifications must identify ways in which the study of the subject can contribute to developing understanding of spiritual, moral, ethical, social and cultural issues, European developments, environmental issues, and health and safety. Further details for this specification are given in Sections 15.1, 15.2, 15.3 and 15.4.

Wales and Northern Ireland

There is no longer any additional material that centres in Wales or Northern Ireland have to teach in order to meet the different requirements of the National Curriculum in these countries.

Therefore, centres may offer any of the AQA specifications without the need to supplement the teaching required in order to meet additional statutory orders applying to students outside England.

2 Specification at a Glance

Additional Science

This specification is one of a suite of GCSE Science specifications offered by AQA. The specification leads to a single award GCSE Additional Science. The award has four assessment units.

There are two tiers of assessment: Foundation (G–C) and Higher (D–A*). The centre-assessed unit is not tiered.

GCSE Additional Science	
Biology 2	
Written paper	25%
45 minutes	45 marks
Chemistry 2	
Written paper	25%
45 minutes	45 marks
Physics 2	
Written paper	25%
45 minutes	45 marks
Additional Science Centre-Assessed Unit (B2, C2 or P2)	
based on normal class practical work	25%
	40 marks
Investigative Skills Assignment (an externally set, internally assessed test taking 45 minutes) + Practical Skills Assessment (a holistic skills assessment)	

← GCSE Additional Science 4463

3 Availability of Assessment Units and Entry Details

3.1 Availability of Assessment Units and Subject Awards

Examinations based on this specification are available as follows.

	Written Papers	Centre-Assessed Unit	Subject Award
January	✓		✓
June	✓	✓	✓

3.2 Entry Codes

Normal entry requirements apply, but the following information should be noted.

Each assessment unit has a separate unit entry code, as follows:

Biology 2	BLY2F or BLY2H
Chemistry 2	CHY2F or CHY2H
Physics 2	PHY2F or PHY2H
Additional Science centre-assessed unit	ASCC

For Biology 2, Chemistry 2 and Physics 2, the entry code determines the tier taken.

The units which contribute to the subject award GCSE Additional Science are: Biology 2, Chemistry 2, Physics 2 and the Additional Science centre-assessed unit.

The Subject Code for entry to the GCSE Additional Science award is 4463.

3.3 Entry Restrictions

Each specification is assigned to a national classification code, indicating the subject area to which it belongs. 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.

The classification code for this specification is 1320.

The subject award in GCSE Additional Science has common units with other specifications in the AQA GCSE Sciences suite. Biology 2 is common to GCSE Additional Science and GCSE Biology. Equivalent statements apply to Chemistry and Physics.

It is **not** a requirement to take the same tier for every written paper. Candidates can opt to take different tiers for the different papers and can choose to resit a written paper at a different tier.

3.4 Private Candidates

This specification is available for private candidates. Private candidates should write to AQA for a copy of *Supplementary Guidance for Private Candidates.*

3.5 Access Arrangements and Special Consideration

AQA pays due regard to the provisions of the Disability Discrimination Act 1995 in its administration of this specification.

Arrangements may be made to enable candidates with disabilities or other difficulties to access the assessment. An example of an access arrangement is the production of a Braille paper for a candidate with a visual impairment. Special consideration may be requested for candidates whose work has been affected by illness or other exceptional circumstances.

Further details can be found in the Joint Council for Qualifications (JCQ) document:
Access Arrangements and Special Consideration
Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations
GCE, AEA, VCE, GCSE, GNVQ, Entry Level & Key Skills
This document can be viewed via the AQA website (www.aqa.org.uk)

Applications for access arrangements and special consideration should be submitted to AQA by the Examinations Officer at the centre.

3.6 Language of Examinations

All assessment will be through the medium of English. Assessment materials will not be provided in Welsh or Gaeilge.

Scheme of Assessment

4 Introduction

4.1 National Criteria

This GCSE Additional Science specification complies with the following:

- the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland 2004, including the common criteria for all qualifications and the additional criteria for GCSE
- the GCSE Criteria for Science
- the GCSE, GCE, VCE, GNVQ and AEA Code of Practice 2008.

4.2 Background

This GCSE Additional Science specification is part of the AQA GCSE Science suite, which comprises:

GCSE Science A
GCSE Science B
GCSE Additional Science (this specification)
GCSE Additional Applied Science
GCSE Biology
GCSE Chemistry
GCSE Physics
GCSE Applied Science (Double Award)

A matching Entry Level Certificate specification for Science is also available.

The suite enables centres to offer a range of flexible progression routes from KS3 through KS4 Science to further studies.

As noted in Section 1.1, the GCSE Criteria for Science require a greater emphasis on 'How Science Works' in these new specifications. AQA is grateful to staff in the School of Education of the University of Durham for assistance in addressing this requirement. The procedural content of this specification draws substantially on pioneering work conducted at the University of Durham on 'Concepts of Evidence', using a subset of these concepts which are appropriate to GCSE Sciences. For more information about this work visit: www.dur.ac.uk/richard.gott/Evidence/cofev.htm

University staff have also assisted AQA senior examiners in developing the assessment of the procedural content in relation to the substantive content, in both the written papers and the centre-assessed unit. Initial pilot work by the University has helped significantly in designing assessments which are accessible to students at KS4. AQA acknowledges this indebtedness.

Rationale

The rationale of the six general science specifications (GCSE Science A, GCSE Science B, GCSE Additional Science, GCSE Biology, GCSE Chemistry and GCSE Physics) is the appropriate exploration of 'How Science Works' in contexts which are relevant to the role of science in society and which are able to serve as a foundation for progression to further learning. A body of content has been identified which underpins the knowledge and understanding of 'How Science Works' at all levels. This 'procedural content' relates to the processes of scientific activity. The 'substantive content' comprises the Biology, Chemistry, Physics or other science content. In these specifications the procedural content and the substantive content are presented in separate sections in order to ensure that there is a coherent and consistent understanding of what candidates are required to know, understand and be able to do. However, it is expected that delivery of the procedural content will be integrated.

Integrating 'How Science Works' (procedural content)

Although the procedural content is presented in a separate section in the general science specifications, it is not expected that it is taught separately from the substantive content. Teachers might teach a topic of substantive content (eg reflex action, fractional distillation, or features of electromagnetic waves) or of procedural content (eg methods of collecting scientific data) but often they will deliver a blend of procedural and substantive content (eg when teaching about the greenhouse effect and global warming).

In order to reflect this approach, each sub-section of substantive content has details of activities which enable candidates to develop their skills, knowledge and understanding of how science works (the procedural content), then details are given of the substantive contexts that need to be known and understood in order to undertake the activities. This is supplemented by signposting which highlights opportunities to develop the skills, knowledge and understanding of the investigative aspects of the procedural content, and opportunities to encourage knowledge and understanding of how scientific evidence is used. Further details about integrating the procedural content are given in Section 9.1.

Assessment in the written papers will also reflect this approach. Parts of questions may address procedural content, substantive content or a blend of both. Candidates will be expected to apply their procedural knowledge, understanding and skills in a wide range of substantive contexts.

Each of the specifications has particular features and these are described in the following paragraphs.

GCSE Science A and GCSE Science B

Students can begin KS4 with a general science course based on either GCSE Science A or GCSE Science B. These are both single award qualifications. They cover all aspects of a good science education: evaluating evidence and the implications of science for society; explaining, theorising and modelling in science; and procedural and technical knowledge of science practice, though with an emphasis on the first aspect, namely, evaluating evidence and the implications of science for society. The weighting given to the procedural content in these specifications is higher than in the other general science specifications, and the substantive contexts lend themselves to engagement with the societal implications of scientific knowledge at a level which is appropriate to key stage 4. Both these specifications therefore provide the opportunity for all students to develop the science knowledge, understanding and skills needed for adult life, but they also give a good basis for further study of science.

These specifications have identical content, covering the whole programme of study for KS4 Science, with the subject areas of Biology, Chemistry and Physics presented separately so that they can be taught by subject specialists if this suits the staffing and/or teaching strategy in the centre. The assessment styles for Science A and Science B are different, though they share a common model for centre assessment. Students who are successful in GCSE Science could study a level 3 science qualification such as AS Science for Public Understanding, but would find progression to GCE Biology, Chemistry, Physics and Applied Science difficult without further preparation. Many will undertake a level 2 course such as GCSE Additional Science or GCSE Additional Applied Science before continuing to level 3 courses.

GCSE Science A

The specific feature of this specification is that external assessment is available through 'bite size' objective tests. Each of the three units, Biology 1, Chemistry 1 and Physics 1, is divided into two equal sections and each section is examined in a separate 30 minute test. The tests are available in November, March and June. The objective tests are available as paper-based and on-screen tests in centres.

GCSE Science B

In contrast, GCSE Science B does not offer assessment through the 'bite-size' test route but has 45 minute written papers with structured questions. There is one paper for each of Biology 1, Chemistry 1 and Physics 1, available in January and June.

GCSE Applied Science (Double Award)

Alternatively, students embarking on KS4 and wishing from the outset to specialise in a vocational approach to Science can be offered GCSE Double Award Applied Science. This is a qualification which has been developed from the previous GCSE Applied Science specification but unlike its predecessor it covers the whole programme of study for KS4 Science, enabling the requirement to teach the programme to be met (see Section 1.2). The assessment comprises four units; three portfolio units and one unit which is externally assessed.

ELC Science

Candidates who may not be ready to take GCSE Science at the same time as their contemporaries can study for the Entry Level Certificate in Science. This has the same breadth of content as GCSE Science, but less depth. Teaching for ELC Science can enable the requirement to teach the programme of study for KS4 Science to be met (see Section 1.2) and students can be taught alongside students preparing for GCSE Science (if they cannot be taught separately). Students who have succeeded in ELC Science can progress to GCSE Science. Assessment is through the completion of units of content with the success criteria being clearly focussed on skills rather than depth of knowledge.

GCSE Additional Science

This is a single award GCSE, separate from and taken after or at the same time as GCSE Science A or B. This award together with an award in GCSE Science provides the nearest equivalent to the previous GCSE Science: Double Award. The content follows on from that of GCSE Science, and the centre assessment follows the same model as used for Science A and Science B. However, the emphasis of this specification, and the three separate sciences, GCSE Biology, Chemistry and Physics, is somewhat different. Whereas GCSE Science A and B emphasise evaluating evidence and the implications of science for society, these specifications have a greater emphasis on explaining, theorising and modelling in science.

There are three 45 minute written papers with structured questions, one paper for each of Biology 2, Chemistry 2 and Physics 2, available in January and June. Courses based on this specification form a firm basis for level 3 courses in the sciences such as AS and A Level Biology, Chemistry and Physics.

GCSE Additional Applied Science

This is another single award GCSE, which could be taken after or at the same time as GCSE Science A or B. It emphasises the procedural and technical knowledge of science practice, so is suitable for students who want to learn more about vocational contexts which are relevant to the modern world. The subject content is set in three vocational contexts: sports science, food science and forensic science. Together with GCSE Science, it would form a firm basis for level 3 courses in the sciences such as GCE Applied Science.

GCSE Biology, Chemistry, Physics

Each of these single award GCSEs would provide the basis for the study of the corresponding GCE science. Like GCSE Additional Science, they emphasise explaining, theorising and modelling in science. Taken together they include the whole programme of study for KS4 Science, enabling the statutory requirement to be met. Students could take courses based on these specifications directly after KS3 Science. Alternatively some students may prefer to take GCSE Science to provide a general background in KS4 Science, then specialise in one or more separate science(s).

Centre-Assessed Unit

The general science GCSEs (Science A, Science B, Additional Science, Biology, Chemistry and Physics) share a common approach to centre assessment. This is based on the belief that assessment should encourage practical activity in science, and that practical activity should encompass a broad range of types of activity. The previous model of practical assessment based on 'investigations' has become a straightjacket to practical activity in the classroom, and it is the intention that the model adopted will avoid this.

The centre-assessed unit is a combination of practical skills assessment (a holistic assessment on a 6 point scale) and a written test. Before taking a test, candidates undertake practical work relating to a topic under normal class conditions and, during their work, they collect data. They bring their data to the test. The written test is taken in a subsequent lesson but under examination conditions. Tests are externally set, but internally marked, using marking guidance provided by AQA. Each test will have questions relating to the candidate's data and questions which relate to additional data provided in the question paper. Several tests relevant to each unit will be available at any one time, and the tests can be taken at times chosen by the teacher. Further details are given in Sections 16–18.

4.3 Prior Level of Attainment and Recommended Prior Learning

This key stage 4 GCSE specification builds on the knowledge, understanding and skills set out in the National Curriculum programme of study for KS3 Science. While there is no specific prior level of attainment required for candidates to undertake a course of study based on this specification, a level of scientific, literacy and numeracy skills commensurate with having followed a programme of study at key stage 3 is expected.

4.4 Progression

This qualification is a recognised part of the National Qualifications Framework. As such, GCSE is a level 2 qualification and provides progression from key stage 3 to post-16 studies.

A course based on this specification provides a worthwhile course for candidates of various ages and from diverse backgrounds in terms of general education and lifelong learning. Candidates would be unlikely to find progression direct from the programme of study for KS3 Science easy, without also studying GCSE Science. Progression from GCSE Additional Science could be to GCE Biology, Chemistry or Physics. Alternatively, students could progress to AS Science for Public Understanding.

5 Aims

A course based on this specification should encourage candidates to:

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

6 Assessment Objectives

6.1

The scheme of assessment will require candidates to demonstrate the abilities detailed under assessment objectives below in the context of the subject content in Sections 10–13.

6.2 Assessment Objective 1 (AO1)

Knowledge and understanding of science and how science works

Candidates should be able to:

a) demonstrate knowledge and understanding of the scientific facts, concepts, techniques and terminology in the specification
b) show understanding of how scientific evidence is collected and its relationship with scientific explanations and theories
c) show understanding of how scientific knowledge and ideas change over time and how these changes are validated.

6.3 Assessment Objective 2 (AO2)

Application of skills, knowledge and understanding

Candidates should be able to:

a) apply concepts, develop arguments or draw conclusions related to familiar and unfamiliar situations
b) plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem
c) show understanding of how decisions about science and technology are made in different situations, including contemporary situations and those raising ethical issues
d) evaluate the impact of scientific developments or processes on individuals, communities or the environment.

6.4 Assessment Objective 3 (AO3)

Practical, enquiry and data handling skills

Candidates should be able to:

a) carry out practical tasks safely and skilfully
b) evaluate the methods they use when collecting first-hand and secondary data
c) analyse and interpret qualitative and quantitative data from different sources
d) consider the validity and reliability of data in presenting and justifying conclusions.

7 Scheme of Assessment

7.1 Assessment Units

The Scheme of Assessment comprises four units: Biology 2, Chemistry 2, Physics 2, and the Additional Science centre-assessed unit.

Biology 2	Written Paper	45 minutes
25% of the marks		45 marks

The unit comprises a written paper with short answer questions. The questions assess the subject content in Sections 10 (up to 9 marks) and 11 (at least 36 marks). The paper is available at Foundation and Higher Tier. All questions are compulsory.

Chemistry 2	Written Paper	45 minutes
25% of the marks		45 marks

The unit comprises a written paper with short answer questions. The questions assess the subject content in Sections 10 (up to 9 marks) and 12 (at least 36 marks). The paper is available at Foundation and Higher Tier. All questions are compulsory.

Physics 2	Written Paper	45 minutes
25% of the marks		45 marks

The unit comprises a written paper with short answer questions. The questions assess the subject content in Sections 10 (up to 9 marks) and 13 (at least 36 marks). The paper is available at Foundation and Higher Tier. All questions are compulsory.

Additional Science Centre-Assessed Unit	
25% of the marks	40 marks

The unit comprises an Investigative Skills Assignment, which is normal class practical work followed by an externally set, internally assessed test taking 45 minutes, and a Practical Skills Assessment which is a holistic practical skills assessment. The unit assesses parts of the content in Section 10 (these are detailed in Section 17).

7.2 Weighting of Assessment Objectives

The approximate relationship between the relative percentage weighting of the Assessment Objectives (AOs) and the overall Scheme of Assessment is shown in the following table:

Assessment Objectives	**Unit Weightings (%)**				**Overall Weighting of AOs (%)**
	Biology 2	**Chemistry 2**	**Physics 2**	**Centre-Assessed Unit 2**	
AO1	12	12	12	-	36
AO2	13	13	13	5	44
AO3	-	-	-	20	20
Overall Weighting (%)	25	25	25	25	**100**

Candidates' marks for each assessment unit are scaled to achieve the correct weightings.

7.3 Tiering and Assessment

The centre-assessed unit is not tiered. In the other assessments for this specification, the papers are tiered with Foundation Tier being aimed at grades C–C, and Higher Tier being aimed at grades A*–D. Questions for the Higher Tier will be more demanding requiring higher level skills allowing candidates to access the higher grades. See Section 9.4 for information about tiering and subject content. Different tiers can be taken for different papers.

The level of demand of questions depends on factors such as the nature of the underlying scientific concepts being tested, amount of cueing provided including the plausibility of distractors, the context/application in which the question is contained, whether the response required is directed or open, and the extent to which reference material must be used in order to respond. Consideration of such factors allows GCSE Science questions to be allocated to one of three levels of demand (low, standard and high). Foundation Tier papers contain low and standard demand questions, while Higher Tier papers contain standard and high demand questions.

7.4 Mathematical and Other Requirements

The knowledge and skills in mathematics which are relevant to science and which are given below will not be exceeded in making assessments in this specification. Candidates will not be prevented from demonstrating achievement in science by mathematics which is excessively demanding.

FT and HT

- The four rules applied to whole numbers and decimals
- Use of tables and charts
- Interpretation and use of graphs
- Drawing graphs from given data
- Reading, interpreting and drawing simple inferences from tables
- Vulgar and decimal fractions and percentages

- Scales
- Elementary ideas and application of common measures of rate
- Averages/means and the purpose for which they are used
- Substitution of numbers for words and letters in formulae (without transformation of simple formulae)

HT only (in addition to the requirements listed above)

- Square and square root
- Conversion between vulgar and decimal fractions and percentages
- The four rules applied to improper (and mixed) fractions
- Expression of one quantity as a percentage of another; percentage change
- Drawing and interpreting of related graphs
- Idea of gradient
- Transformation of formulae
- Simple linear equations with one unknown
- Elementary ideas and applications of direct and inverse proportion

Units, symbols and nomenclature

Units, symbols and nomenclature used in examination papers will normally conform to the recommendations contained in the following.

- *Signs, Symbols and Systematics – the ASE companion to 16–19 Science.* Association for Science Education (ASE), 2000. ISBN 0 86357 312 6
- *Signs, Symbols and Systematics – the ASE companion to 5–16 Science.* Association for Science Education (ASE), 1995. ISBN 0 86357 232 4

Any generally accepted alternatives used by candidates will be given appropriate credit.

Data sheet and formulae list

A data sheet is provided with the Chemistry 2 written paper. This includes a periodic table and other information. See Appendix D. For the Physics 2 written paper, where a formula is required to answer a question, the formula or formulae will be given in that question. However, candidates may be asked to identify the units.

Communication skills

AQA takes care that candidates are not prevented from demonstrating achievement in science by the use of language in question papers which is inappropriately complex and hinders comprehension. Similarly, while the assessment of communication is not a primary function of this specification, candidates are required to demonstrate scientific communication skills. These are described in Section 9.2.

Scientific communication skills are specifically targeted by questions in the Investigative Skills Assignment (ISA) part of the centre-assessed unit. The externally set test for every ISA has a question in which the scoring of marks is in part dependent on skills such as presenting information, developing an argument and drawing a conclusion.

In addition, candidates will have difficulty in scoring the marks for science in any of the written assessments if they do not:

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

In presenting their answers, they will also need to use scientific conventions (including chemical equations) and mathematical language (including formulae) accurately and appropriately to score all the available marks.

Subject Content

8 Summary of Subject Content

8.1	How Science Works	10.1	The thinking behind the doing
		10.2	Fundamental ideas
		10.3	Observation as a stimulus to investigation
		10.4	Designing an investigation
		10.5	Making measurements
		10.6	Presenting data
		10.7	Using data to draw conclusions
		10.8	Societal aspects of scientific evidence
		10.9	Limitations of scientific evidence
8.3	Biology 2	11.1	What are animals and plants built from?
		11.2	How do dissolved substances get into and out of cells?
		11.3	How do plants obtain the food they need to live and grow?
		11.4	What happens to energy and biomass at each stage in a food chain?
		11.5	What happens to the waste material produced by plants and animals?
		11.6	What are enzymes and what are some of their functions?
		11.7	How do our bodies keep internal conditions constant?
		11.8	Which human characteristics show a simple pattern of inheritance?
8.3	Chemistry 2	12.1	How do sub-atomic particles help us to understand the structure of substances?
		12.2	How do structures influence the properties and uses of substances?
		12.3	How much can we make and how much do we need to use?
		12.4	How can we control the rates of chemical reactions?
		12.5	Do chemical reactions always release energy?
		12.6	How can we use ions in solutions?

8.4 Physics 2

13.1 How can we describe the way things move?

13.2 How do we make things speed up or slow down?

13.3 What happens to the movement energy when things speed up or slow down?

13.4 What is momentum?

13.5 What is static electricity, how can it be used and what is the connection between static electricity and electric currents?

13.6 What does the current through an electrical current depend on?

13.7 What is mains electricity and how can it be used safely?

13.8 Why do we need to know the power of electrical appliances?

13.9 What happens to radioactive substances when they decay?

13.10 What are nuclear fission and nuclear fusion?

9 Introduction to Subject Content

9.1 Integrating the Procedural Content

The subject content of this specification is presented in four sections: the procedural content ('How Science Works'), and three sections of substantive content, Biology 2, Chemistry 2 and Physics 2. To aid understanding of the changes that have been introduced in the teaching, learning and assessment of science at key stage 4, the procedural content is stated separately in Section 10 from the Biology, Chemistry and Physics content in Sections 11–13. However, it is intended that the procedural content is integrated and delivered in the context of the content in Biology 2, Chemistry 2 and Physics 2.

The organisation of each sub-section of the substantive content is designed to facilitate this approach. Each of the sub-sections in Biology 2, Chemistry 2 and Physics 2 starts with the statement: 'Candidates should use their skills, knowledge and understanding of how science works (to)'. This introduces a number of activities, for example:

- evaluating information about the effect of food on health
- considering the social, economic and environmental impacts of exploiting metal ores
- comparing and contrasting the advantages and disadvantages of using different energy sources to generate electricity.

These are intended to enable candidates to develop many aspects of the skills, knowledge and understanding of how science works. In general, the activities address using scientific evidence. Other aspects of the skills, knowledge and understanding of how science works, particularly obtaining scientific evidence, will be better developed through investigative work, and it is expected that teachers will want to adopt a practical approach to the teaching of many topics.

In each sub-section, the contexts for the activities and associated practical work are introduced by the statement: 'Their skills, knowledge and understanding of how science works should be set in these substantive contexts'. Sentences such as this follow.

- Processed food often contains a high proportion of fat and/or salt.
- Ores contain enough metal to make it economical to extract the metal and this changes over time.
- Electricity can be produced directly from the Sun's radiation using solar cells.

These sentences define the scope of the Biology, Chemistry and Physics content.

In order to assist teachers in identifying sections of the content which lend themselves to the delivery of the procedural content, two symbols have been used.

The first, shown here, identifies parts of the content which lend themselves to extended investigative work of the type needed to explore Sections 10.3–10.7 of the procedural content. These sections are about obtaining valid and reliable scientific evidence. These parts of the content may form the contexts for Investigative Skills Assignments (see also Section 18.2).

? The second, shown here, identifies parts of the content which lend themselves to activities which allow Sections 10.2 and 10.8–10.9 to be considered. These sections are about using scientific evidence, for example, how scientific evidence can contribute to decision making and how scientific evidence is limited.

Further guidance about the delivery of 'How Science Works' in the context of the substantive content is being prepared for publication in the Teacher's Guide for this specification.

In the written papers, questions will be set which examine the procedural content in the context of the substantive content. Candidates will be required to use their knowledge, understanding and skills in both the procedural and substantive content to respond to questions. In some cases it is anticipated that candidates will use additional information which is given to them, and demonstrate their understanding by applying the principles and concepts in the substantive content to unfamiliar situations.

To compensate for the additional teaching time that will be involved in delivering 'How Science Works', the substantive content sections (Biology 2, Chemistry 2 and Physics 2) have been substantially reduced compared with the previous specifications.

9.2 Communication Skills

Throughout their GCSE Science course, candidates should be encouraged to develop and improve their scientific communication skills.

These include:

- recalling, analysing, interpreting, applying and questioning scientific information or ideas
- using both qualitative and quantitative approaches
- presenting information, developing an argument and drawing a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools.

These skills will be developed through the activities that candidates undertake during their course, including those required for this specification by the statements at the beginning of each section of the substantive content. Appropriate use of these skills will enable candidates to be successful in the written assessments for this specification.

There is further information in Section 7.4 about scientific communication in assessments including the use of scientific, technical and mathematical language, conventions and symbols.

9.3 ICT Skills

In undertaking activities to develop their knowledge and understanding of how science works, candidates should be given opportunities to:

- collect data from primary and secondary sources, using ICT sources and tools
- present information, develop arguments and draw conclusions using ICT tools.

Opportunities to use ICT sources and tools occur throughout the content of this specification. They are signposted in Sections 11–13 by the symbol shown, and are listed below under four headings.

- Use the internet (and other primary and secondary sources) to find information or data about:
  - uses of enzymes in the home and industry (Section 11.6)
  - modern methods of treating diabetes (Section 11.7)
  - DNA fingerprinting (Section 11.8)
  - development and application of new materials including nanoscience (Section 12.2)
  - atom economy and sustainable development (Section 12.3)
  - conditions used in industrial processes in terms of energy required (Section 12.5)
  - effect of conditions on position of equilibrium in reversible reactions (Section 12.5)
  - stopping distance of vehicles (Section 13.2)
  - safe discharge of static electricity (Section 13.5)
  - uses of static electricity (Section 13.5)

- Use sensors and dataloggers to capture data in practical work
  - enzymes in digestion (Section 11.6)
  - describing movement of a straight line (Sections 13.1 and 13.2)
  - finding kinetic energy of moving bodies (Section 13.3)
  - potential differences in d.c. and a.c. supplies from oscilloscope traces (Section 13.7)

- Use spreadsheets or databases for data analysis, for modelling or to explore patterns
  - periodic table and atomic structure (Section 12.1)
  - rates of reaction (Section 12.4)

- Use electronic resources eg software simulations, video clips
  - atomic structure – electrons in energy levels (Section 12.1)
  - chemical bonding and structure (Section 12.1)
  - relationship between structure and properties (Section 12.2)
  - yield in chemical reactions and atom economy (Section 12.3)
  - reversible reactions (Section 12.3)
  - electrolysis (Section 12.6)
  - describing movement in a straight line (Section 13.1 and 13.2)
  - resultant forces (Section 13.2)
  - terminal velocity (Section 13.2)
  - using idea of momentum to explain safety features (Section 13.4)
  - development of nuclear model of atom (Section 13.9)
  - radioactive decay (Section 13.9)
  - chain reactions (Sections 13.10)

9.4 Tiering and Subject Content

In this specification there is additional content needed for Higher Tier candidates. Questions in the Higher Tier papers will also be more demanding, allowing candidates to access the higher grades.

HT ❖ Shown like this, HT indicates the additional material needed only by Higher Tier candidates.

10 How Science Works – the Procedural Content

This section contains a statement of the procedural content that candidates need to know and understand in order to be successful in any of the assessment units of this specification. It should be read in conjunction with Sections 11–13, where cross-references to this section have been included to show activities in the context of biology, chemistry and physics which can be used to develop candidates' skills, knowledge and understanding of how science works.

Candidates should be encouraged to carry out practical work throughout the course and to collect their own data carefully. They should work individually and in groups and should always consider the safety aspects of experimental work.

10.1 The thinking behind the doing

Science attempts to explain the world in which we live. It provides technologies that have had a great impact on our society and the environment. Scientists try to explain phenomena and solve problems using evidence. The data to be used as evidence must be reliable and valid, as only then can appropriate conclusions be made.

A scientifically literate citizen should, amongst other things, be equipped to question, and engage in debate on, the evidence used in decision-making.

The reliability of evidence refers to how much we trust the data. The validity of evidence depends on the reliability of the data, as well as whether the research answers the question. If the data is not reliable the research cannot be valid.

To ensure reliability and validity in evidence, scientists consider a range of ideas which relate to:

- how we observe the world
- designing investigations so that patterns and relationships between variables may be identified
- making measurements by selecting and using instruments effectively
- presenting and representing data
- identifying patterns, relationships and making suitable conclusions.

These ideas inform decisions and are central to science education. They constitute the 'thinking behind the doing' that is a necessary complement to the subject content of biology, chemistry and physics.

The sections below introduce the key ideas relating to evidence that underpin scientific practice.

10.2 Fundamental ideas

Evidence must be approached with a critical eye. It is necessary to look closely at how measurements have been made and what links have been established. Scientific evidence provides a powerful means of forming opinions. These ideas pervade all of 'How Science Works'.

Candidates should know and understand

- It is necessary to distinguish between opinion based on valid and reliable evidence and opinion based on non-scientific ideas (prejudices, whim or hearsay).
- Continuous variables (any numerical values, eg weight, length or force) give more information than ordered variables (eg small, medium or large lumps) which are more informative than categoric variables (eg names of metals). A variable may also be discrete, that is, restricted to whole numbers (eg the number of layers of insulation).
- Scientific investigations often seek to identify links between two or more variables. These links may be:
  - causal, in that a change in one variable causes a change in another
  - due to association, in that changes in one variable and a second variable are linked by a third variable (eg an association noted between soil acidity and crop growth may be the effect of a third variable, fertiliser type and quantity, on both)
  - due to chance occurrence (eg increase in the early 20th century in radio use was accompanied by an increase in mental illness).
- Evidence must be looked at carefully to make sure that it is:
  - reliable, ie it can be reproduced by others
  - valid, ie it is reliable *and* answers the original question.

10.3 Observation as a stimulus to investigation

Observation is the link between the real world and scientific ideas. When we observe objects, organisms or events we do so using existing knowledge. Observations may suggest hypotheses and lead to predictions that can be tested.

Candidates should know and understand

- Observing phenomena can lead to the start of an investigation, experiment or survey. Existing theories and models can be used creatively to suggest explanations for phenomena (hypotheses). Careful observation is necessary before deciding which are the most important variables. Hypotheses can then be used to make predictions that can be tested. An example is the observation that shrimp only occur in parts of a stream. Knowledge about shrimp and water flow leads to a hypothesis relating the distribution to the stream flow rate. A prediction leads to a survey that looks at both variables.
- Data from testing a prediction can support or refute the hypothesis or lead to a new hypothesis. For example, the data from the shrimp survey could suggest that, at slow flow rates, oxygen availability might determine abundance.
- If the theories and models we have available to us do not completely match our data or observations, we need to check the validity of our observations or data, or amend the theories or models.

10.4 Designing an investigation

An investigation is an attempt to determine whether or not there is a relationship between variables. Therefore it is necessary to identify and understand the variables in an investigation. The design of an investigation should be scrutinised when evaluating the validity of the evidence it has produced.

Candidates should know and understand

- An independent variable is one that is changed or selected by the investigator. The dependent variable is measured for each change in the independent variable.
- Any measurement must be valid in that it measures only the appropriate variable, for instance colour change in a pH indicator to measure respiration in woodlice could be affected by their excretion.

Fair Test

- It is important to isolate the effects of the independent variable on the dependent variable. This may be achieved more easily in a laboratory environment than in the field, where it is harder to control all variables.
- A fair test is one in which only the independent variable affects the dependent variable, as all other variables are kept the same.
- In field investigations it is necessary to ensure that variables that change their value do so in the same way for all measurements of the dependent variable (eg in a tomato growth trial, all plants are subject to the same weather conditions).
- When using large-scale survey results, it is necessary to select data from conditions that are similar (eg if a study is to survey the effect of age on blood pressure, a group of people with approximately the same diet or weight could be used).
- Control groups are often used in biological and medical research to ensure that observed effects are due to changes in the independent variable alone (eg in drug experiments, a placebo drug is used as a control).

Choosing values of a variable

- Care is needed in selecting values of variables to be recorded in an investigation. A trial run will help identify appropriate values to be recorded, such as the number of repeated readings needed and their range and interval. For example, in an investigation of the effect of temperature on enzyme activity it is necessary to:
  - use a sufficient amount of enzyme so that its activity can be detected
  - use a sensible range of temperatures
  - have readings 'closer together' (at smaller intervals) where a change in pattern is detected.

Accuracy and precision.

- Readings should be repeated to improve the reliability of the data. An accurate measurement is one which is close to the true value.
- The design of an investigation must provide data with sufficient accuracy. For example, measures of blood alcohol levels must be accurate enough to be able to determine whether the person is legally fit to drive.
- The design of an investigation must provide data with sufficient precision to form a valid conclusion. For example, in an investigation into the bounce of different balls, less precision is needed to tell if a tennis ball bounces higher than a squash ball than if you wanted to distinguish between the bounce of two very similar tennis balls.

10.5 Making measurements

When making measurements we must consider such issues as inherent variation due to variables that have not been controlled, human error and the characteristics of the instruments used. Evidence should be evaluated with the reliability and validity of the measurements that have been made in mind.

A single measurement

- There will always be some variation in the actual value of a variable no matter how hard we try to repeat an event. For instance, if a ball is dropped and doesn't land on exactly the same point on its surface there will be a slight difference in the rebound height.
- When selecting an instrument, it is necessary to consider the accuracy inherent in the instrument and the way it has to be used. For example, expensive thermometers are likely to give a reading nearer to the true reading and to be more accurately calibrated.
- The sensitivity of an instrument refers to the smallest change in a value that can be detected. For example, bathroom scales are not sensitive enough to detect the weekly changes in the mass of a baby, whereas scales used by a midwife are sensitive enough to permit a growth chart to be plotted.
- Even when an instrument is used correctly, human error may occur which could produce random differences in repeated readings or a systematic shift from the true value which could, for instance, occur due to incorrect use or poor calibration.
- Random error can result from inconsistent application of a technique. Systematic error can result from consistent misapplication of a technique.
- Any anomalous values should be examined to try and identify the cause and, if a product of a poor measurement, ignored.

10.6 Presenting data

To explain the relationship between two or more variables, data may be presented in such a way as to make the patterns more evident. There is a link between the type of graph used and the type of variable represented. The choice of graphical representation depends upon the type of variable they represent.

Candidates should know and understand

- The range of the data refers to the maximum and minimum values.
- The mean (or average) of the data refers to the sum of all the measurements divided by the number of measurements taken.
- Tables are an effective means of displaying data but are limited in how they portray the design of an investigation.
- Bar charts can be used to display data in which the independent variable is categoric and the dependent variable continuous.
- Line graphs can be used to display data in which both the independent and dependent variables are continuous.
- Scattergrams can be used to show an association between two variables (eg water content of soil and height of plants).

10.7 Using data to draw conclusions

The patterns and relationships observed in data represent the behaviour of the variables in an investigation. However, it is necessary to look at patterns and relationships between variables with the limitations of the data in mind in order to draw conclusions.

Candidates should know and understand

- Patterns in tables and graphs can be used to identify anomalous data that require further consideration.
- A line of best fit can be used to illustrate the underlying relationship between variables.
- The relationships that exist between variables can be linear (positive or negative, eg height of wax remaining in a candle and time it has been burning) or directly proportional (eg extension of a spring and applied force). On a graph, the relationship could show as a curve (eg velocity against time for a falling object).
- Conclusions must be limited by the data available and not go beyond them. For example, the beneficial effects of a new drug may be limited to the sample used in the tests (younger men perhaps) and not the entire population.

Evaluation

- In evaluating a whole investigation the reliability and validity of the data obtained must be considered. The reliability of an investigation can be increased by looking at data obtained from secondary sources, through using an alternative method as a check and by requiring that the results are reproducible by others.

10.8 Societal aspects of scientific evidence

A judgement or decision relating to social-scientific issues may not be based on evidence alone, as other societal factors may be relevant.

Candidates should know and understand

- The credibility of the evidence is increased if a balanced account of the data is used rather than a selection from it which supports a particular pre-determined stance.
- Evidence must be scrutinised for any potential bias of the experimenter, such as funding sources or allegiances.
- Evidence can be accorded undue weight, or dismissed too lightly, simply because of its political significance. If the consequences of the evidence might provoke public or political disquiet, the evidence may be downplayed.
- The status of the experimenter may influence the weight placed on evidence; for instance, academic or professional status, experience and authority. It is more likely that the advice of an eminent scientist will be sought to help provide a solution to a problem than that of a scientist with less experience.
- Scientific knowledge gained through investigations can be the basis for technological developments.
- Scientific and technological developments offer different opportunities for exploitation to different groups of people.
- The uses of science and technology developments can raise ethical, social, economic and environmental issues.
- Decisions are made by individuals and by society on issues relating to science and technology.

10.9 Limitations of scientific evidence

Science can help us in many ways but it cannot supply all the answers.

We are still finding out about things and developing our scientific knowledge. There are some questions that we cannot answer, maybe because we do not have enough reliable and valid evidence. For example, it is generally accepted that the extra carbon dioxide in the air (from burning fossil fuels) is linked to global warming, but some scientists think there is not sufficient evidence and that there are other factors involved.

And there are some questions that science cannot answer at all. These tend to be questions where beliefs and opinions are important or where we cannot collect reliable and valid scientific evidence. For example, science may be able to answer questions that start 'How can we ..' such as 'How can we clone babies?' but questions starting 'Should we ..' such as 'Should we clone babies?' are for society to answer.

11 Unit Biology 2

At the beginning of each sub-section, activities are stated which develop candidates' skills, knowledge and understanding of how science works. Details are then given of the substantive contexts in which these skills, knowledge and understanding should be set. It is expected that, where appropriate, teachers will adopt a practical approach enabling candidates to develop skills in addition to procedural knowledge and understanding.

11.1 What are animals and plants built from?

All living things are made up of cells. The structures of different types of cells are related to their functions.

Candidates should use their skills, knowledge and understanding of how science works:

- to relate the structure of different types of cells to their function in a tissue or an organ.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Most human cells like most other animal cells have the following parts:
  - a nucleus which controls the activities of the cell
  - cytoplasm in which most of the chemical reactions take place
  - a cell membrane which controls the passage of substances in and out of the cell
  - mitochondria, which is where most energy is released in respiration
  - ribosomes, which is where protein synthesis occurs.
- Plant cells also have a cell wall which strengthens the cell. Plant cells often have:
  - chloroplasts which absorb light energy to make food
  - a permanent vacuole filled with cell sap.
- The chemical reactions inside cells are controlled by enzymes.
- Cells may be specialised to carry out a particular function.

11.2 How do dissolved substances get into and out of cells?

To get into or out of cells, dissolved substances have to cross the cell membranes.

Candidates skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Dissolved substances can move into and out of cells by diffusion and osmosis.
- Diffusion is the spreading of the particles of a gas, or of any substance in solution, resulting in a net movement from a region where they are of a higher concentration. The greater the difference in concentration, the faster the rate of diffusion. Oxygen required for respiration passes through cell membranes by diffusion.
- Water often moves across boundaries by osmosis. Osmosis is the diffusion of water from a dilute to a more concentrated solution through a partially permeable membrane that allows the passage of water molecules.

- Differences in the concentrations of the solutions inside and outside a cell cause water to move into or out of the cell by osmosis.

11.3 How do plants obtain the food they need to live and grow?

Green plants use light energy to make their own food. They obtain the raw materials they need to make this food from the air and the soil.

Candidates should use their skills, knowledge and understanding of how science works:

- to interpret data showing how factors affect the rate of photosynthesis and evaluate the benefits of artificially manipulating the environment in which plants are grown.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Photosynthesis is summarised by the equation:

  carbon dioxide + water (+ light energy) → glucose + oxygen

- During photosynthesis:
  - light energy is absorbed by a green substance called chlorophyll which is found in chloroplasts in some plant cells
  - this energy is used by converting carbon dioxide and water into sugar (glucose)
  - oxygen is released as a by-product.
- The rate of photosynthesis may be limited by:
  - low temperature
  - shortage of carbon dioxide
  - shortage of light.
- Light, temperature and the availability of carbon dioxide interact and in practice any one of them may be the factor that limits photosynthesis.
- The glucose produced in photosynthesis may be converted into insoluble starch for storage. Plant cells use some of the glucose produced during photosynthesis for respiration.
- Plant roots absorb mineral salts including nitrates needed for healthy growth. For healthy growth plants need mineral ions including:
  - nitrate – for producing amino acids which are then used to form proteins
  - magnesium – which is needed for chlorophyll production.
- The symptoms shown by plants growing in conditions where mineral ions are deficient include:
  - stunted growth if nitrate ions are deficient
  - yellow leaves if magnesium ions are deficient.

11.4 What happens to energy and biomass at each stage in a food chain?

By observing the numbers and sizes of the organisms in food chains we can find out what happens to energy and biomass as it passes along the food chain.

Candidates should use their skills, knowledge and understanding of how science works: ?

- to interpret pyramids of biomass and construct them from appropriate information
- to evaluate the positive and negative effects of managing food production and distribution, and to be able to recognise that practical solutions to human needs may require compromise between competing priorities.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Radiation from the Sun is the source of energy for most communities of living organisms. Green plants capture a small part of the solar energy which reaches them. This energy is stored in the substances which make up the cells of the plants.
- The mass of living material (biomass) at each stage in a food chain is less than it was at the previous stage. The biomass at each stage can be drawn to scale and shown as a pyramid of biomass.
- At each stage in a food chain, less material and less energy are contained in the biomass of the organisms. This means that the efficiency of food production can be improved by reducing the number of stages in food chains.
- The efficiency of food production can also be improved by restricting energy loss from food animals by limiting their movement and by controlling the temperature of their surroundings.
- The amounts of material and energy contained in the biomass of organisms is reduced at each successive stage in a food chain because:
  - some materials and energy are always lost in the organisms' waste materials
  - respiration supplies all the energy needs for living processes, including movement. Much of this energy is eventually lost as heat to the surroundings
  - these losses are especially large in mammals and birds whose bodies must be kept at a constant temperature which is usually higher than that of their surroundings.

11.5 What happens to the waste material produced by plants and animals?

Many trees shed their leaves each year and most animals produce droppings at least once a day. All plants and animals also eventually die. Microbes play an important part in decomposing this material so that it can be used again by plants. The same material is recycled over and over.

Candidates skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Living things remove materials from the environment for growth and other processes. These materials are returned to the environment either in waste materials or when living things die and decay.

- Materials decay because they are broken down (digested) by micro-organisms. Microorganisms digest materials faster in warm, moist conditions. Many microorganisms are also more active when there is plenty of oxygen.
- The decay process releases substances which plants need to grow.
- In a stable community, the processes which remove materials are balanced by processes which return materials. The materials are constantly cycled.
- The constant cycling of carbon is called the carbon cycle. In the carbon cycle:
  - carbon dioxide is removed from the environment by green plants for photosynthesis. The carbon from the carbon dioxide is used to make carbohydrates, fats and proteins which make up the body of plants
  - some of the carbon dioxide is returned to the atmosphere when green plants respire
  - when green plants are eaten by animals and these animals are eaten by other animals, some of the carbon becomes part of the fats and proteins which make up their bodies
  - when animals respire some of this carbon becomes carbon dioxide and is released into the atmosphere
  - when plants and animals die, some animals and microorganisms feed on their bodies. Carbon is released into the atmosphere as carbon dioxide when these organisms respire
  - by the time the microorganisms and detritus feeders have broken down the waste products and dead bodies of organisms in ecosystems and cycled the materials as plant nutrients, all the energy originally captured by green plants has been transferred.

11.6 What are enzymes and what are some of their functions?

Enzymes are biological catalysts that have many functions both inside and outside cells.

Candidates should use their skills, knowledge and understanding of how science works:

- to evaluate the advantages and disadvantages of using enzymes in home and industry.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Catalysts increase the rate of chemical reactions. Biological catalysts are called enzymes.
- Enzymes are protein molecules made up of long chains of amino acids. These long chains are folded to produce a special shape which enables other molecules to fit into the enzyme. This shape is vital for the enzyme's function. High temperatures destroy this special shape. Different enzymes work best at different pH values.
- Enzymes inside living cells catalyse processes such as respiration, protein synthesis and photosynthesis.

- During aerobic respiration (respiration which uses oxygen) chemical reactions occur which:
  - use glucose (a sugar) and oxygen
  - release energy.
- Most of the reactions in aerobic respiration take place inside mitochondria.
- Aerobic respiration is summarised by the equation:

  glucose + oxygen → carbon dioxide + water (+ energy)

- The energy that is released during respiration is used:
  - to build up larger molecules using smaller ones
  - in animals, to enable muscles to contract
  - in mammals and birds, to maintain a steady body temperature in colder surroundings
  - in plants, to build up sugars, nitrates and other nutrients into amino acids which are then built up into proteins.
- Enzymes inside living cells catalyse the reactions that build up amino acids and proteins.
- Some enzymes work outside the body cells. The digestive enzymes are produced by specialised cells in glands and in the lining of the gut. The enzymes then pass out of the cells into the gut where they come into contact with food molecules. They catalyse the breakdown of large molecules into smaller molecules:
  - the enzyme amylase is produced in the salivary glands, the pancreas and the small intestine. This enzyme catalyses the breakdown of starch into sugars in the mouth and small intestine
  - protease enzymes are produced by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of proteins into amino acids in the stomach and the small intestine
  - lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of lipids (fats and oils) into fatty acids and glycerol in the small intestine
  - the stomach also produces hydrochloric acid. The enzymes in the stomach work most effectively in these acid conditions
  - the liver produces bile which is stored in the gall bladder before being released into the small intestine. Bile neutralises the acid that was added to food in the stomach. This provides alkaline conditions in which enzymes in the small intestine work most effectively.
- Some microorganisms produce enzymes which pass out of the cells. These enzymes have many uses in the home and in industry.
- In the home, biological detergents may contain protein-digesting and fat-digesting enzymes (proteases and lipases).

- In industry:
  - proteases are used to 'pre-digest' the protein in some baby foods
  - carbohydrases are used to convert starch into sugar syrup
  - isomerase is used to convert glucose syrup into fructose syrup, which is much sweeter and therefore can be used in smaller quantities in slimming foods.

11.7 How do our bodies keep internal conditions constant?

Humans need to remove waste products from their bodies to keep their internal environment relatively constant.

Candidates should use their skills, knowledge and understanding of how science works:

- to evaluate the data from the experiments by Banting and Best which led to the discovery of insulin
- to evaluate modern methods of treating diabetes.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Waste products which have to be removed from the body include:
  - carbon dioxide produced by respiration – most of this leaves the body via the lungs when we breathe out
  - urea produced in the liver by the breakdown of excess amino acids – this is removed by the kidneys in the urine, which is temporarily stored in the bladder.
- Internal conditions which are controlled include the water content of the body, the ion content of the body, temperature and blood sugar levels.
- If the water or ion content of the body is wrong, too much water may move into or out of the cells and damage them. Water and ions enter the body when we eat and drink.
- Sweating helps to cool the body. More water is lost when it is hot, and more water has to be taken as drink or in food to balance this loss.
- Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of blood flowing through the brain. Also temperature receptors in the skin send impulses to the centre giving information about skin temperature.

HT ❖ If the core body temperature is too high:
  - blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost
  - sweat glands release more sweat which cools the body as it evaporates.

HT ❖ If the core body temperature is too low:
  - blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries
  - muscles may 'shiver' – their contraction needs respiration which releases some energy as heat.

- The blood glucose concentration of the body is monitored and controlled by the pancreas. The pancreas produces the hormone insulin which allows glucose to move from the blood into the cells.
- Diabetes is a disease in which a person's blood glucose concentration may rise to a fatally high level because the pancreas does not produce enough of the hormone insulin. Diabetes may be treated by careful attention to diet and by injecting insulin into the body.

11.8 Which human characteristics show a simple pattern of inheritance?

What sex human beings are, and whether or not they inherit certain diseases, show a very simple pattern of inheritance.

Candidates should use their skills, knowledge and understanding of how science works:

- to explain why Mendel proposed the idea of separately inherited factors and why the importance of this discovery was not recognised until after his death
- to interpret genetic diagrams
- [?] to make informed judgements about the social and ethical issues concerning the use of stem cells from embryos in medical research and treatments
- to make informed judgements about the economic, social and ethical issues concerning embryo screening that they have studied or from information that is presented to them
- HT ❖ to predict and/or explain the outcome of crosses between individuals for each possible combination of dominant and recessive alleles of the same gene
- HT ❖ to construct genetic diagrams.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- In body cells the chromosomes are normally found in pairs. Body cells divide by mitosis to produce additional cells during growth or to produce replacement cells. Body cells have two sets of genetic information; sex cells (gametes) have only one set.
- HT ❖ Cells in reproductive organs – testes and ovaries in humans - divide to form gametes.
- HT ❖ The type of cell division in which a cell divides to form gametes is called meiosis.

  When a cell divides to form gametes:
  - copies of the chromosomes are made
  - then the cell divides twice to form four gametes, each with a single set of chromosomes.
- When gametes join at fertilisation, a single body cell with new pairs of chromosomes is formed. A new individual then develops by this cell repeatedly dividing by mitosis.

- Most types of animal cells differentiate at an early stage whereas many plant cells retain the ability to differentiate throughout life. In mature animals, cell division is mainly restricted to repair and replacement. Cells from human embryos and adult bone marrow, called stem cells, can be made to differentiate into many different types of cells eg nerve cells. Treatment with these cells may help conditions such as paralysis.
- The cells of the offspring produced by asexual reproduction are produced by mitosis from the parental cells. They contain the same genes as the parents.
- Sexual reproduction gives rise to variation because, when gametes fuse, one of each pair of alleles comes from each parent.
- In human body cells, one of the 23 pairs of chromosomes carries the genes which determine sex. In females the sex chromosomes are the same (XX) in males the sex chromosomes are different (XY).
- Some characteristics are controlled by a single gene. Each gene may have different forms called alleles.
- An allele which controls the development of a characteristic when it is present on only one of the chromosomes is a dominant allele.
- An allele which controls the development of characteristics only if the dominant allele is not present is a recessive allele.
- Chromosomes are made up of large molecules of DNA (deoxyribose nucleic acid). A gene is a small section of DNA.

HT ❖ Each gene codes for a particular combination of amino acids which make a specific protein.

- Each person (apart from identical twins) has unique DNA. This can be used to identify individuals in a process known as DNA fingerprinting.
- Some disorders are inherited:
  - Huntington's disease – a disorder of the nervous system – is caused by a dominant allele of a gene and can therefore be passed on by only one parent who has the disorder
  - cystic fibrosis – a disorder of cell membranes – must be inherited from both parents. The parents may be carriers of the disorder without actually having the disorder themselves. It is caused by a recessive allele of a gene and can therefore be passed on by parents, neither of whom has the disorder.

  (Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.)
- Embryos can be screened for the alleles that cause these and other genetic disorders.

12 Unit Chemistry 2

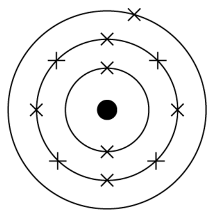
At the beginning of each sub-section, activities are stated which develop candidates' skills, knowledge and understanding of how science works. Details are then given of the substantive contexts in which these skills, knowledge and understanding should be set. It is expected that, where appropriate, teachers will adopt a practical approach enabling candidates to develop skills in addition to procedural knowledge and understanding.

12.1 How do sub-atomic particles help us to understand the structure of substances?

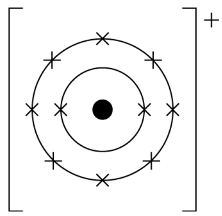
Simple particle theory is developed in this unit to include atomic structure and bonding. The arrangement of electrons in atoms can be used to explain what happens when elements react and how atoms join together to form different types of substances.

Candidates should use their skills, knowledge and understanding of how science works:

- to represent the electronic structure of the first twenty elements of the periodic table in the following forms:

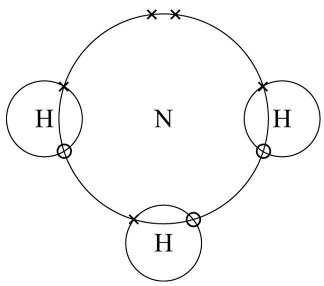
for sodium  and 2,8,1

- to represent the electronic structure of the ions in sodium chloride, magnesium oxide and calcium chloride in the following forms:

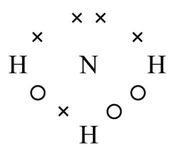
for sodium ion (Na^+)  and $[2,8]^+$

- to represent the covalent bonds in molecules such as water, ammonia, hydrogen, hydrogen chloride, chlorine, methane and oxygen and in giant structures such as diamond and silicon dioxide in the following forms:

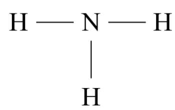
for ammonia (NH_3)



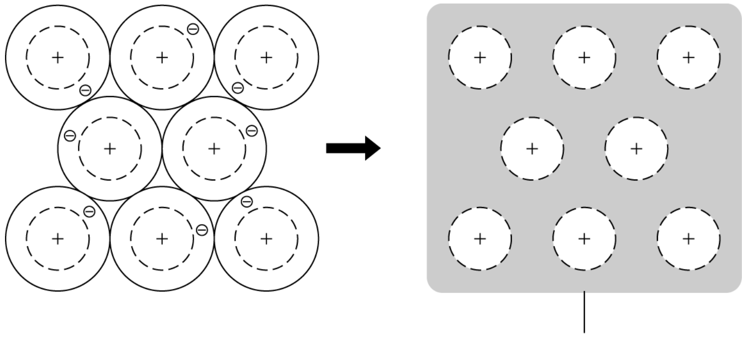
and/or



and/or



HT ❖ to represent the bonding in metals in the following form:



HT ❖ to write balanced chemical equations for reactions.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Atoms have a small central nucleus made up of protons and neutrons around which there are electrons.
- The relative electrical charges are as shown:

Name of particle	Charge
Proton	+1
Neutron	0
Electron	–1

- In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.
- All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons.
- The number of protons in an atom is called its atomic number (proton number). Atoms are arranged in the modern periodic table in order of their atomic number (proton number).
- Electrons occupy particular energy levels. Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available energy levels (innermost available shells). (Though only energy levels are referred to throughout this specification, candidates may answer in terms of shells if they prefer.)
- Elements in the same group in the periodic table have the same number of electrons in the highest energy levels (outer electrons).
- Compounds are substances in which atoms of two, or more, elements are not just mixed together but chemically combined.
- Chemical bonding involves either transferring or sharing electrons in the highest occupied energy levels (shells) of atoms.

- When atoms form chemical bonds by transferring electrons, they form ions. Atoms that lose electrons become positively charged ions. Atoms that gain electrons become negatively charged ions. Ions have the electronic structure of a noble gas (Group 0).
- The elements in Group 1 of the periodic table, the alkali metals, have similar chemical properties. They all react with non-metal elements to form ionic compounds in which the metal ion has a single positive charge.
- The elements in Group 7 of the periodic table, the halogens, have similar chemical properties. They react with the alkali metals to form ionic compounds in which the halide ions have a single negative charge.
- An ionic compound is a giant structure of ions. Ionic compounds are held together by strong forces of attraction between oppositely charged ions. These forces act in all directions in the lattice and this is called ionic bonding.
- When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. Some covalently bonded substances consist of simple molecules such as H_2, Cl_2, O_2, HCl, H_2O and CH_4. Others have giant covalent structures (macromolecules), such as diamond and silicon dioxide.

HT ❖ Metals consist of giant structures of atoms arranged in a regular pattern. The electrons in the highest occupied energy levels (outer shell) of metal atoms are delocalised and so free to move through the whole structure. This corresponds to a structure of positive ions with electrons between the ions holding them together by strong electrostatic attractions.

12.2 How do structures influence the properties and uses of substances?

Substances that have simple molecular, giant ionic and giant covalent structures have very different properties. Ionic, covalent and metallic bonds are strong. The forces between molecules are weaker, eg in carbon dioxide and iodine. Nanomaterials have new properties because of their very small size.

Candidates should use their skills, knowledge and understanding of how science works:

- to relate the properties of substances to their uses
- to suggest the type of structure of a substance given its properties
- to evaluate developments and applications of new materials, eg nanomaterials, smart materials.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Substances that consist of simple molecules are gases, liquids or solids that have relatively low melting points and boiling points.

HT ❖ Substances that consist of simple molecules have only weak forces between the molecules (intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils.

- Substances that consist of simple molecules do not conduct electricity because the molecules do not have an overall electric charge.

- Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces in all directions between oppositely charged ions. These compounds have high melting points and high boiling points.
- When melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move and carry the current.
- Atoms that share electrons can also form giant structures or macromolecules. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures (lattices) of atoms. All the atoms in these structures are linked to other atoms by strong covalent bonds and so they have very high melting points.
- In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure, so diamond is very hard.
- In graphite, each carbon atom bonds to three others, forming layers. The layers are free to slide over each other and so graphite is soft and slippery.

HT ❖ In graphite, one electron from each carbon atom is delocalised. These delocalised electrons allow graphite to conduct heat and electricity.

HT ❖ Metals conduct heat and electricity because of the delocalised electrons in their structures.

- The layers of atoms in metals are able to slide over each other and so metals can be bent and shaped.
- Nanoscience refers to structures that are 1-100 nm in size, of the order of a few hundred atoms. Nanoparticles show different properties to the same materials in bulk and have a high surface area to volume ratio, which may lead to the development of new computers, new catalysts, new coatings, highly selective sensors and stronger and lighter construction materials.

12.3 How much can we make and how much do we need to use?

The relative masses of atoms can be used to calculate how much to react and how much we can produce, because no atoms are gained or lost in chemical reactions. In industrial processes, atom economy is important for sustainable development.

Candidates should use their skills, knowledge and understanding of how science works:

- to calculate chemical quantities involving formula mass (M_r) and percentages of elements in compounds

HT ❖ to calculate chemical quantities involving empirical formulae, reacting masses and percentage yield

? HT ❖ to calculate the atom economy for industrial processes and be able to evaluate sustainable development issues related to this economy.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Atoms can be represented as shown:

  Mass number 23
  Na
  Atomic Number 11

- The relative masses of protons, neutrons and electrons are:

Name of particle	Mass
Proton	1
Neutron	1
Electron	Very small

- The total number of protons and neutrons in an atom is called its mass number.
- Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element.

HT ❖ The relative atomic mass of an element (A_r) compares the mass of atoms of the element with the ^{12}C isotope. It is an average value for the isotopes of the element.

- The relative formula mass (M_r) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula.
- The relative formula mass of a substance, in grams, is known as one mole of that substance.
- The percentage of an element in a compound can be calculated from the relative mass of the element in the formula and the relative formula mass of the compound.

HT ❖ The masses of reactants and products can be calculated from balanced symbol equations.

- Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because:
  - the reaction may not go to completion because it is reversible
  - some of the product may be lost when it is separated from the reaction mixture
  - some of the reactants may react in ways different to the expected reaction.

HT ❖ The amount of a product obtained is known as the yield. When compared with the maximum theoretical amount as a percentage, it is called the percentage yield.

- The atom economy (atom utilisation) is a measure of the amount of starting materials that end up as useful products. It is important for sustainable development and for economical reasons to use reactions with high atom economy.
- In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented:

$$A + B \rightleftharpoons C + D$$

For example:

ammonium chloride ⇌ ammonia + hydrogen chloride

HT ❖ When a reversible reaction occurs in a closed system, equilibrium is reached when the reactions occur at exactly the same rate in each direction.

HT ❖ The relative amounts of all the reacting substances at equilibrium depend on the conditions of the reaction.

- Although reversible reactions may not go to completion, they can still be used efficiently in continuous industrial processes, such as the Haber process that is used to manufacture ammonia.
- The raw materials for the Haber process are nitrogen and hydrogen. Nitrogen is obtained from the air and hydrogen may be obtained from natural gas or other sources.
- The purified gases are passed over a catalyst of iron at a high temperature (about 450 °C) and a high pressure (about 200 atmospheres). Some of the hydrogen and nitrogen reacts to form ammonia. The reaction is reversible so ammonia breaks down again into nitrogen and hydrogen:

  nitrogen + hydrogen ⇌ ammonia

- On cooling, the ammonia liquefies and is removed. The remaining hydrogen and nitrogen is re-cycled.

HT ❖ The reaction conditions are chosen to produce a reasonable yield of ammonia quickly.

12.4 How can we control the rates of chemical reactions?

Being able to speed up or slow down chemical reactions is important in everyday life and in industry. Changes in temperature, concentration of solutions, surface area of solids and the presence of catalysts all affect the rates of reactions.

Candidates should use their skills, knowledge and understanding of how science works:

- to interpret graphs showing the amount of product formed (or reactant used up) with time, in terms of the rate of the reaction
- to explain and evaluate the development, advantages and disadvantages of using catalysts in industrial processes.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The rate of a chemical reaction can be found by measuring the amount of a reactant used or the amount of product formed over time:

$$\text{Rate of reaction} = \frac{\text{Amount of reactant used or amount of product formed}}{\text{Time}}$$

- The rate of a chemical reaction increases:
  - if the temperature increases
  - if the concentration of dissolved reactants or the pressure of gases increases
  - if solid reactants are in smaller pieces (greater surface area)
  - if a catalyst is used.

- Chemical reactions can only occur when reacting particles collide with each other and with sufficient energy. The minimum amount of energy particles must have to react is called the activation energy.
- Increasing the temperature increases the speed of the reacting particles so that they collide more frequently and more energetically. This increases the rate of reaction.
- Increasing the concentration of reactants in solutions and increasing the pressure of reacting gases also increases the frequency of collisions and so increases the rate of reaction.

HT ❖ Concentrations of solutions are given in moles per cubic decimetre (mol/dm^3). Equal volumes of solutions of the same molar concentration contain the same number of moles of solute, ie the same number of particles.

HT ❖ Equal volumes of gases at the same temperature and pressure contain the same number of molecules. (Candidates will not be expected to find concentrations of solutions or volumes of gases in this Unit.)

- Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts.
- Catalysts are important in increasing the rates of chemical reactions used in industrial processes to reduce costs.

12.5 Do chemical reactions always release energy?

Chemical reactions involve energy transfers. Many chemical reactions involve the release of energy. For other chemical reactions to occur, energy must be supplied. In industrial processes, energy requirements and emissions need to be considered both for economic reasons and for sustainable development.

Candidates should use their skills, knowledge and understanding of how science works:

- to describe the effects of changing the conditions of temperature and pressure on a given reaction or process
- to evaluate the conditions used in industrial processes in terms of energy requirements.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When chemical reactions occur, energy is transferred to or from the surroundings.
- An exothermic reaction is one that transfers energy, often as heat, to the surroundings. Examples of exothermic reactions include combustion, many oxidation reactions and neutralisation.
- An endothermic reaction is one that takes in energy, often as heat, from the surroundings. Endothermic reactions include thermal decompositions.
- If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example:

$$\text{hydrated copper sulfate (blue)} \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}} \text{anhydrous copper sulfate (white)} + \text{water}$$

The reverse reaction can be used as a test for water.

HT ❖ When a reversible reaction occurs in a closed system, equilibrium is reached when the reactions occur at exactly the same rate in each direction.

HT ❖ The relative amounts of all the reacting substances at equilibrium depend on the conditions of the reaction.

HT ❖ If the temperature is raised, the yield from the endothermic reaction increases and the yield from the exothermic reaction decreases.

HT ❖ If the temperature is lowered, the yield from the endothermic reaction decreases and the yield from the exothermic reaction increases.

HT ❖ In gaseous reactions, an increase in pressure will favour the reaction that produces the least number of molecules as shown by the symbol equation for that reaction.

HT ❖ These factors, together with reaction rates, are important when determining the optimum conditions in industrial processes, including the Haber process.

- It is important for sustainable development as well as economic reasons to minimise energy requirements and energy wasted in industrial processes. Non-vigorous conditions mean less energy is used and less is released into the environment.

12.6 How can we use ions in solutions?

Ionic compounds have many uses and can provide other substances. Electrolysis is used to produce alkalis and elements such as chlorine and hydrogen. Oxidation-reduction reactions do not just involve oxygen. Soluble salts can be made from acids and insoluble salts can be made from solutions of ions.

Candidates should use their skills, knowledge and understanding of how science works:

- to predict the products of electrolysing solutions of ions
- to suggest methods to make a named salt
- to explain and evaluate processes that use the principles described in this unit

HT ❖ to complete and balance supplied half equations for the reactions occurring at the electrodes during electrolysis.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The state symbols in equations are (s), (l), (g) and (aq).
- When an ionic substance is melted or dissolved in water, the ions are free to move about within the liquid or solution.
- Passing an electric current through ionic substances that are molten or in solution breaks them down into elements. This process is called electrolysis.
- During electrolysis, positively charged ions move to the negative electrode, and negatively charged ions move to the positive electrode.

- At the negative electrode, positively charged ions gain electrons (reduction) and at the positive electrode, negatively charged ions lose electrons (oxidation).
- If there is a mixture of ions, the products formed depend on the reactivity of the elements involved.

HT ❖ Reactions at electrodes can be represented by half equations, for example:

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

- The electrolysis of sodium chloride solution produces hydrogen and chlorine. Sodium hydroxide solution is also produced. These are important reagents for the chemical industry.
- Copper can be purified by electrolysis using a positive electrode made of the impure copper and a negative electrode of pure copper in a solution containing copper ions.
- Insoluble salts can be made by mixing appropriate solutions of ions so that a precipitate is formed. Precipitation can be used to remove unwanted ions from solutions, for example in treating water for drinking or in treating effluent.
- Soluble salts can be made from acids by reacting them with:
  - metals - not all metals are suitable, some are too reactive and others are not reactive enough
  - insoluble bases – the base is added to the acid until no more will react and the excess solid is filtered off
  - alkalis - an indicator can be used to show when the acid and alkali have completely reacted to produce a salt solution.
- Salt solutions can be crystallised to produce solid salt.
- Metal oxides and hydroxides are bases. Soluble hydroxides are called alkalis.
- The particular salt produced in any reaction between an acid and a base or alkali depends on:
  - the acid used (hydrochloric acid produces chlorides, nitric acid produces nitrates, sulfuric acid produces sulfates)
  - the metal in the base or alkali.
- Ammonia dissolves in water to produce an alkaline solution. It is used to produce ammonium salts. Ammonium salts are important as fertilisers.
- Hydrogen ions $H^+(aq)$ make solutions acidic and hydroxide ions $OH^-(aq)$ make solutions alkaline. The pH scale is a measure of the acidity or alkalinity of a solution.
- In neutralisation reactions, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation:

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

13 Unit Physics 2

At the beginning of each sub-section, activities are stated which develop candidates' skills, knowledge and understanding of how science works. Details are then given of the substantive contexts in which these skills, knowledge and understanding should be set. It is expected that, where appropriate, teachers will adopt a practical approach enabling candidates to develop skills in addition to procedural knowledge and understanding.

13.1 How can we describe the way things move?

Even when things are moving in a straight line, describing their movement is not easy. They can move with different speeds and can also change their speed and/or direction (accelerate). Graphs can help us to describe the movement of the body. These may be distance-time graphs or velocity-time graphs.

Candidates should use their skills, knowledge and understanding of how science works:

- to construct distance-time graphs for a body moving in a straight line when the body is stationary or moving with a constant speed
- to construct velocity-time graphs for a body moving with a constant velocity or a constant acceleration
- HT ❖ to calculate the speed of a body from the slope of a distance-time graph.
- HT ❖ to calculate the acceleration of a body from the slope of a velocity-time graph
- HT ❖ to calculate the distance travelled by a body from a velocity-time graph.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The slope of a distance-time graph represents speed.
- The velocity of a body is its speed in a given direction.
- The acceleration of a body is given by:

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

- The slope of a velocity-time graph represents acceleration.
- The area under a velocity-time graph represents distance travelled.

13.2 How do we make things speed up or slow down?

To change the speed of a body an unbalanced force must act on it.

Candidates should use their skills, knowledge and understanding of how science works:

- to draw and interpret velocity-time graphs for bodies that reach terminal velocity, including a consideration of the forces acting on the body
- to calculate the weight of a body using:

$$\underset{\text{(newton, N)}}{\text{weight}} = \underset{\text{(kilogram, kg)}}{\text{mass}} \times \underset{\text{(newton/kilogram, N/kg)}}{\text{gravitational field strength}}$$

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Whenever two bodies interact, the forces they exert on each other are equal and opposite.
- A number of forces acting on a body may be replaced by a single force which has the same effect on the body as the original forces all acting together. The force is called the resultant force.
- If the resultant force acting on a stationary body is zero the body will remain stationary.
- If the resultant force acting on a stationary body is not zero the body will accelerate in the direction of the resultant force.
- If the resultant force acting on a moving body is zero the body will continue to move at the same speed and in the same direction.
- If the resultant force acting on a moving body is not zero the body will accelerate in the direction of the resultant force.
- Force, mass and acceleration are related by the equation:

resultant force	=	mass	×	acceleration
(newton, N)		(kilogram, kg)		(metre/second^2, m/s^2)

- When a vehicle travels at a steady speed the frictional forces balance the driving force.
- The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance.
- The stopping distance of a vehicle depends on the distance the vehicle travels during the driver's reaction time and the distance it travels under the braking force.
- A driver's reaction time can be affected by tiredness, drugs and alcohol.
- A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle.
- The faster a body moves through a fluid the greater the frictional force which acts on it.
- A body falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force on the body will be zero and it will fall at its terminal velocity.

13.3 What happens to the movement energy when things speed up or slow down?

When a body speeds up or slows down, its kinetic energy increases or decreases. The forces which cause the change in speed do so by transferring energy to, or from, the body.

Candidates should use their skills, knowledge and understanding of how science works:

- to discuss the transformation of kinetic energy to other forms of energy in particular situations.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When a force causes a body to move through a distance, energy is transferred and work is done.
- Work done = energy transferred.
- The amount of work done, force and distance are related by the equation:

work done (joule, J) = force applied (newton, N) × distance moved in direction of force (metre, m)

- Work done against frictional forces is mainly transformed into heat.
- For an object that is able to recover its original shape, elastic potential is the energy stored in the object when work is done on the object to change its shape.
- The kinetic energy of a body depends on its mass and its speed.

HT ❖ Calculate the kinetic energy of a body using the equation:.

kinetic energy (joule, J) = ½ × mass (kilogram, kg) × speed^2 ((metre/second)^2, $(m/s)^2$)

13.4 What is momentum?

The faster a body is moving the more kinetic energy it has. It also has momentum. When working out what happens to bodies as a result of explosions or collisions it is more useful to think in terms of momentum than in terms of energy.

Candidates should use their skills, knowledge and understanding of how science works:

- to use the conservation of momentum (in one dimension) to calculate the mass, velocity or momentum of a body involved in a collision or explosion
- to use the ideas of momentum to explain safety features.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Momentum, mass and velocity are related by the equation:

momentum (kilogram metre/second, kg m/s) = mass (kilogram, kg) × velocity (metre/second, m/s)

- Momentum has both magnitude and direction.
- When a force acts on a body that is moving, or able to move, a change in momentum occurs.
- Momentum is conserved in any collision/explosion provided no external forces act on the colliding/exploding bodies.

HT ❖ Force, change in momentum and time taken for the change are related by the equation:

$$\text{force (newton, N)} = \frac{\text{change in momentum (kilogram metre/second, kg(m/s))}}{\text{time taken for the change (second, s)}}$$

13.5 What is static electricity, how can it be used and what is the connection between static electricity and electric currents?

Static electricity can be explained in terms of electrical charges. When electrical charges move we get an electric current.

Candidates should use their skills, knowledge and understanding of how science works:

- to explain why static electricity is dangerous in some situations and how precautions can be taken to ensure that the electrostatic charge is discharged safely
- to explain how static electricity can be useful.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material onto the other.
- The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge.
- When two electrically charged bodies are brought together they exert a force on each other.
- Two bodies that carry the same type of charge repel. Two bodies that carry different types of charge attract.
- Electrical charges can move easily through some substances, eg metals.
- The rate of flow of electrical charge is called the current.
- A charged body can be discharged by connecting it to earth with a conductor. Charge then flows through the conductor.

HT ❖ The greater the charge on an isolated body the greater the potential difference between the body and earth. If the potential difference becomes high enough a spark may jump across the gap between the body and any earthed conductor which is brought near it.

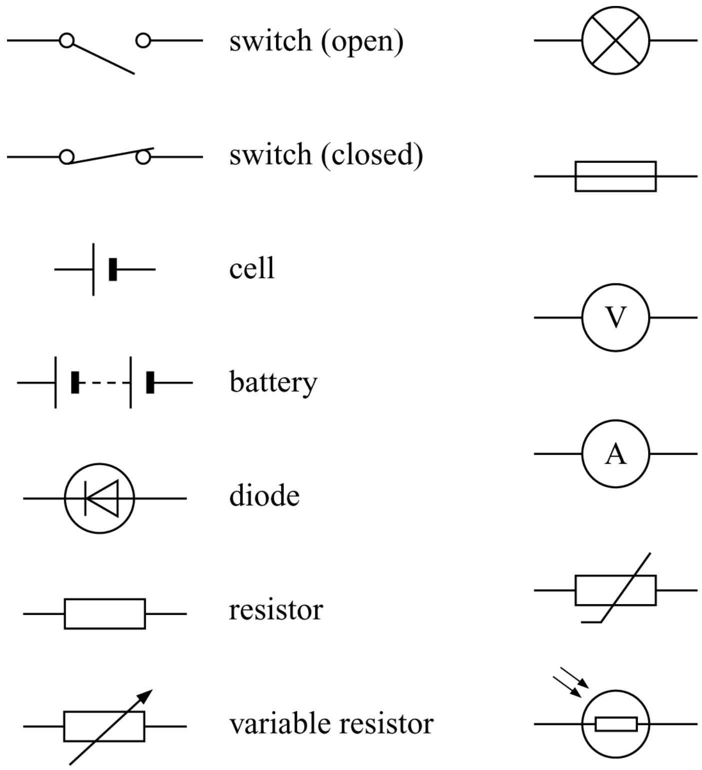
- Electrostatic charges can be useful, for example in photocopiers and smoke precipitators and the basic operation of these devices.

13.6 What does the current through an electrical circuit depend on?

The size of the current in a circuit depends on how hard the supply tries to push charge through the circuit and how hard the circuit resists having charge pushed through it.

Candidates should use their skills, knowledge and understanding of how science works:

- to interpret and draw circuit diagrams using standard symbols. The following standard symbols should be known:

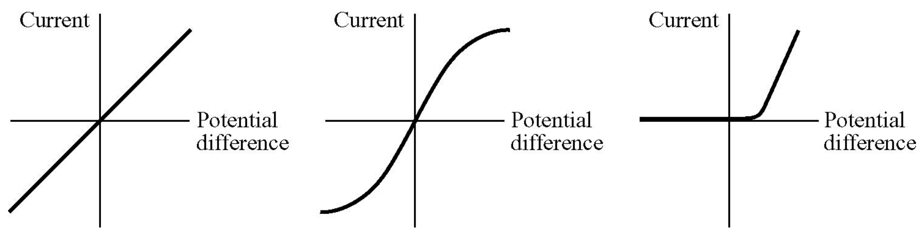


- to apply the principles of basic electrical circuits to practical situations.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Current-potential difference graphs are used to show how the current through a component varies with the potential difference across it.

A resistor at constant temperature | A filament lamp | A diode



- The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor.
- Potential difference, current and resistance are related by the equation:

potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω)

- The resistance of a component can be found by measuring the current through, and potential difference across, the component.

- The resistance of a filament lamp increases as the temperature of the filament increases.
- The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.
- The resistance of a light-dependent resistor (LDR) decreases as light intensity increases.
- The resistance of a thermistor decreases as the temperature increases (ie knowledge of negative temperature coefficient thermistor only is required).
- The current through a component depends on its resistance. The greater the resistance the smaller the current for a given potential difference across the component.
- The potential difference provided by cells connected in series is the sum of the potential difference of each cell (depending on the direction in which they are connected).
- For components connected in series:
  - the total resistance is the sum of the resistance of each component
  - there is the same current through each component
  - the total potential difference of the supply is shared between the components.
- For components connected in parallel:
  - the potential difference across each component is the same
  - the total current through the whole circuit is the sum of the currents through the separate components.

13.7 What is mains electricity and how can it be used safely?

Mains electricity is useful but can be very dangerous. It is important to know how to use it safely.

Candidates should use their skills, knowledge and understanding of how science works:

- to recognise errors in the wiring of a three-pin plug
- to recognise dangerous practice in the use of mains electricity
- to compare potential differences of d.c. supplies and the peak potential differences of a.c. supplies from diagrams of oscilloscope traces

HT ❖ to determine the period and hence the frequency of a supply from diagrams of oscilloscope traces.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Cells and batteries supply current which always passes in the same direction. This is called direct current (d.c.).
- An alternating current (a.c.) is one which is constantly changing direction. Mains electricity is an a.c. supply. In the UK it has a frequency of 50 cycles per second (50 hertz).
- UK mains supply is about 230 volts.
- Most electrical appliances are connected to the mains using cable and a three-pin plug.

- The structure of electrical cable.
- The structure of a three-pin plug.
- Correct wiring of a three-pin plug.
- If an electrical fault causes too great a current the circuit should be switched off by a fuse or a circuit breaker.
- When the current in a fuse wire exceeds the rating of the fuse it will melt, breaking the circuit.
- Appliances with metal cases are usually earthed.
- The earth wire and fuse together protect the appliance and the user.

HT ❖ The live terminal of the mains supply alternates between positive and negative potential with respect to the neutral terminal.

HT ❖ The neutral terminal stays at a potential close to zero with respect to earth.

13.8 Why do we need to know the power of electrical appliances?

Electrical appliances transform energy. The power of an electrical appliance is the rate at which it transforms energy. Most appliances have their power and the potential difference of the supply they need printed on them. From this we calculate their current and the fuse they need.

Candidates should use their skills, knowledge and understanding of how science works:

- to calculate the current through an appliance from its power and the potential difference of the supply and from this determine the size of fuse needed.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- Electric current is the rate of flow of charge.
- When an electrical charge flows through a resistor, electrical energy is transformed into heat energy.
- The rate at which energy is transformed in a device is called the power.

$$\underset{\text{(watt, W)}}{\text{power}} = \frac{\text{energy transformed (joule, J)}}{\text{time (second, s)}}$$

- Power, potential difference and current are related by the equation:

$$\underset{\text{(watt, W)}}{\text{power}} = \underset{\text{(ampere, A)}}{\text{current}} \times \underset{\text{(volt, V)}}{\text{potential difference}}$$

HT ❖ Energy transformed, potential difference and charge are related by the equation:

$$\underset{\text{(joule, J)}}{\text{energy transformed}} = \underset{\text{(volt, V)}}{\text{potential difference}} \times \underset{\text{(coulomb, C)}}{\text{charge}}$$

HT ❖ The amount of electrical charge that flows is related to current and time by the equation:

$$\underset{\text{(coulomb, C)}}{\text{charge}} = \underset{\text{(ampere, A)}}{\text{current}} \times \underset{\text{(second, s)}}{\text{time}}$$

13.9 What happens to radioactive substances when they decay?

To understand what happens to radioactive substances when they decay we need to understand the structure of the atoms from which they are made.

Candidates should use their skills, knowledge and understanding of how science works: HT

❖ to explain how the Rutherford and Marsden scattering experiment led to the 'plum pudding' model of the atom being replaced by the nuclear model.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- The relative masses and relative electric charges of protons, neutrons and electrons.
- In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no net electrical charge.
- Atoms may lose or gain electrons to form charged particles called ions.
- All atoms of a particular element have the same number of protons.
- Atoms of different elements have different numbers of protons.
- Atoms of the same element which have different numbers of neutrons are called isotopes.
- The total number of protons in an atom is called its atomic number.
- The total number of protons and neutrons in an atom is called its mass number.
- The effect of alpha and beta decay on radioactive nuclei.
- The origins of background radiation.

13.10 What are nuclear fission and nuclear fusion?

Nuclear fission is the splitting of atomic nuclei and is used in nuclear reactors as a source of heat energy which can be transformed to electrical energy. Nuclear fusion is the joining together of atomic nuclei and is the process by which energy is released in stars.

Candidates should use their skills, knowledge and understanding of how science works:

- to sketch a labelled diagram to illustrate how a chain reaction may occur.

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

- There are two fissionable substances in common use in nuclear reactors, uranium 235 and plutonium 239.
- Nuclear fission is the splitting of an atomic nucleus.
- For fission to occur the uranium 235 or plutonium 239 nucleus must first absorb a neutron
- The nucleus undergoing fission splits into two smaller nuclei and 2 or 3 neutrons and energy is released.
- The neutrons may go on to start a chain reaction.
- Nuclear fusion is the joining of two atomic nuclei to form a larger one.
- Nuclear fusion is the process by which energy is released in stars.

Key Skills and Other Issues

14 Key Skills – Teaching, Developing and Providing Opportunities for Generating Evidence

14.1 Introduction

The Key Skills Qualification requires candidates to demonstrate levels of achievement in the Key Skills of *Application of Number, Communication* and *Information and Communication Technology*.

The units for the 'wider' Key Skills of *Improving own Learning and Performance, Working with Others* and *Problem-Solving* are also available. The acquisition and demonstration of ability in these 'wider' Key Skills is deemed highly desirable for all candidates, but they do not form part of the Key Skills Qualification.

Copies of the Key Skills units may be downloaded from the QCA web site (http://www.qca.org.uk/keyskills).

Copies of the Key Skills specification may be downloaded from the AQA website (www.aqa.org.uk).

14.2 Teaching, Developing and Providing Opportunities for Generating Evidence

Areas of study and learning that can be used to encourage the acquisition and use of Key Skills, and to provide opportunities to generate evidence, are signposted in the tables below. Key Skills signposting indicates naturally occurring opportunities for the development of Key Skills during teaching, learning and assessment. Candidates will not necessarily achieve the signposted Key Skill through the related evidence.

Application of Number Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
N1.1 Interpret information from **two** different sources. At least **one** source must include a table, chart, graph or diagram.	✓	✓	✓	✓
N1.2 Carry out and check calculations to do with: a. amounts or sizes b. scales or proportion c. handling statistics.	✓	✓	✓	✓
N1.3 Interpret results of your calculations and present your findings – in two different ways using charts or diagrams.	✓	✓	✓	✓

Application of Number Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
N2.1 Interpret information from a suitable source.	✓	✓	✓	✓
N2.2 Use your information to carry out calculations to do with: a. amounts or sizes b. scales or proportions c. handling statistics d. using formulae.	✓	✓	✓	✓
N2.3 Interpret the results of your calculations and present your findings.	✓	✓	✓	✓

Communication Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	**Biology 2**	**Chemistry 2**	**Physics 2**
C1.1 Take part in either a **one-to-one** discussion or a **group** discussion.	✓	✓	✓	✓
C1.2 Read and obtain information from at least **one** document.	✓	✓	✓	✓
C1.3 Write **two** different types of documents.	✓	✓	✓	✓

Communication Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Science Centre-Assessed Unit	**Biology 2**	**Chemistry 2**	**Physics 2**
C2.1a Take part in a group discussion.	✓	✓	✓	✓
C2.1b Give a talk of at least four minutes.	✓	✓	✓	✓
C2.2 Read and summarise information from at least **two** documents about the same subject. Each document must be a minimum of 500 words long.	✓	✓	✓	✓
C2.3 Write **two** different types of documents each one giving different information. One document must be at least 500 words long.	✓	✓	✓	✓

Information and Communication Technology Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
ICT1.1 Find and select relevant information.	✓	✓	✓	✓
ICT1.2 Enter and develop information to suit the task.	✓	✓	✓	✓
ICT1.3 Develop the presentation so that the final output is accurate and fit for purpose.	✓	✓	✓	✓

Information and Communication Technology Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
ICT2.1 Search for and select information to meet your needs. Use different information sources for each task and multiple search criteria in at least one case.	✓	✓	✓	✓
ICT2.2 Explore and develop the information to suit the task and derive new information.	✓	✓	✓	✓
ICT2.3 Present combined information such as text with image, text with number, image with number.	✓	✓	✓	✓

Improving own Learning and Performance Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
LP1.1 Confirm your targets and plan how to meet these with the person setting them.	✓	✓	✓	✓
LP1.2 Follow your plan, to help meet targets and improve your performance.	✓	✓	✓	✓
LP1.3 Review your progress and achievements in meeting targets, with an appropriate person.	✓	✓	✓	✓

Improving own Learning and Performance Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
LP2.1 Help set targets with an appropriate person and plan how these will be met.	✓	✓	✓	✓
LP2.2 Take responsibility for some decisions about your learning, using your plan to help meet targets and improve your performance.	✓	✓	✓	✓
LP2.3 Review progress with an appropriate person and provide evidence of your achievements.	✓	✓	✓	✓

Working with Others Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
WO1.1 Confirm you understand the given objectives, and plan for working together.	✓	✓	✓	✓
WO1.2 Work with others towards achieving given objectives.	✓	✓	✓	✓
WO1.3 Identify ways you helped top achieve things and how to improve your work with others.	✓	✓	✓	✓

Working with Others Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
WO2.1 Plan work with others.	✓	✓	✓	✓
WO2.2 Work co-operatively towards achieving identified objectives.	✓	✓	✓	✓
WO2.3 Review your contributions and agree ways to improve work with others.	✓	✓	✓	✓

Problem Solving Level 1

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
PS1.1 Confirm with an appropriate person that you understand the given problem and identify ways of tackling it.	✓	✓	✓	✓
PS1.2 Confirm with an appropriate person what you will do and follow your plan for solving the problem.	✓	✓	✓	✓
PS1.3 Check with an appropriate person if the problem has been solved and how to improve your problem solving skills.	✓	✓	✓	✓

Problem Solving Level 2

What you must do …	Signposting of Opportunities for Generating Evidence in Subject Content			
	Additional Science Centre-Assessed Unit	Biology 2	Chemistry 2	Physics 2
PS2.1 Identify a problem with help from an appropriate person, and identify different ways of tackling it.	✓	✓	✓	✓
PS2.2 Plan and try out at least one way of solving the problem.	✓	✓	✓	✓
PS2.3 Check if the problem has been solved and identify ways to improve problem solving skills.	✓	✓	✓	✓

15 Spiritual, Moral, Ethical, Social, Cultural and Other Issues

15.1 Spiritual, Moral, Ethical, Social and Cultural Issues

The study of science can contribute to an understanding of spiritual, moral, ethical, social and cultural issues. The following are examples of opportunities to promote candidates' development through the teaching of science.

Spiritual

Through candidates sensing the natural, material and physical world they live in, reflecting on their part in it, exploring questions such as the ultimate structure of matter, the integration of processes both in microscopic cells and the whole human body, and experiencing a sense of awe and wonder at the natural world. Sections 11.1, 11.5, 11.6, 12.1, 12.2 and 13.9 are relevant.

Moral and ethical

Through helping candidates see the need to draw conclusions using observation and evidence rather than preconception or prejudice, and through discussion of the implications of the uses of scientific knowledge, including the recognition that such uses can have both beneficial and harmful effects. Exploration of values and ethics relating to applications of science and technology is possible. Sections 10.8, 11.3, 11.7, and 13.10 are relevant.

Social

Through helping candidates recognise how the formation of opinion and the justification of decisions can be informed by experimental evidence, and drawing attention to how different interpretations of scientific evidence can be used in discussing social issues. Sections 11.3, 11.5, 11.6, 11.7, 12.2, 12.4, 12.5, 13.2, and 13.9 are relevant.

Cultural

Through helping candidates recognise how scientific discoveries and ideas have affected the way people think, feel, create, behave and live, and drawing attention to how cultural differences can influence the extent to which scientific ideas are accepted, used and valued. Sections 10.2, 11.3, 11.6, 11.7, 12.2, 13.4 and 13.10 are relevant.

15.2 European Dimension

AQA has taken account of the 1988 Resolution of the Council of the European Community in preparing this specification and associated specimen papers.

There are opportunities in this specification to relate the study of topics to wider European or global contexts. In particular, a broader European context could be used in relation to Sections 11.3, 11.6, 11.7, 12.2, 13.7 and 13.10.

15.3 Environmental Issues

AQA has taken account of the 1988 Resolution of the Council of the European Community and the Report *"Environmental Responsibility: An Agenda for Further and Higher Education"* 1993 in preparing this specification and associated specimen papers.

This specification allows responsible attitudes to environmental issues to be fostered. In particular, environmental issues can be considered in relation to Sections 11.3, 11.4, 12.5, and 13.10.

15.4 Health and Safety

Teaching about health and safety during practical science forms part of the teaching requirements for this specification (see Section 18.3). However, more general teaching requirements about health and safety are as applicable to science as to other subjects. Examples can be found in Sections 11.1, 11.2, 11.5, 12.2, 12.3, 12.4, 12.5, 12.6, 13.1, 13.2, 13.4, 13.5, 13.6, 13.7, 13.8 and 13.9

When working with equipment and materials, in practical activities and in different environments, including those that are unfamiliar, candidates should be taught:

- about hazards, risks and risk control
- to recognise hazards, assess consequent risks and take steps to control the risks to themselves and others
- to use information to assess the immediate and cumulative risks
- to manage their environment to ensure the health and safety of themselves and others
- to explain the steps they take to control risks.

Centres are reminded of requirements to make their own risk assessments under COSHH regulations in relation to the many materials and processes involved in the teaching of this subject.

15.5 Citizenship

This specification allows treatment of aspects of citizenship through the contribution made to candidates' moral, ethical, social and cultural development (see Section 15.1), through opportunities to teach about the European dimension (see Section 15.2) and through opportunities to promote an understanding of, and responsible attitudes towards, environmental issues (see Section 15.3).

15.6 Avoidance of Bias

AQA has taken great care in the preparation of this specification and associated specimen papers to avoid bias of any kind.

15.7 Use of Organisms

Nothing in this specification requires candidates or teachers to kill animals. Live animals brought into the laboratory for study should be kept unstressed in suitable conditions and should, wherever possible, be returned unharmed to their habitats. Studies of animals and plants in their habitats should aim at minimal disturbance.

Centre-Assessed Unit

16 Nature of the Centre-Assessed Unit

Candidates should be encouraged to carry out practical and investigational work throughout the course. They should work safely and accurately, both individually and in groups. This work should cover the skills and knowledge in Section 10: fundamental ideas, observation, investigation design, measurement, data presentation, identifying patterns in relationships and any social aspects of scientific evidence.

AQA identifies some areas of the specification suitable for investigational work and provides ISAs (Investigative Skills Assignments) in the form of written tests relating to these areas of the specification. Candidates are required to carry out practical work beforehand and bring their own data with them. Teachers use their judgement and the marking guidance from AQA to mark each ISA. Teachers are also required to make a holistic assessment of the general practical and safety skills of each candidate. The best ISA mark and the general practical and safety skills assessment are needed for the mark for this unit. It counts for 25% of the total marks for the award.

17 Investigative Knowledge and Skills for Centre-Assessed Unit

17.1 Introduction

The knowledge and understanding which are assessed by the centre-assessed unit are detailed in full in Section 10. The following is a summary of the Procedural Content which teachers and candidates may find useful in preparing for this unit. It contains the following sections:

- Fundamental ideas
- Observation
- Designing an investigation
- Making measurements
- Presenting data
- Identifying patterns and relationships in data
- Societal aspects of scientific evidence
- Limitations of scientific evidence

A Glossary of Terms relating to 'How Science Works' is provided in Appendix D.

17.2	Fundamental ideas	Candidates should be able to understand what is meant by scientific evidence and thus be able to distinguish between opinions based on scientific facts and opinions based on hearsay evidence or bias.
17.3	Observation	Candidates should be able to recognise key features and make observations in a rational and unbiased manner. They should realise that observations are often the starting point of investigations and may be used as a basis for classification. They should realise that observations can lead to hypotheses and predictions, and that data from observations may support, refute or lead to new hypotheses.
17.4	Designing an Investigation	
	Design of investigations: Variable structure	Candidates should be able to distinguish between the dependent and the independent variable. They should also know the difference between categoric and continuous variables.
	Design: Validity, 'fair tests' and controls	Candidates should be able to describe the attributes of a 'fair test', ie one in which only the chosen independent variable has been allowed to influence the dependent variable. They should also be able to identify other key variables that must either be controlled or, if that is not possible, at least monitored. They should appreciate that in field investigations and surveys there are particular requirements to ensure a fair test, and that control groups are often appropriate to ensure that changes are due to the independent variable.
	Design: Choosing values	Candidates should be able to specify the range of, and interval between, readings to be taken and to appreciate that these can often be determined by means of a preliminary trial run. They should also be able to specify the number of readings to be taken.
	Design: Accuracy and precision	Candidates should be able to explain how an investigation can be designed so that it will render data which is sufficiently accurate and precise as to enable a sensible conclusion to be drawn.
	Reliability and validity of the design	Candidates should be able to evaluate the design of an experiment or investigation by commenting on the ways in which the experimenter did or did not achieve reliability and validity.
17.5	Making Measurements	
	Measurement	Candidates should be able to identify situations in which natural inherent variation in a measurement has been caused by uncontrolled variables, human error or the characteristics of the instrument used.
	Instruments: Underlying relationships	Candidates should be able to explain how a measuring instrument can utilise the relationship between two variables, eg that the length of the mercury column in a thermometer is related directly to the temperature.

Instruments: Calibration and error

Candidates should be able to explain that a measuring instrument is calibrated before use, eg a scale is marked on it by using some known, fixed points. They should know that a measuring instrument may have a zero error and that the smallest scale divisions must be smaller than the value that they are trying to measure. They should realise that the sensitivity of the instrument should be taken into account. They should realise that random errors can result from an inconsistent technique.

Reliability and validity of a single measurement

Candidates should know that the reliability of a measurement may be improved by data from secondary sources, by others repeating the investigation or by using another instrument as a crosscheck. They should understand that for a measurement to be valid the instrument or technique must be actually measuring that which is intended.

The choice of an instrument for measuring a datum

Candidates should be able to distinguish between precision and accuracy. An accurate measurement is one which is close to the true value . Precision is related to the smallest scale division on the measuring instrument that you are using.

In the examples below, measurements were taken of the length of a laboratory bench. Each vertical line on the scale represents a reading.

Diagram (a) shows a set of results which is very precise but not very accurate.

Diagram (b) shows a set of results which is very accurate but not very precise.

Diagram (a)

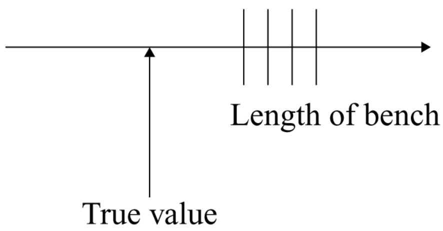
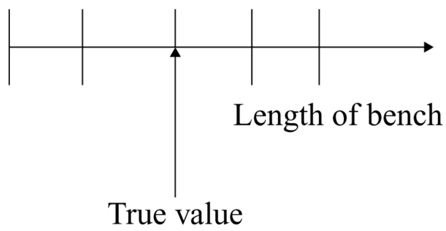


Diagram (b)



Sampling a datum

Candidates should be able to determine the optimum number of measurements and repeats to be made, and to identify any anomalous results.

Statistical treatment of measurements of data

Candidates should be able to state the range of the measurements that have been made, quoting the maximum and minimum values and to calculate the mean.

Reliability and validity of a datum

Candidates should be able to ascertain whether a measurement or observation is (a) reliable, ie has it been crosschecked and (b) valid, ie has the appropriate variable been measured?

17.6 Presenting Data

Tables	Candidates should be able to draw up a results table such that data can be presented in a meaningful and easy to understand way.
Data presentation	Candidates should be able to decide upon the most appropriate method of presenting and analysing data. Such methods include tables, bar charts, line graphs, scattergrams, histograms and pie charts.

17.7 Identifying Patterns and Relationships in Data

Patterns and relationships in data	Candidates should be able to recognise and describe patterns in data and draw conclusions from them. Such patterns include linear and proportional relationships, curves and empirical relationships. They should be capable of drawing and interpreting lines of best fit. They should also be aware that anomalous data may need to be excluded before such a pattern is identified.
Reliability and validity of the data in the whole investigation	Candidates should be able to explain why further evidence may be needed in order to draw a firm conclusion and how this extra evidence may be obtained.

17.8 Societal Aspects of Scientific Evidence

Relevant societal aspects	Candidates should be able to explain how the consequences of scientific experiments may impinge upon society. They should understand that the credibility of scientific research may suffer as the result of any bias by the experimenters. They should also be aware of the consequences of scientific research and understand that acceptability is influenced by a range of other factors, such as ethical, social, economic and environmental issues.

17.9 Limitations of Scientific Evidence

Candidates should realise that it is sometimes difficult to collect sufficient evidence to answer a question. There are also questions that cannot be answered by looking at scientific evidence alone, for example, questions where moral judgements are involved.

18 Guidance on Managing the Centre-Assessed Unit

18.1 Outline

The total marks for this unit are derived in two ways.

Investigative Skills Assignment (ISA)

During the course, candidates carry out practical work on any aspect of science relevant to the specification. When the candidate has carried out practical work on one of the topics listed by AQA as being available for assessment, the teacher may assess the candidate on investigative skills. In a normal timetabled lesson but under controlled conditions, the candidate is provided with an ISA, supplied by AQA. The maximum time allowed for each ISA is 45 minutes. The candidate must be provided in this session with the data that he or she has collected during the practical work. The ISA is in two parts.

(a) Section 1

This consists of a number of questions relating directly to the candidate's own data. This data must be stapled to the answer sheet.

The number of marks allocated to this section is between 14 and 20.

(b) Section 2

At the start of this section, candidates are supplied with another set of data, relating to the same topic from the specification in which the candidate has conducted his or her practical work. A number of questions relating to the analysis and evaluation of this data then follow. Candidates are expected to make appropriate comparisons between their own and the presented data.

The number of marks allocated to this section is between 14 and 20.

Candidates may attempt any number of the ISAs supplied by AQA, in any of the contexts of Biology 2, Chemistry 2 or Physics 2 and the best mark obtained is submitted.

Practical Skills Assessment (PSA)

Candidates are assessed throughout the course on the implementation of practical work, using a scale from 0 to 6.

The mark submitted for practical skills should be judged by the teacher over the duration of the course. Teachers may wish to use this section for formative assessment and keep an ongoing record of each candidate's performance, but the mark submitted should represent the candidate's practical abilities over the whole course.

Work to be submitted

The work to be submitted for each candidate consists of their best Investigative Skills Assignment (ISA) and a Candidate Record Form showing the marks for this ISA and the Practical Skills Assessment (PSA).

18.2 Investigative Skills Assignments (ISA)

Candidates will be expected to carry out practical work within certain specified areas of the content of the Specification for Biology 2, Chemistry 2 or Physics 2. AQA will provide assignments and marking guidance on topics from the specification such as the following.

Suitable topics

Unit Biology 2

- The rate of photosynthesis may be limited by:
  - low temperature
  - shortage of carbon dioxide
  - shortage of light.

  Typical investigation: Find out how the rate of photosynthesis depends upon light intensity.

- Materials decay because they are broken down (digested) by microorganisms. Microorganisms digest materials faster in warm, moist conditions. Many microorganisms are also more active when there is plenty of oxygen.

  Typical investigation: Investigate the best conditions for a compost heap.

- Catalysts increase the rate of chemical reactions. Biological catalysts are called enzymes. Enzymes are protein molecules made up of long chains of amino acids. These long chains are folded to produce a special shape which enables other molecules to fit into the enzyme. This shape is vital for the enzyme's function. High temperatures destroy this special shape. Different enzymes work best at different pH values.

  Typical investigation: The effect of temperature upon enzyme activity.

Unit Chemistry 2

- The amount of a product obtained is known as the yield. When compared with the maximum theoretical amount as a percentage, it is called the percentage yield.

  Typical investigation: Measurement of yield of ammonia in the Haber process using a computer simulation.

- The rate of a chemical reaction increases:
  - if the temperature increases
  - if the concentration of dissolved reactants or the pressure of gases increases
  - if solid reactants are in smaller pieces (greater surface area)
  - if a catalyst is used.

  Typical investigation: Investigate how the rate of reaction between calcium carbonate and hydrochloric acid depends upon concentration or temperature.

- Passing an electric current through molten ionic substances or solutions of ions, breaks them down into elements. This process is called electrolysis.

  Typical investigation: Factors that affect the deposition of copper when electrolysing copper sulfate solution.

Unit Physics 2

- A body falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force on the body will be zero and it will fall at its terminal velocity.

  Typical investigation: Measuring the terminal velocity of different parachutes.

- To use the conservation of momentum (in one dimension) to calculate the mass, velocity or momentum of a body involved in a collision or explosion.

  Typical investigation: Measurement of momentum changes when trolleys collide.

- The resistance of a filament lamp increases as the temperature of the filament increases.

  Typical investigation: Investigating how resistance changes as the lamp increases in brightness with increased current.

In Sections 11–13 this symbol is used to identify topics which are suitable for extended investigative work. These topics in addition to those listed above may form the basis for future ISAs. However, the list and the signposted topics are not intended to be exhaustive – both are provided for illustrative purposes only. Nonetheless, practical work in these areas will provide a good preparation for formal assessment in the centre-assessed unit including the ISAs.

Getting started

A suitable strategy would be to teach the knowledge that underlies Section 10 and the skills that provide for the gathering of data. Candidates should gain an understanding of the application of these concepts by applying them to supported practical studies and practice tests. Candidates should then be assessed when they apply these abilities in the formal ISA situation.

The proposed task should allow for candidates to work individually to obtain data suitable for analysis or, if working in groups, allow the contribution of individual candidates to be identified and assessed.

Candidates may include supportive second-hand data and whole-class data. It is important however that the candidate identifies the data that has been collected under his or her direction. Whilst some practical situations can only be effectively conducted in groups, each candidate must have completed a set of data that has been derived under their own direction. Candidates should keep an independent record of the raw data collected in preparation for the ISA.

The assignments, setting guidance and marking guidance are made available to centres at the beginning of each academic year. Copies should be kept locked away securely until used. If they are to be used on more than one occasion, then centres must ensure security between sessions. AQA is issuing two tests in the first year that each centre-assessed unit for a specification is available. At least one extra test is issued each year so that centres have a choice of which test to offer. Each test is available for two years.

Using the assignments

Whilst carrying out the practical work, candidates are expected to make and record detailed observations in a suitable way. Measurements should be made with an appropriate level of precision and accuracy and the data recorded logically in an appropriately constructed table. Candidates should use ICT where appropriate.

Candidates should be supplied with an outline method and asked to make their own results table. The outline method and instructions should not be too prescriptive. Centres are provided with setting guidance which will detail any particular requirements. As far as possible AQA does not put any restriction on the method to be used in the investigation.

Candidates must present, while the work is in progress, the data collected in a suitable table. They should not be assessed using evidence from formal reports written after the completion of the practical work. For certain ISAs, candidates are also required to process the data into a graph or chart. Where this is the case, teachers are notified in the setting guidance. Teachers should collect the table of data (and graphs or charts if appropriate) from each candidate at the end of the practical session and store it in readiness for the ISA.

The ISA should be taken as soon as possible after completion of the practical work, in a suitable timetabled lesson. Candidates should work on their own and in silence. Each candidate is provided with an ISA to which the teacher has stapled the candidate's own data record.

Section 1 of the ISA contains questions concerning the candidate's own data. Section 2 provides the candidate with additional data on the same topic which the candidate is required to analyse, evaluate and comment upon. Answers to both sections are written on the question paper. At the end of 45 minutes, the papers are collected from the candidates. Teachers are required to mark these papers, using a set of marking guidelines provided by AQA.

Candidates absent for the preliminary practical work

If a candidate is absent for the practical work, the teacher may supply the candidate with some data to use in Section 1 and the teacher can mark it, but the mark for Section 1 cannot be submitted. However, a mark for Section 2 on its own may be submitted.

Security of assignments

When teachers have marked the ISAs, they may tell candidates their marks but they may not return the papers. Completed ISAs should be treated like examination papers and kept under secure conditions while the ISA is valid.

Practice ISAs from specimen or training material can be used to teach candidates the skills required, feeding back their marks as formative assessment. However, ISAs which are currently valid cannot be given back to the candidates. Candidates may sit any number of ISAs and the best mark can be submitted for certification.

18.3 Practical Skills Assessment (PSA)

This assessment may be made at any time during the course of a candidate's normal practical work.

The nature of the assessment

Since the skills in this section involve implementation, they must be assessed while the candidate is carrying out practical work. In order to provide appropriate opportunities to demonstrate the necessary skills, instructions provided must not be too prescriptive but should allow candidates to make decisions for themselves, particularly concerning the conduct of practical work, their organisation and the manner in which equipment is used.

Centres should bear in mind that a high performance should reflect the ability to work methodically and safely, demonstrating competence in the required manipulative skills and efficiency of managing time.

The assessment criteria

Candidates should:

- use apparatus and materials in an appropriate and careful way
- carry out work in a methodical and organised way
- work with due regard for safety and with appropriate consideration for the well-being of living organisms and the environment.

Descriptors are provided for 2, 4 and 6 marks. These descriptors should be used to judge the mark which best describes a candidate's performance.

IMPLEMENTATION OF PRACTICAL WORK	
PERFORMANCE LEVEL	**SKILLS**
2	*Practical work is conducted:* • safely, but with help to work in an organised manner. *The candidate:* • uses the apparatus with assistance.
4	*Practical work is conducted:* • safely and in a reasonably organised manner. *The candidate:* • uses the apparatus skilfully and without the need for assistance.
6	*Practical work is conducted:* • safely and in a well-organised manner. *The candidate:* • uses the apparatus skilfully in a demanding context.

NB In order to gain 5 or 6 marks, a candidate must:

- demonstrate competence with a range of equipment, some of which is quite complex
- take all measurements to an appropriate level of accuracy
- present, while the work is in progress, the data collected in a suitable table.

Descriptors are designed to be hierarchical so that a description at a particular mark subsumes descriptions at lower marks. Use should be made of intermediate marks (1, 3 and 5) when performance exceeds one description but only partly satisfies the next.

At each of the marks (2, 4 and 6) there are two bullet points. If **neither** of the bullet points for 2 marks is matched, the candidate should be awarded zero marks. If **either** of the bullet points for 2 marks is matched, the candidate will score 1 mark. If **both** bullet points for 2 marks are matched, the candidate will score 2 marks.

Once 2 marks have been awarded, consideration may be given to the two bullet points for 4 marks: matching either one will allow 3 marks to be awarded, both will result in 4 marks. Similarly, once 4 marks have been gained, consideration may be given to the two bullet points for 6 marks in order to determine whether the candidate should be awarded 5 or 6 marks.

18.4 Further Support

Apart from material published in the specification, support for this unit is provided in a number of ways:

- **A Teacher's Guide** published by AQA includes information and advice from the Principal Moderator. This will be supplemented by further booklets containing examples of work.
- **Centre-Assessed Unit Advisers** are appointed by AQA and are available to give centres advice. Details are sent to the Head of Department at individual centres, or may be obtained from the Subject Department at AQA's Guildford office. Advice will normally be given in response to telephone or e-mail enquiries but will be restricted to:
  - issues relating to the carrying out of assignments for assessment
  - standards of marking
  - administrative issues
  - discussion of feedback from moderators.

  Advisers do not mark work.
- **Annual meetings** will be held on a regional basis, usually at the beginning of the academic year. These meetings discuss aspects of internal assessment which have given rise to concern and provide opportunities to standardise procedures and marking. Attendance in the first year of a new programme of assessment is compulsory, as is attendance by centres where there has been serious misinterpretation of the requirements of the specification. Centres will be informed directly if they are required to attend.

19 Supervision and Authentication

19.1 Supervision of Candidates' Work

The centre-assessed unit comprises an Investigative Skills Assignment (ISA) and a Practical Skills Assessment (PSA) for each candidate. It is expected that the preliminary practical work for the ISAs and the work assessed for the PSA are carried out under normal class conditions, with a degree of supervision of candidates corresponding to those conditions. However, ISAs should be taken under controlled conditions with candidates working in silence. They may sit the ISA in their usual classroom (or laboratory) providing this allows them to be suitably spaced to avoid the possibility of cheating.

19.2 Unfair Practice

At the start of the course, the supervising teacher is responsible for informing candidates of the AQA regulations concerning malpractice. The penalties for malpractice are set out in the AQA regulations. Centres must report suspected malpractice to AQA.

19.3 Authentication of Candidates' Work

Both the candidate and the teacher are required to sign declarations confirming that the work submitted for assessment is the candidate's own. The teacher declares that the work was conducted under the specified conditions, and records details of any additional assistance.

20 Standardisation

20.1 Standardising Meetings

Annual standardising meetings will usually be held in the autumn term. Centres entering candidates for the first time must send a representative to the meetings. Attendance is also mandatory in the following cases:

- where there has been a serious misinterpretation of the specification requirements
- where the management of the centre-assessed unit by a centre has been inappropriate
- where a significant adjustment has been made to a centre's marks in the previous year's examination.

Otherwise attendance is at the discretion of centres. At these meetings support will be provided for centres in the development of appropriate preliminary practical work and assessment procedures.

20.2 Internal Standardisation of Marking

The centre is required to standardise the assessments across different teachers and teaching groups to ensure that all candidates at the centre have been judged against the same standards. If two or more teachers are involved in marking the centre-assessed unit, one teacher must be designated as responsible for internal standardisation. Common pieces of work must be marked on a trial basis and differences between assessments discussed at a training session in which all teachers involved must participate. The teacher responsible for standardising the marking must ensure that the training includes the use of reference and archive materials such as work from a previous year or examples provided by AQA. The centre is required to send to the moderator the Centre Declaration Sheet, duly signed, to confirm that the marking of centre-assessed work at the centre has been standardised. If only one teacher has undertaken the marking, that person must sign this form.

A specimen Centre Declaration Sheet appears in Appendix B.

21 Administrative Procedures

21.1 Recording Assessments

Teachers should keep records of their assessments during the course in a form which facilitates the complete and accurate submission of final centre assessments at the end of the course. Candidates may undertake a number of ISAs. Candidates should complete the details required on the front cover of each ISA in full. The data collected by each candidate in the preliminary practical work should be firmly attached (ie stapled or by treasury tag) to the candidate's ISA script. The candidates' work must be marked according to the marking guidelines provided by AQA, and the marks entered on the front cover. Towards the end of the course, the teacher must select the ISA with the highest mark and must award a mark for the PSA, using the criteria in the grid in Section 18. This mark and the mark for the ISA should be entered on a Candidate Record Form, together with supporting information and details of any additional help given in the spaces provided. The completed Candidate Record Form for each candidate must be attached to the work and made available to AQA on request.

Candidate Record Forms are available on the AQA website in the Administration area. They can be accessed via the following link http://www.aqa.org.uk/admin/p_course.php. The exact design may be modified before the operational version is issued and the correct year's Candidate Record Forms should always be used.

21.2 Submitting Marks and Sample Work for Moderation

The total mark for the centre-assessed unit for each candidate must be submitted to AQA on the mark sheets provided or by Electronic Data Interchange (EDI) by the specified date. Centres will be informed which candidates' work is required in the samples to be submitted to the moderator.

An Investigative Skills Assignment (ISA) mark submitted for one centre-assessed unit (SCYC, ASCC, BLYC, CHYC or PHYC) should not be resubmitted for another centre-assessed unit, even if the ISA is valid for that unit. It is a requirement that new work is submitted for each centre-assessed unit entered.

21.3 Factors Affecting Individual Candidates

Teachers should be able to accommodate the occasional absence of candidates by ensuring that the opportunity is given for them to make up missed assessments.

Special consideration should be requested for candidates whose work has been affected by illness or other exceptional circumstances. Information about the procedure is issued separately.

If work is lost, AQA should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. AQA will advise on the procedures to be followed in such cases.

Where special help which goes beyond normal learning support is given, AQA must be informed so that such help can be taken into account when assessment and moderation take place.

Candidates who move from one centre to another during the course sometimes present a problem for a scheme of centre assessment. Possible courses of action depend on the stage at which the move takes place. Teachers should note that centre assessment in GCSE Sciences is no longer a common component across all awarding bodies, and therefore there is less flexibility than before in transferring credit for centre assessment undertaken for a specification of an awarding body other than AQA. Centres should contact AQA at the earliest possible stage for advice about appropriate arrangements in individual cases.

21.4 Retaining Evidence

The centre must retain all the work of all candidates, with Candidate Record Forms attached. These must be kept under secure conditions from the time they are assessed, to allow for the possibility of an enquiry about results. This includes ISAs other than the one with the highest mark. If an enquiry about results is to be made, the work must remain under secure conditions until requested by AQA.

Beyond that time, it is preferred that candidates' work is shredded. In particular, centres must ensure that the security of ISA question papers which are still valid is not compromised.

22 Moderation

22.1 Moderation Procedures

Moderation of the centre-assessed unit is by inspection of a sample of candidates' work, sent by post from the centre to a moderator appointed by AQA. The centre marks must be submitted to AQA and the sample of work must reach the moderator by the specified date in the year in which the qualification is awarded.

Following the re-marking of the sample work, the moderator's marks are compared with the centre marks to determine whether any adjustment is needed in order to bring the centre's assessments into line with standards generally. In some cases it may be necessary for the moderator to call for the work of other candidates. In order to meet this possible request, centres must have available the work and Candidate Record Form of every candidate entered for the examination and be prepared to submit it on demand. Mark adjustments will normally preserve the centre's order of merit, but where major discrepancies are found, AQA reserves the right to alter the order or merit.

22.2 Post-Moderation Procedures

On publication of the GCSE results, the centre is supplied with details of the final marks for the centre-assessed unit.

The candidates' work is returned to the centre after the examination with a report form from the moderator giving feedback on the accuracy of the assessments made, and the reasons for any adjustments to the marks.

Some candidates' work may be retained by AQA for archive purposes.

Awarding and Reporting

23 Grading, Shelf-Life and Re-Sits

23.1 Qualification Titles

The qualification based on this specification has the following title: AQA General Certificate of Secondary Education in Additional Science.

23.2 Grading System

The qualification will be graded on an 8 point grade Scale A*, A, B, C, D, E, F and G. Candidates who fail to reach the minimum standard for grade G will be recorded as U (unclassified) and will not receive a qualification certificate.

23.3 Grading of Unit Results and Subject Awards

The achievement of each candidate on each unit is reported as a grade on the scale A*–G and as a UMS (Uniform Mark Scale) score.

UMS scores are related to grades as follows:

Range of UMS score		
Written paper	**Centre-assessed unit**	**Grade**
90–100	90–100	A*
80–89	80–89	A
70–79	70–79	B
60–69	60–69	C
50–59	50–59	D
40–49	40–49	E
30–39	30–39	F
20–29	20–29	G
0–19	0–19	U

The relationship of raw marks to UMS scores is determined separately for each unit, and where appropriate for each tier (see Section 23.4), through the awarding procedures for each series. This allows for any variation in the demand of the assessments between series to be taken into consideration. Raw marks which represent the minimum performance to achieve a grade are chosen, and these boundary marks are assigned the minimum UMS score for the grade. Between boundaries interpolation is used to relate raw marks to UMS scores.

When a candidate is entered for a subject award, the grade for the qualification is obtained by adding together the UMS scores for the units which contribute to the subject award, and using the following relationship between total UMS score and grade:

Range of total UMS score	Grade
360–400	A*
320–359	A
280–319	B
240–279	C
200–239	D
160–199	E
120–159	F
80–119	G
0–79	U

23.4 Grading and Tiers

The centre-assessed unit is not tiered and the full range of grades A*–G is available to candidates for this unit.

For the other units, candidates take either the Foundation Tier or the Higher Tier. For candidates entered for the Foundation Tier, grades C–G are available. For candidates entered for the Higher Tier, A*–D are available. There is a safety net for candidates entered for the Higher Tier, where an allowed grade E will be awarded if candidates just fail to achieve grade D. Candidates who fail to achieve a grade E on the Higher Tier or grade G on the Foundation Tier will be reported as unclassified.

For these tiered units, candidates cannot obtain a UMS score corresponding to a grade which is above the range for the tier entered. For example, the maximum UMS score for candidates on a Foundation Tier written paper such as Biology 2 is 69. In other words, they cannot achieve a UMS score corresponding to grade B. Candidates who just fail to achieve grade E on the Higher Tier receive the UMS score corresponding to their raw mark ie they do not receive a UMS score of zero.

During the awarding procedures the relationship between raw marks and UMS score is decided for each tier separately. Where a grade is available on two tiers, for example grade C, the two raw marks chosen as the boundary for the grade on the two tiers are given the same UMS score. Therefore candidates receive the same UMS score for the same achievement whether this is demonstrated on the Foundation or the Higher Tier assessments.

23.5 Shelf-life of Unit Results

The shelf-life of individual unit results, prior to certification of the qualification, is limited only by the shelf-life of the specification.

23.6 Re-Sits

Each assessment unit may be re-taken an unlimited number of times within the shelf-life of the specification. The best result will count towards the final award. However, marks for individual externally assessed units may be counted once only to a GCSE award.

23.7	Minimum Requirements	Candidates will be graded on the basis of work submitted for assessment.
23.8	Awarding and Reporting	This specification complies with the grading, awarding and certification requirements of the current GCSE, GCE, VCE, GNVQ and AEA Code of Practice, and will be revised in the light of any subsequent changes in future years.

Appendices

A Grade Descriptions

The following grade descriptions indicate the level of attainment characteristic of the given grade at GCSE. They give a general indication of the required learning outcomes at each specific grade. The descriptions should be interpreted in relation to the content outlined 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 (see Section 6) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

Grade A

Candidates demonstrate a detailed knowledge and understanding of science content and how science works, encompassing the principal concepts, techniques, and facts across all areas of the specification. They use technical vocabulary and techniques with fluency, clearly demonstrating communication and numerical skills appropriate to a range of situations.

They demonstrate a good understanding of the relationships between data, evidence and scientific explanations and theories. They are aware of areas of uncertainty in scientific knowledge and explain how scientific theories can be changed by new evidence.

Candidates use and apply their knowledge and understanding in a range of tasks and situations. They use this knowledge, together with information from other sources, effectively in planning a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.

Candidates describe how, and why, decisions about uses of science are made in contexts familiar to them, and apply this knowledge to unfamiliar situations. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.

They choose appropriate methods for collecting first-hand and secondary data, interpret and question data skilfully, and evaluate the methods they use. They carry out a range of practical tasks safely and skilfully, selecting and using equipment appropriately to make relevant and precise observations.

Candidates select a method of presenting data appropriate to the task. They draw and justify conclusions consistent with the evidence they have collected and suggest improvements to the methods used that would enable them to collect more valid and reliable evidence.

Grade C Candidates demonstrate a good overall knowledge and understanding of science content and how science works, and of the concepts, techniques and facts across most of the specification. They demonstrate knowledge of technical vocabulary and techniques, and use these appropriately. They demonstrate communication and numerical skills appropriate to most situations.

They demonstrate an awareness of how scientific evidence is collected and are aware that scientific knowledge and theories can be changed by new evidence.

Candidates use and apply scientific knowledge and understanding in some general situations. They use this knowledge, together with information from other sources, to help plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.

They describe how, and why, decisions about uses of science are made in some familiar contexts. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.

They carry out practical tasks safely and competently, using equipment appropriately and making relevant observations, appropriate to the task. They use appropriate methods for collecting first-hand and secondary data, interpret the data appropriately, and undertake some evaluation of their methods.

Candidates present data in ways appropriate to the context. They draw conclusions consistent with the evidence they have collected and evaluate how strongly their evidence supports these conclusions.

Grade F Candidates demonstrate a limited knowledge and understanding of science content and how science works. They use a limited range of the concepts, techniques and facts from the specification, and demonstrate basic communication and numerical skills, with some limited use of technical terms and techniques.

They show some awareness of how scientific information is collected and that science can explain many phenomena.

They use and apply their knowledge and understanding of simple principles and concepts in some specific contexts. With help they plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem, using a limited range of information in an uncritical manner. They are aware that decisions have to be made about uses of science and technology and, in simple situations familiar to them, identify some of those responsible for the decisions. They describe some benefits and drawbacks of scientific developments with which they are familiar and issues related to these.

They follow simple instructions for carrying out a practical task and work safely as they do so.

Candidates identify simple patterns in data they gather from first-hand and secondary sources. They present evidence as simple tables, charts and graphs, and draw simple conclusions consistent with the evidence they have collected.

B Record Forms

AQA
ASSESSMENT and QUALIFICATIONS ALLIANCE

Centre-assessed work
Centre Declaration Sheet

Qualification: ✓	ELC		GCSE		GCE		GNVQ		FSMQ		Key Skills	

Specification title: .... **Unit code(s):** ....

Centre name: .... **Centre no:** | | | | | |

Authentication of candidates' work

This is to certify that marks/assessments have been given in accordance with the requirements of the specification and that every reasonable step has been taken to ensure that the work presented is that of the candidates named.

Any assistance given to candidates beyond that given to the class as a whole and beyond that described in the specification has been recorded on the *Candidate Record Form*(s) and has been taken into account. The marks/assessments given reflect accurately the unaided achievement of the candidates.

Signature(s) of teacher(s) responsible for assessment

Teacher 1: .... **Teacher 4:** ....

Teacher 2: .... **Teacher 5:** ....

Teacher 3: .... **Teacher 6:** ....

(continue overleaf if necessary)

Internal standardisation of marking

Each centre must standardise assessment across different teachers/assessors and teaching groups to ensure that all candidates at the centre have been judged against the same standards.

If two or more teachers/assessors are involved in marking/assessing, one of them must be designated as responsible for standardising the assessments of all teachers/assessors at the centre.

I confirm that *[tick* either *(a)* or *(b)]*

☐ (a) the procedure described in the specification has been followed at this centre to ensure that the assessments are of the same standard for all candidates; or

☐ (b) I have marked/assessed the work of all candidates.

Signed: .... **Date:** ....

Signature of Head of Centre: .... **Date:** ....

Candidate Record Forms are available on the AQA website in the Administration area. They can be accessed via the following link http://www.aqa.org.uk/admin/p_course.php

C

Overlaps with other Qualifications

Specifications covering the KS4 Programme of Study

Many of the specifications in the AQA GCSE Sciences suite described in Section 4.2 cover the Programme of Study for KS4 Science, and there is therefore significant overlap between them. The content in GCSE Science A and GCSE Science B is identical, and all the content in these specifications can be found in GCSE Applied Science (Double Award). In addition, each of the nine units, Biology 1–3, Chemistry 1–3 and Physics 1–3 is identical, regardless of the specification to which it contributes. The procedural content in Section 10 of all the general specifications is the same.

The entry restrictions in Section 3.3 reflect this overlap.

Relationship to Other Subjects

Some of the knowledge, skills and understanding included in this specification may also be encountered by candidates following courses leading towards other subject qualifications. This is a feature of National Curriculum provision and means that the specification can complement other subjects and enable candidates to consolidate their learning. Some overlap exists with the following GCSE subjects:

- Human Physiology and Health
- Environmental Science
- Electronics.

D

Data sheet

AQA
ASSESSMENT and QUALIFICATIONS ALLIANCE

Data Sheet

1. Reactivity Series of Metals

Potassium — most reactive
Sodium
Calcium
Magnesium
Aluminium
Carbon
Zinc
Iron
Tin
Lead
Hydrogen
Copper
Silver
Gold
Platinum — least reactive

(elements in italics, though non-metals, have been included for comparison)

2. Formulae of Some Common Ions

Positive ions

Name	Formula
Hydrogen	H^+
Sodium	Na^+
Silver	Ag^+
Potassium	K^+
Lithium	Li^+
Ammonium	NH_4^+
Barium	Ba^{2+}
Calcium	Ca^{2+}
Copper(II)	Cu^{2+}
Magnesium	Mg^{2+}
Zinc	Zn^{2+}
Lead	Pb^{2+}
Iron(II)	Fe^{2+}
Iron(III)	Fe^{3+}
Aluminium	Al^{3+}

Negative ions

Name	Formula
Chloride	Cl^-
Bromide	Br^-
Fluoride	F^-
Iodide	I^-
Hydroxide	OH^-
Nitrate	NO_3^-
Oxide	O^{2-}
Sulfide	S^{2-}
Sulfate	SO_4^{2-}
Carbonate	CO_3^{2-}

3. The Periodic Table of Elements

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 Lanthanides (atomic numbers 58 –71) and the Actinides (atomic numbers 90–103) have been omitted.

Cu and **Cl** have not been rounded to the nearest whole number.

E

Glossary of Terms

Accuracy An accurate measurement is one which is close to the true value.

Calibration This involves fixing known points and then marking a scale on a measuring instrument, between these fixed points.

Data This refers to a collection of measurements.

For example: Data can be collected for the volume of a gas or the type of rubber.

Datum The singular of data.

Errors,

- random These cause readings to be different from the true value. Random errors may be detected and compensated for by taking a large number of readings.

For example: Random errors may be caused by human error, a faulty technique in taking the measurements, or by faulty equipment.

- systematic These cause readings to be spread about some value other than the true value; in other words, all the readings are shifted one way or the other way from the true value.

For example: A systematic error occurs when using a wrongly calibrated instrument.

- zero These are a type of systematic error. They are caused by measuring instruments that have a false zero.

For example: A zero error occurs when the needle on an ammeter fails to return to zero when no current flows, or when a top-pan balance shows a reading when there is nothing placed on the pan.

Evidence This comprises data which have been subjected to some form of validation. It is possible to give a measure of importance to data which has been validated when coming to an overall judgement.

Fair test A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

For example: A fair test can usually be achieved by keeping all other variables constant.

Precision The precision of a measurement is determined by the limits of the scale on the instrument being used. Precision is related to the smallest scale division on the measuring instrument that you are using. It may be the case that a set of precise measurements has very little spread about the mean value.

For example, using a ruler with a millimetre scale on it to measure the thickness of a book will give greater precision than using a ruler that is only marked in centimetres.

Reliability The results of an investigation may be considered reliable if the results can be repeated. If someone else can carry out your investigation and get the same results, then your results are more likely to be reliable. One way of checking reliability is to compare your results with those of others. The reliability of data can be improved by carrying out repeat measurements and calculating a mean.

True Value This is the accurate value which would be found if the quantity could be measured without any errors at all.

Validity

Data is only valid for use in coming to a conclusion if the measurements taken are affected by a single independent variable only. Data is not valid if for example a fair test is not carried out or there is observer bias.

For example: In an investigation to find the effect on the rate of a reaction when the concentration of the acid is changed, it is important that concentration is the only independent variable. If, during the investigation, the temperature also increased as you increased the concentration, this would also have an effect on your results and the data would no longer be valid.

Variables,

– categoric

A categoric variable has values which are described by labels.

When you present the result of an investigation like this, you should not plot the results on a line graph; you must use a bar chart or pie chart.

For example: If you investigate the effect of acid on different metals, eg copper, zinc and iron, the type of metal you are using is a categoric variable.

– continuous

A continuous variable is one which can have any numerical value.

When you present the result of an investigation like this you should use a line graph.

For example: If you investigate the effect on the resistance of changing the length of a wire, the length of a wire you are using is a continuous variable since it could have any length you choose.

– control

A control variable is one which may, in addition to the independent variable, affect the outcome of the investigation. This means that you should keep these variables constant; otherwise it may not be a fair test. If it is impossible to keep it constant, you should at least monitor it; in this way you will be able to see if it changes and you may be able to decide whether it has affected the outcome of the experiment.

– dependent and independent variables

Often in science we are looking at 'cause' and 'effect'. You can think of the independent variable as being the 'cause' and the dependent variable as being the 'effect'. In other words, the dependent variable is the thing that changes *as a result* of you changing something else.

– dependent

The dependent variable is the variable the value of which you measure for each and every change in the independent variable.

– independent

The independent variable is the variable for which values are changed or selected by the investigator. In other word, this is the thing that *you deliberately change* to see what effect it has.

– discrete

You may sometimes come across this term. It is a type of categoric variable whose values are restricted to whole numbers.

For example, the number of carbon atoms in a chain.

– ordered

You may sometimes come across this term. It is a type of categoric variable that can be ranked.

For example, the size of marble chips could be described as large, medium or small.