

Contents

WJEC GCSE in Science A/Additional Science Biology/Chemistry/Physics

For Teaching from 2012 For Award from 2014

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This is a linear specification: all assessments must be taken at the end of the course.

Sciences

SUMMARY OF ASSESSMENT

Qualification	Unit details	Time	% weighting	Marks	Assessment
Science A	Biology 1: Adaptation, evolution and body maintenance	1 hour	25%	60 marks (80 UMS)	External
	Chemistry 1: The Earth and its resources	1 hour	25%	60 marks (80 UMS)	External
	Physics 1: Energy, radiation and the Universe	1 hour	25%	60 marks (80 UMS)	External
	Science Controlled Assessment: Research skills, hypothesis testing and safety		25%	63 marks (80 UMS)	Internal
Additional Science	Biology 2: Cells and metabolism, digestion and respiration, biodiversity	1 hour	25%	60 marks (80 UMS)	External
	Chemistry 2: Atoms, bonding and chemical change	1 hour	25%	60 marks (80 UMS)	External
	Physics 2: Electricity, forces and nuclear physics	1 hour	25%	60 marks (80 UMS)	External
	Additional Science Controlled Assessment: Investigation		25%	48 marks (80 UMS)	Internal
Biology	Biology 1: Adaptation, evolution and body maintenance	1 hour	25%	60 marks (80 UMS)	External
	Biology 2: Cells and metabolism, digestion and respiration, biodiversity	1 hour	25%	60 marks (80 UMS)	External
	Biology 3: Transport in plants and animals, homeostasis, microorganisms and disease	1 hour	25%	60 marks (80 UMS)	External
	Biology Controlled Assessment: Investigation		25%	48 marks (80 UMS)	Internal
Chemistry	Chemistry 1: The Earth and its resources	1 hour	25%	60 marks (80 UMS)	External
	Chemistry 2: Atoms, bonding and chemical change	1 hour	25%	60 marks (80 UMS)	External
	Chemistry 3: The chemical industry and analysis	1 hour	25%	60 marks (80 UMS)	External
	Chemistry Controlled Assessment: Investigation		25%	48 marks (80 UMS)	Internal
Physics	Physics 1: Energy, radiation and the Universe	1 hour	25%	60 marks (80 UMS)	External
	Physics 2: Electricity, forces and nuclear physics	1 hour	25%	60 marks (80 UMS)	External
	Physics 3: Electromagnetism, waves, kinetic theory and nucleosynthesis	1 hour	25%	60 marks (80 UMS)	External
	Physics Controlled Assessment: Investigation		25%	48 marks (80 UMS)	Internal

Summary of components

Qualification	External Units (% weighting)			Internal
	Biology	Chemistry	Physics	
Science A	Biology 1 (25%)	Chemistry 1 (25%)	Physics 1 (25%)	Internal 1 (25%)
Additional Science	Biology 2 (25%)	Chemistry 2 (25%)	Physics 2 (25%)	Internal 2 (25%)
	Biology 3 (25%)	Chemistry 3 (25%)	Physics 3 (25%)	
	Internal Biology (25%)	Internal Chemistry (25%)	Internal Physics (25%)	

External Assessment

- Units with the same title (e.g. Biology 1 in GCSE Science A and GCSE Biology) are common units and may be used in aggregation for either qualification.
- All external assessments are tiered.
- All external assessments are composed of structured questions involving some extended prose.

Internal Assessment

- The controlled assessments are untiered.
- The tasks will be provided annually by WJEC, to be marked by teachers and then moderated by WJEC.
- **Science:** short, cross-subject exercises, based upon the subject content of Biology 1, Chemistry 1 and Physics 1.
- **Additional Science:** one investigation chosen from a list of three, each based on the subject content of Biology 2, Chemistry 2 and Physics 2.
- **Biology:** one investigation chosen from a list of 2, each based on the subject content of the Biology units [one investigation is common to Additional Science].
- **Chemistry:** one investigation chosen from a list of 2, each based on the subject content of the Chemistry units [one investigation is common to Additional Science].
- **Physics:** one investigation chosen from a list of 2, each based on the subject content of the Physics units [one investigation is common to Additional Science].

Assessment Opportunities

	Entry Code		June 2014 and each June thereafter
	Subject	Option*	
Biology 1 Foundation	4461	01 or W1	✓
Higher	4461	02 or W2	✓
Chemistry 1 Foundation	4462	01 or W1	✓
Higher	4462	02 or W2	✓
Physics 1 Foundation	4463	01 or W1	✓
Higher	4463	02 or W2	✓
Science A Controlled assessment	4464	01 or W1	✓

Biology 2 Foundation	4471	01 or W1	✓
Higher	4471	02 or W2	✓
Chemistry 2 Foundation	4472	01 or W1	✓
Higher	4472	02 or W2	✓
Physics 2 Foundation	4473	01 or W1	✓
Higher	4473	02 or W2	✓
Additional Science Controlled assessment	4474	01 or W1	✓

Biology 3 Foundation	4483	01 or W1	✓
Higher	4483	02 or W2	✓
Biology Controlled assessment	4484	01 or W1	✓
Chemistry 3 Foundation	4493	01 or W1	✓
Higher	4493	02 or W2	✓
Chemistry Controlled assessment	4494	01 or W1	✓
Physics 3 Foundation	4503	01 or W1	✓
Higher	4503	02 or W2	✓
Physics Controlled assessment	4504	01 or W1	✓

*Option codes: English Medium 01 or 02; Welsh Medium W1 or W2

Subject Award (cash-in) Opportunities

	Entry Code		June 2014 and each year thereafter
	Subject	Option*	
Science (A)	4460	LA or UL	✓
Additional Science	4470	LA or UL	✓
Biology	4480	LA or UL	✓
Chemistry	4490	LA or UL	✓
Physics	4500	LA or UL	✓

*Option codes: English Medium LA; Welsh Medium UL

Qualification Accreditation Numbers

Science A:	600/1036/8
Additional Science:	600/0893/3
Biology:	600/0895/7
Chemistry:	600/1035/6
Physics:	600/1032/0

This is a linear specification: all assessments must be taken at the end of the course.
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Science A

Additional Science

Biology/Chemistry/Physics

1 INTRODUCTION

This document contains a suite of GCSE Science qualifications provided within a common framework: GCSE Science, Additional Science, Biology, Chemistry and Physics. Note that the specification may be updated and the definitive version will appear on the WJEC website.

1.1 Rationale

Science A

This specification meets the General Criteria for GCSE, the GCSE Subject Criteria for Science and the Programmes of Study for Science in England and Wales.

This specification is designed to allow students to develop their appreciation of the knowledge and understanding of the world as established by the scientific community and also the processes undertaken by the scientific community to validate and extend this knowledge. Within the subject areas of this specification students investigate the ways in which the scientific knowledge impacts upon society and in which society influences science.

The specification provides opportunities for students to undertake their own scientific measurements and investigations, and so enables them to develop their skills and their ability to evaluate scientific information.

In order to understand and evaluate scientific information from both scientific and popular sources, students need to develop language and mathematical communication skills. The specification has been designed to allow these skills to be developed and assessed at both higher and foundation tiers.

Additional Science/Biology/Chemistry/Physics

The specifications within this suite are based on an approach which is practically-based, emphasising the role of experimentation in ascertaining the validity of knowledge. The specifications have an emphasis on:

- evaluating evidence and the implications of science for society
- explaining, theorising and modelling in science.

The balance between these is as follows:

GCSE Additional Science builds on the Science qualification and introduces further scientific concepts and understanding. GCSE Biology, Chemistry and Physics explore a wider range of scientific concepts and provide a more detailed knowledge and understanding.

1.2 Aims and Learning Outcomes

Following a course in **GCSE Science A** should encourage learners to be inspired, motivated and challenged by following a broad, coherent, practical, satisfying and worthwhile course of study. It should provide insight into and experience of how science works, stimulating learners' curiosity and encouraging them to engage with science in their everyday lives and to make informed choices about further study and about career choices.

GCSE specifications in Science A must enable learners to:

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

Following a course in **GCSE Additional Science** should encourage learners to be inspired, motivated and challenged by following a broad, coherent, practical, satisfying and worthwhile course of study. It should encourage learners to develop their curiosity about the living, material and physical worlds and provide insight into and experience of how science works. It should enable learners to engage with science and to make informed choices about further study in science and about career choices.

GCSE specifications in Additional Science must enable learners to:

- develop their knowledge and understanding of the material, physical and living worlds
- develop an understanding of the effects of science on society
- develop an understanding of the importance of scale in science
- develop and apply their knowledge and understanding of the nature of science and of the scientific process
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations
- develop their awareness of risk and the ability to assess potential risk in the context of potential benefits

- develop and apply their observational, practical, modelling, enquiry and problem-solving skills and understanding in laboratory, field and other learning environments
- develop their ability to evaluate claims based on science through critical analysis of methodology, evidence and conclusions both qualitatively and quantitatively
- develop their skills in communication, mathematics and the use of technology in scientific contexts.

Following a course in **GCSE Biology/Chemistry/Physics** should encourage learners to be inspired, motivated and challenged by following a broad, coherent, practical, satisfying and worthwhile course of study. It should encourage learners to develop their curiosity about the living / material / physical worlds and provide insight into and experience of how science works. It should enable learners to engage with biology/chemistry/physics and to make informed choices about further study in biology/chemistry/physics related disciplines and about career choices.

GCSE specifications in Biology/Chemistry/Physics must enable learners to:

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

1.3 Prior Learning and Progression

Although there is no specific requirement for prior learning, these specifications build upon the Programmes of Study for Science at Key Stage 3.

Each qualification within the suite provides an appropriate basis for further study. In the case of GCSE Science A this could be progression to Additional Science or to Additional Applied Science or other applied science qualifications.

In the case of Additional Science or the separate sciences – Biology, Chemistry, Physics – this could be to GCE applied qualifications in the sciences.

Equally, the skills and understanding developed, including key skills, are relevant to other qualifications at level 3, whether 'general' or 'vocational'.

1.4 Equality and Fair Assessment

These qualifications may be undertaken through the medium of either English or Welsh. They may be followed by any candidate, irrespective of gender, ethnic, religious or cultural background. They are not age specific and, as such, provide opportunities for candidates to extend their life-long learning.

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

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

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments. For this reason, very few candidates will have a complete barrier to any part of the assessment. Information on reasonable adjustments is found in the Joint Council for Qualifications document, *Regulations and Guidance: Access Arrangements, Reasonable Adjustments and Special Consideration*. This document is available on the JCQ website (www.jcq.org.uk).

Candidates who are still unable to access a significant part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award. They would be given a grade on the parts of the assessment they have taken and there would be an indication on their certificate that not all of the competences have been addressed. This will be kept under review and may be amended in future.

1.5 Classification Codes

Every specification is assigned a national classification code indicating the subject area to which it belongs. The classification codes for this suite of specification are:

- 1010 Biology
- 1110 Chemistry
- 1210 Physics
- 1310 Science
- 1320 Additional Science

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

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

2

CONTENT

INTRODUCTION

Teaching Approaches

It is envisaged that a variety of approaches to the teaching of the content is used. In view of the need to consider the issues, uncertainties and value judgements inherent in some areas of science, a didactic approach may not be appropriate. Case studies, individual projects or discussion groups may be more suitable as a means of exploring such issues. Desk studies and ICT are also a valid means of introducing a variety of data which may not otherwise be available and so extending areas of study.

ICT Skills

ICT is integral to scientific work and as such may be employed in various ways. These include

- word processing and presentation of reports and experimental data;
- spreadsheets for analysis of data;
- drawing packages to create diagrams;
- video to record activities or methods;
- sensors and data loggers for practical investigations such as water analysis;
- time lapse photography for analysing movements
- information searches;
- use of databases;
- software simulations and animations for exploring interactions and for modelling systems and effects.

Further information and practical resources are available from SEP (Science Enhancement Programme) via their website www.sep.co.uk

Information searches

It is important that candidates are taught to think critically about data they obtain, particularly from websites and how it is used e.g. computer presentation of graphs. Any information from secondary sources must be fully attributed and referenced in candidates' work.

Practical Skills

Practical work is an essential feature of science and as such is integral to the content. It may take different forms, including fieldwork. The practical work could form the focal point of the teaching approach as it adds to the candidate's appreciation of the topic. Practical work is, therefore, to be encouraged wherever possible.

Practical skills should be developed via the content throughout the course in order to prepare candidates for the practical assessment and as a means of exploring and enhancing understanding of subject content.

A variety of practical work is suggested below including some exercises which may be used for practical assessment purposes. Experimental work may be examined on the theory papers.

Further ideas and exercises for practical work can be found via the science and subject association websites: Society of Biology, <http://www.societyofbiology.org>; Institute of Physics, <http://www.iop.org>; Royal Society of Chemistry, <http://www.rsc.org>; Association for Science Education, <http://www.ase.org.uk>

Tiering

Some areas of content have been selected for assessment at higher tier only. This content is shown in bold type in the relevant content sections. All content may therefore be examined at higher tier but that in bold will not be examined on foundation tier papers.

Terms

The term *investigate* is used in its broadest sense and, along with terms such as *explore* or *examine*, refers to a range of activities which can include:

- individual experimental work
- group or class experimental work
- teacher demonstrations
- internet searches or examining other secondary sources
- use of ICT simulations, either as a group/class activity or a teacher demonstration.

This list of possibilities is not exhaustive. The form of activity appropriate in any particular instance is at the discretion of the teacher, taking into account the subject matter, the availability of equipment, Health and Safety and COSHH regulations etc.

The interpretation and use of terms, especially those associated with investigative practical work, should comply with the use indicated in the interboard endorsed document *The Language of Measurement*, available via the WJEC website.

Mathematical Requirements

A list of mathematical requirements for science specifications is provided in Appendix 1. This specification provides opportunities for candidates to develop their mathematical skills; however, it should be noted that some areas of content lend themselves more appropriately to particular mathematical skills. The following examples are an indication of particular areas but the list is not exhaustive. The idea of probability is more appropriate in biological contexts such as genetics; ratio/proportion for reactant/product masses using chemical equations, genetic crosses; percentages for composition of compounds or reaction fields in chemistry; simple arithmetic and calculating means could be required wherever numerical data is processed such as practical investigations and more specifically in bond energy and mole calculations, and energy loss in ecosystems.

Teacher Guidance Material

Further information on the interpretation of specification statements, suggestions for practical tasks and sources of information about possible experiments plus details of the development of new practical skills are all provided in the current *Teacher Guidance Material for GCSE Science*. This may be accessed via the WJEC secure website or supplied on CD-rom.

HOW SCIENCE WORKS (HSW) and SCIENTIFIC EVIDENCE

It is important to understand how the body of scientific knowledge has accumulated and what influence new ideas may have upon it. Therefore an understanding of the scientific method is vital for a full appreciation of the range of scientific enquiry and the factors which influence it.

The delivery of this course should therefore be via a 'scientific enquiry' approach. Using observation, questioning, testing evidence and concluding, candidates should be aware of the way in which scientific information is built up and constantly reviewed. Although investigations give a unique opportunity for candidates to develop the skills to plan, collect, analyse, interpret and analyse information, these skills should not be confined to practical work and candidates should be encouraged to question how information has been obtained and verified.

ICT is a useful and important tool which can be used to collect information by internet searches, using sensors and dataloggers to capture data in practical work, using spreadsheets or databases for data analysis, for modelling or using electronic resources e.g. software simulations, video clips. It is, however, important that candidates are taught to think critically about data they obtain, particularly from websites.

There is sometimes a tendency to oversimplify or provide a clear cut answer which is not entirely justified, for example:

- There is a tendency to search for procedures and 'clear cut' results that support a hypothesis. However, it is important that candidates are made aware in their investigations that the data do not always support a hypothesis and that sometimes the data are inconclusive.
- Devising and testing a scientific explanation is not a simple or straightforward process. There may be problems with the data. The collected data may not really reflect the whole picture or an observation may be incorrect. The measurements made may not be completely relied upon, because of the limitations of the measuring equipment or the person using it.
- The process of giving explanations is not straightforward. They do not simply 'emerge' from the data. Thinking up an explanation is a creative step. So, it is quite possible for different people to arrive at quite different explanations for patterns which were observed in the same data. The decisions made will all be influenced by personal interpretations and deductions.

Candidates need to understand these and other such issues which are inherent in the scientific process. These aspects should therefore be highlighted during the teaching of the course and used to steer the approach taken in the delivery of content. The following is a summary for teachers of the background process on which HSW is based. The summary is intended to be a stimulus for thinking around the scientific process and associated aspects.

1. Nature of scientific knowledge

What is it?
 How certain are we of it / the 'facts'?
 How do we obtain it?
 How is it verified – is it fixed?

2. Scientific method

Professional scientists work in many ways. The following sequence represents an attempt to identify some significant aspects of the scientific process. It should be borne in mind that not all the aspects will be equally important and the details of the stages will not always be the same. In many cases, scientists will not follow this sequence linearly but will move back to an earlier stage as a result of reviewing the evidence.

- (i) Make an observation
 Often, a scientific development is initiated by a scientist noticing an event or phenomenon. Often this will be followed by repeating the observation under controlled conditions.
- (ii) Formulate the question or hypothesis
 This is designed specifically to explore an observation/phenomenon or to pose an explanation which is capable of being tested.
- (iii) Design the 'test'
 The test needs to be an appropriate one to answer the question or to test the hypothesis – designing a suitable test is a creative act.
- (iv) Make measurements/collect data
 The data collection is the carrying out of the test. The data should be suitable to answer the question and a scientist will review the success of the data collection and modify the test if necessary.
- (v) Present data
 The data are presented in an appropriate way, usually in tables and graphs which are designed appropriately to show trends and/or relationships between variables.
- (vi) Find patterns/relationships in data
 The displayed data are subjected to an open-minded analysis. A scientist will review the data to interpret and identify trends and relationships shown.
- (vii) Draw conclusion
 The quality of the data will be used to justify the level of confidence that a scientist has in the findings and to evaluate the degree of fit of the data with the hypothesis or current model/interpretation.
- (viii) Explain mechanism/develop theories
 Creative thought is used to explain findings / give 'balance of probability' answer / develop new hypothesis or theory. This will give rise to a new requirement to design tests to scrutinise these ideas.
- (ix) Scientific collaboration/review of findings
 The findings are released to the wider scientific community for validation. This often happens with preliminary findings and allows for additional insights from others and checks on methodology and interpretation.

- (x) Ongoing review
As further information becomes available from the wider scientific community, review leads to amended interpretation and theory.

3. Wider aspects

- (i) Effect of/on society
Developments in science and technology are useful for society but in a context of the risk management of consequential effects.
- (ii) Framework for application in society
Overview by society is carried out via government to determine acceptability/regulate use.

Scientists need to be able to communicate in a variety of ways, depending upon the nature of the task, audience and purpose. Candidates therefore need to develop these skills. They need to be able to communicate their ideas with clarity and precision and to present a scientific argument in a logical manner, drawing conclusions that are based on, and argued from the available evidence. Candidates need to learn to use the appropriate scientific and technical language to support their statements. This includes presenting and using graphical and mathematical language as well as more descriptive writing.

Candidates need to be taught how to think about questions so that they can recall, analyse and interpret scientific information or ideas appropriately. Candidates' understanding of How Science Works will be assessed both in the external examinations and in the controlled assessment. The context for the assessment of How Science Works is not restricted to any specific set of statements in the subject content of the specification units.

The development of scientific ideas over time and an insight into how decisions about science are made should be considered during the course, along with the relevance of scientific information to society. Scientific knowledge and expertise provide benefits for individuals and society, but at times also pose moral and ethical problems which only society can address. Candidates should therefore be provided with an appreciation of the cumulative nature of scientific evidence, tempered by its limitations, and how perceptions and decisions about science are influenced by external attitudes and contexts.

The specification contains historical examples of the development of scientific thought. Amongst these are:

- Mendel's work on inheritance
- the acceptance of plate tectonics
- the establishment of the Big Bang model
- the layered-earth model.

It is vital that candidates understand that the same processes which were involved in the development of these ideas underpin all of science. The narrative that teachers develop in teaching the specification is their own, but it is important that, outside the set-piece examples above, candidates are made aware of the processes of science in a broad range of contexts so that they can become informed and critical participants in scientific debate. Many, if not all of the topics covered in the specification lend themselves to an inquiry, questioning and evidence-led approach. Some of these topics provide opportunities for analysing the process of experimentation and others are appropriate for discussing the relationship between science, engineering and society. Examples of both of these, from each area of science covered in the specification, appear below.

Biology

- Development of environmental policies whereby the need for economic development and requirements of society for housing, energy etc. are balanced against possible effects on and damage to the environment and issues of sustainability. [Biology 1 and Biology 2]
- Experiments which involve enzymes require critical design and analysis e.g. to remove any implicit assumption that all enzymes have an optimum temperature of 37°C; the possible need for buffers depending on specific circumstances around the reactions involved.

Chemistry

- Nanoscience: An opportunity to discuss just how far should we proceed along the road of meddling with 'the building blocks of nature'. Nano-sized particles of many substances have different properties to those associated with larger-scale amounts. An exciting new array of materials with countless future applications in industry and medicine or potential disaster for individuals and society? [Chemistry 1] <http://science.howstuffworks.com/nanotechnology.htm>
- The experimental process: Developing an appreciation of the varying degrees of accuracy of measurement required e.g. simply an excess of base when neutralising an acid to prepare a salt, to the nearest 1 cm³ when measuring solutions for rate of reaction investigations and values to the nearest 0.1 cm³ for titration. [Chemistry 1, 2 and 3]

Physics

- Development of energy policy – conventional power stations / nuclear / renewable energy / global warming. This topic, from Physics 1, lends itself to discussion of politics which is informed by science. The relationship to many areas in the specification is brought out in MacKay, *Sustainable Energy – without the hot air* (ISBN 978-0-9544529-3-3 or www.withouthotair.com). The controversial selection of data was a hot topic in spring 2010. [Physics 1 but with applications in Physics 2 and 3 also.]
- Modelling radioactive decay using random number generators / dice usefully illustrates the effect of sample size in an investigation in which the measured quantity is highly variable. [Physics 2]

Practical Work

- Nomenclature and definitions relating to practical work have been updated and are available in the publication entitled 'The Language of Measurement' available from ASE (www.ase.org.uk) or extracts are available from www.gettingpractical.org.uk Particular attention is drawn to the following points from 'The Language of Measurement':

As the term 'reliability' has a common everyday usage, it may result in ambiguity. It is recommended, therefore, that this term should be avoided. For data the terms 'repeatable' and 'reproducible' are preferred, as they are clear. For conclusions from an experiment, evaluative statements can mention 'confidence' in the quality of evidence.

Further clarification of these terms is available in 'The Language of Measurement'.
- The content sections for Biology 1, 2 and 3 cite possible practical investigations many of which refer to practicals available either from the Society of Biology (www.societyofbiology.org) or SAPS (www-saps.plantsci.cam.ac.uk)

SCIENCE A and BIOLOGY

BIOLOGY 1

Adaptation, evolution and body maintenance

1. VARIETY OF LIFE, ADAPTATION AND COMPETITION

Candidates should:

- (a) understand that living organisms show a range of sizes, features and complexity. Appreciate the broad descriptive grouping into plants - non-flowering and flowering; animals - invertebrates and vertebrates; microorganisms – fungi, bacteria, algae. (Detailed knowledge of group features is not required.)
- (b) know that organisms which have similar features and characteristics can be classified together in a logical way. Morphological features or DNA analysis can be used and as more information becomes available changes are made to the classification. Recently the 3 Domain classification has been preferred to the 5 Kingdom classification. Understand the need for a scientific system for identification and the need for scientific as opposed to 'common' names. Know that international committees decide on scientific names.
- (c) investigate and understand that organisms have morphological and behavioural adaptations which enable them to survive in their environment. Possible investigations: Identification of freshwater invertebrates in enclosed water (e.g. pond or water butt) and their respiratory adaptations.
- (d) know that the types of organisms in an area are affected by other types of organisms by investigating relationships using local or second hand data/ ICT modelling.
- (e) know that individual organisms have a need for resources from their environment e.g. food, water, light and minerals and understand that the size of a population may be affected by competition for these resources along with predation, disease and pollution.

2. MONITORING THE ENVIRONMENT, ENERGY FLOW AND NUTRIENT TRANSFER

Candidates should:

- (a) understand the issues surrounding the need to balance the human requirements for food and economic development with the needs of wildlife. Discuss how the collection of detailed, reliable scientific information and monitoring by biologists could help to inform, manage and reduce the impact of development on the environment e.g. the role of the Environment Agency.

- (b) discuss the advantages and drawbacks of intensive farming methods, such as using fertilisers, pesticides, disease control and battery methods to increase yields. Investigate the issues surrounding the question of the source of TB infection in cattle, including the role of the scientific community in planning valid experiments in order to inform policy decisions and how different interpretations can be applied to reach various possible outcomes.
- (c) investigate using suitable data, how indicator species and changes in pH and oxygen levels may be used as signs of pollution in a stream and investigate how lichens can be used as indicators of air pollution. Understand that mathematical modelling can be used to analyse and predict effects. Possible investigations: Use of oxygen/pH sensors to investigate pollution levels in waterways.
- (d) explore information about the heavy metals which may be present in industrial waste and the types of pesticides used on crops. Some of these chemicals enter the food chain, accumulate in animal bodies and may reach a toxic level and so have harmful effects. Discuss and understand that the effects of pesticides, such as DDT, became apparent in the early 1960s and the initial observation, accumulation and interpretation of scientific evidence emphasised the need to monitor the effects and control the use of these chemicals.
- (e) understand that untreated sewage and fertilisers may cause rapid growth of photosynthesisers, plants and algae, in water. When the plants and algae die, the microbes, which break them down, increase in number and further use up the dissolved oxygen in the water. Animals, including fish, which live in the water may suffocate. Possible investigations: Exploring the effect of increasing concentrations of nitrate on the growth of duckweed (*Lemna*).
- (f) understand that radiation from the Sun is the source of energy for most ecosystems/communities of living organisms and that green plants, and other photosynthetic organisms such as algae, capture a small percentage of the solar energy which reaches them. Investigate data about food chains and food webs and understand that they show the transfer of energy between organisms and involve producers; first, second and third stage consumers; herbivores and carnivores.
- (g) understand that at each stage in the food chain energy is used in repair and in the maintenance and growth of cells whilst energy is lost in waste materials and as heat during respiration.
- (h) use data to construct and interpret pyramids of numbers and biomass.
- (i) understand that carbon is constantly cycled in nature by the carbon cycle via photosynthesis which incorporates it and respiration which releases it.
- (j) know that microorganisms, bacteria and fungi, feed on waste materials from organisms and that when plants and animals die their bodies are broken down by microorganisms bringing about decay. These microorganisms respire and release carbon dioxide into the atmosphere. Understand what happens when decay is prevented. Burning fossil fuels releases carbon dioxide. Possible investigations: Investigate the decay of leaves in different environmental conditions e.g. soil pH, temperature and in bags of different mesh size. Experiments to investigate the microbial decay of fruit or vegetables.

- (k) understand that nutrients are released in decay, e.g. nitrates and phosphates, and that these nutrients are then taken up by other organisms resulting in nutrient cycles. In a stable community the processes which remove materials are balanced by processes which return materials.
- (l) **understand that nitrogen is also recycled through the activity of soil bacteria and fungi acting as decomposers, converting proteins and urea into ammonia. This is converted to nitrates which are taken up by plant roots and used to make new protein. Computer modelling may be used to investigate and predict the effects of factors influencing the process. (Denitrification and nitrogen fixation are not required.)**
- (m) **investigate the action of urease on urea.**

3. INHERITANCE

Candidates should:

- (a) understand that genes are sections of DNA molecules that determine inherited characteristics and are in pairs. Genes have different forms, called alleles.
- (b) know that chromosomes are linear arrangements of genes and that chromosomes that are found in pairs in body cells are strands of DNA. DNA contains coded information for the production of different types of proteins. These proteins determine how cells function.
Possible investigations: practical extraction of DNA from cells.
- (c) understand that an organism's DNA can be analysed by 'genetic profiling' and how this can be used to show the similarity between two DNA samples. The process involves cutting the DNA into short pieces which are then separated into bands. The pattern of the bands produced can be compared to show the similarity between two DNA samples, for instance in criminal cases, paternity cases and in comparisons between species for classification purposes.
Advances in technology now make such analysis widely available.
- (d) discuss the benefits of DNA profiling, for example to identify the presence of certain genes which may be associated with a particular disease. As this likelihood may be based on statistical probability, understand that it raises issues such as risk-benefit considerations and disclosure of information along with wider ethical issues of ownership and human rights which are subject to value judgement by society.
- (e) understand that when gametes are formed the chromosome number is halved and the genetic composition of the daughter cells is not identical (the term, meiosis, and knowledge of stages are not required). Fertilisation restores normal chromosome number.
- (f) know that in human body cells, one of the pairs of chromosomes, XX or XY, carries the genes which determine sex. These separate and combine randomly at fertilisation.

- (g) be able to understand and complete Punnett squares and explain the outcomes of monohybrid crosses including ratios. The following terms should be understood: genotype, phenotype, dominant, recessive, F1, F2, selfing, heterozygous, heterozygote, homozygous and homozygote and an understanding of simple Mendelian ratios. (Incomplete dominance is not required.) **Understand that most characteristics are controlled by more than one gene.**
- (h) consider the scientific process of observation, experimentation and deduction that led Gregor Mendel to propose the mechanism of inheritance. Discuss why the significance of the work was not recognised and validated by scientists for many years.
- (i) know that genes can be transferred artificially from one species to another. Understand that the introduction of genes from herbicide-resistant plants into soya bean plants, so increasing their resistance to herbicides, may increase the crop yield due to reduced competition. Understand the potential disadvantages and issues involved. (Names of enzymes are not required.)
- (j) investigate and evaluate the potential benefits and problems posed by advances in GM crop technology. Understand the need to collect reliable data, e.g. the use of farm scale field trials, in order that possible effects on the environment and on health should be understood. The data may be used to help formulate policy decisions regarding the planting of these crops and to inform consumers. Understand the need for unbiased information and interpretation as it affects the public perception of foods containing GM products and informs risk management considerations of possible consequences.

4. VARIATION

Candidates should:

- (a) examine the variation in height/length in individuals of the same species by collecting and analysing data and know that variation may be due to environmental or genetic causes. **Understand that variation may be continuous or discontinuous.**
- (b) understand that sexual reproduction leads to offspring that are genetically different from the parents unlike asexual reproduction where genetically identical offspring called clones are produced from a single parent. Sexual reproduction therefore gives rise to increased variation.
- (c) understand that new genes result from changes, mutations, in existing genes and that mutations occur at random. Most mutations have no effect but some may be beneficial or harmful. Mutation rates can be increased by ionising radiation. (Reference to specific ionising radiation is not required.)
- (d) understand that some mutations cause conditions which may be passed on in families, as is shown by the mechanism of inheritance of cystic fibrosis, and be able to interpret family trees. Discuss the issues surrounding the development and use of gene therapy which has been tried as a means to alleviate the symptoms in cystic fibrosis sufferers but has greater potential as advances are made in knowledge and technology.

5. EVOLUTION

Candidates should:

- (a) know that heritable variation is the basis of evolution.
- (b) consider how individuals with characteristics adapted to their environment are more likely to survive and breed successfully. Discuss the use and limitations of a model to illustrate the effect of camouflage colouring in predator and prey relationships.
- (c) know that the genes which have enabled these better adapted individuals to survive are then passed on to the next generation. This is natural selection as proposed by Charles Darwin and accepted by scientists. Work continues to fully understand the process as further evidence from genetics and molecular biology is collected. The process of natural selection is sometimes too slow for organisms to adapt to new environmental conditions and so organisms may become extinct.
Possible investigations: a model for natural selection - spaghetti worms.
- (d) understand that evolution is ongoing as shown by the development of resistance to antimicrobial chemicals by bacteria or Warfarin resistance in rats.

6. RESPONSE AND REGULATION

Candidates should:

- (a) know that sense organs are groups of receptor cells, which respond to specific stimuli: light, sound, touch, temperature, chemicals, and then relay this information as electrical impulses along neurones to the central nervous system. (Details of structure of sense organs is not required.)
- (b) investigate sensitivity and reaction times.
Possible investigations: falling metre rule experiment; assessing skin sensitivity - temperature receptors.
- (c) explore experimentally the positive response of plant shoots to light, phototropism, and plant roots to gravity, gravitropism. Phototropism is due to a plant hormone. (Details of hormones or mechanism are not required).
Possible investigations: time lapse photography of markers on plants could be used to compare growth rates/responses by different species and/or under different conditions.
- (d) understand the reasons why animals need to regulate the conditions inside their bodies to keep them relatively constant and protected from harmful effects.

- (e) understand that hormones are chemical messengers, carried by the blood, which control many body functions. Investigate data showing the relationship between glucose and insulin levels in the blood. Understand that glucose levels need to be kept within a constant range so when the blood glucose level rises, the pancreas releases the hormone insulin, a protein, into the blood. This causes the liver to reduce the glucose level by converting glucose to insoluble glycogen and then storing it.
(Details of endocrine glands, other hormones, glucagon are not required.)
- (f) know that diabetes (type 1) is a condition in which a person's blood glucose may rise to a fatally high level because the body does not produce enough insulin. Understand that it can be diagnosed by the presence of glucose in the urine and the methods of treating the condition. Carry out testing of artificial urine samples for glucose using a suitable method, such as Benedicts.
- (g) recognise and label a simplified given diagram of a vertical section through the skin to show: hair, erector muscle, sweat gland, sweat duct, sweat pore, blood vessels. Understand the role of these structures in temperature regulation: change in diameter of blood vessels, sweating, erection of hairs; shivering as a means of generating heat.
Possible investigations: Investigate and interpret information about sweating and temperature; observe prepared sections of skin under a microscope.
- (h) understand the principles of negative feedback mechanisms to maintain optimum conditions inside the body as illustrated by the control of glucose levels by insulin and glucagon and by the control of body temperature.**

7. HEALTH

Candidates should:

- (a) understand that different foods have different energy content and understand that energy from food, when it is in excess, is stored as fat by the body. Investigate experimentally the comparative energy content of different foods by burning. (Peanuts should not be burned due to the risk of allergy.)
- (b) explore and discuss available data, e.g. from ICT searches and food labelling, about the sugar, fat and additives in foods and the implications, particularly for health.
- (c) understand that some conditions are affected by lifestyle choices and investigate information/data about the effects that alcohol and drug abuse have on the chemical processes in people's bodies. Examine and consider data about the incidence of diabetes (type 2) and the possible relationship with lifestyle.
- (d) understand that health is affected by a variety of factors and that science and technology may provide the answer to some health problems. Understand that some treatments may involve risk-benefit assessments.
- (e) understand that some conditions can be prevented in a variety of ways and that some can be treated by drugs or by other therapies. Discuss the associated issues some of which may be viewed from a scientific and moral perspective.
- (f) understand that new drug treatments may have side effects and extensive, large scale, rigorous testing is required including risk management. Discuss the associated risks, benefits and ethical issues including the use of animals for testing drugs and whether this is superseded by new technologies.

SCIENCE A and CHEMISTRY

CHEMISTRY 1

The Earth and its resources

1. ELEMENTS & THE PERIODIC TABLE

Candidates should:

- (a) understand that elements are the basic building blocks of all substances and cannot be broken down into simpler substances by chemical means.
- (b) know that elements are made up of only one type of atom and that each atom contains a positively charged nucleus and orbiting negatively charged electrons.
- (c) be aware that Mendeleev, in developing the modern form of the Periodic Table, observed recurring patterns in the properties of elements when arranged in order of relative atomic mass, but used creative thought to realise that he needed to leave gaps for elements that had not been discovered at that time; this enabled him to predict the properties of the undiscovered elements.
- (d) be able to describe an element's position in the Periodic Table in terms of its group and its period.
- (e) know that metals are good conductors of heat and electricity, malleable and ductile, and are generally hard, dense and shiny with high melting points and boiling points, while non-metals are generally poor conductors with low melting points and boiling points.
- (f) appreciate that metals are found on the left hand side and in the centre of the Periodic Table, non-metals on the right-hand side and that elements with intermediate properties are found between the metals and non-metals e.g. silicon in Group 4.
- (g) examine data about the physical and chemical properties of elements to establish trends within groups and to make predictions based on these trends.

2. COMPOUNDS

Candidates should:

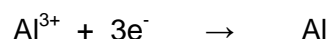
- (a) know that in a chemical reaction, atoms are rearranged but none are created or destroyed.
- (b) understand that new substances called compounds are formed when atoms of two or more elements combine and that each compound has its own chemical formula.
- (c) be able to interpret given chemical formulae i.e. name the elements, state the number of atoms of each element and the total number of atoms present, including formulae containing hydroxide, nitrate, carbonate and sulfate ions.
- (d) be able to draw and interpret space-filler type diagrams for simple molecules using a key (showing an appreciation of which atoms are joined to which).
- (e) understand that electrons are transferred from metal atoms to non-metal atoms, forming positively charged metal ions and negatively charged non-metal ions, when ionic compounds are formed.
- (f) be able to write chemical formulae for ionic compounds given the formulae of the ions that they contain, including formulae containing hydroxide, nitrate, carbonate and sulfate ions.

3. METALS

Candidates should:

- (a) know that ores found in the Earth's crust contain metals combined with other elements and that these metals can be extracted using chemical reactions.
- (b) understand that some unreactive metals (e.g. gold) can be found uncombined and that the difficulty involved in extracting metals increases as their reactivity increases.
- (c) investigate the relative reactivities of metals by displacement (e.g. iron nail in copper(II) chloride solution) and competition reactions (e.g. thermit reaction) and write and interpret word equations and balance symbol equations to describe the reactions, **including those which feature nitrates and sulfates**.
- (d) explain reduction and oxidation in terms of removal or gain of oxygen and recognise their occurrence in reactions e.g. during thermit reaction and in the blast furnace.
- (e) explain why iron ore, coke and limestone are the raw materials placed in the blast furnace in order to extract iron.
- (f) write and interpret the word equation for the reduction of iron(III) oxide by carbon monoxide and balance the symbol equation.

- (g) understand that the extraction of aluminium requires greater energy input than the extraction of iron and that the method used to extract the most reactive metals (including aluminium) is electrolysis.
- (h) explain the process of electrolysis of molten ionic compounds e.g. lead(II) bromide, in terms of ion movement and electron gain/loss, using the terms electrode, anode, cathode and electrolyte.
- (i) balance given electrode equations in terms of charge **and atoms**.
- (j) apply their understanding of electrolysis to the industrial extraction of aluminium and balance the following electrode equations in terms of charge **and atoms**.



- (k) discuss issues of sustainability relating to the extraction of metals including iron and aluminium e.g. siting of plants, fuel & energy costs, greenhouse emissions and recycling, and evaluate the social and economic impact of their extraction and use.
- (l) explain the uses of aluminium, copper and titanium in terms of the following relevant properties:
- aluminium – strong, low density, good conductor of heat and electricity, resistant to corrosion
 - copper – very good conductor of heat and electricity, malleable and ductile, attractive colour and lustre
 - titanium – hard, strong, low density, resistant to corrosion, high melting point.
- (m) understand that an alloy is a mixture made by mixing molten metals and that its properties can be modified by changing its composition.
- (n) know that nano-scale silver particles have antibacterial, antiviral and antifungal properties leading to new uses in hygiene and medicine.
- (o) relate the uses of nano-scale particles to their properties.
- (p) assess the potential risks of current and future developments in nanoscience in the context of potential benefits e.g. using nano-scale materials in battery electrodes for electric vehicles or in solar cells.

4. NON-METALS

Candidates should:

- (a) know that many non-metals, including nitrogen, oxygen, neon and argon, are found in the air.
- (b) understand that hydrogen and oxygen can be produced from water by electrolysis and that twice the volume of hydrogen as oxygen is produced.
- (c) carry out tests to identify hydrogen gas and oxygen gas.
- (d) know that hydrogen burns in air, releasing usable energy, and be able to write and interpret the word equation and balance the symbol equation for the reaction.
- (e) discuss and explain the advantages and disadvantages of hydrogen as a fuel in terms of its abundance, combustion product, renewability and storage issues, extraction costs and safety issues.
- (f) know that chlorine and iodine can be obtained from compounds in sea water but appreciate that this is no longer considered to be an economically viable source of iodine.
- (g) explain the uses of chlorine, iodine, helium, neon and argon in terms of the following relevant properties:
 - chlorine – poisonous/toxic, kills bacteria
 - iodine – poisonous/toxic, kills bacteria
 - helium – very low density, very unreactive
 - neon – emits light when electric current passes through it
 - argon – very unreactive.
- (h) know that sodium fluoride, taken in toothpaste or in the water supply, prevents tooth decay and appreciate that scientists gathered evidence to establish this fact by a range of survey techniques.
- (i) understand the arguments for and against fluoridation of the water supply, including the ethical issue of removing freedom of choice for the individual.

5. REACTIONS OF ACIDS

Candidates should:

- (a) be able to classify substances as acidic, alkaline or neutral in terms of the pH scale, including acid/alkali strength.
- (b) investigate the reactions of acids with metals and explain their observations in terms of the metals' position in the reactivity series.
- (c) know that the neutralisation of dilute acids with bases (including alkalis) and carbonates is exothermic and that carbonates effervesce in acid and that these patterns can be used to make predictions and plan procedures to distinguish between given bases, carbonates and salts.
- (d) carry out test to identify carbon dioxide gas.
- (e) prepare crystals of soluble salts, such as copper(II) sulfate, from insoluble bases and carbonates.
- (f) be able to write and interpret word equations and balance chemical equations to describe the reactions of metals, bases (including alkalis) and carbonates with the following acids:

hydrochloric acid, nitric acid and sulfuric acid.

6. THE PRODUCTION & USES OF FUELS & PLASTICS

Candidates should:

- (a) understand that crude oil is a complex mixture of hydrocarbons that was formed over millions of years from the remains of simple marine organisms.
- (b) appreciate that crude oil is a finite resource and that decisions made about its uses have global social, economic and environmental impact.
- (c) know that crude oil is separated into less complex mixtures, called fractions, which contain hydrocarbons with boiling points in the same range.
- (d) understand that while most fractions are used as fuels, others are further processed by cracking to make small, reactive molecules called monomers, which can be used to make plastics.
- (e) know that small reactive molecules called monomers are joined together to form polymers in a process known as polymerisation.
- (f) understand that many plastics, including polythene, PVC, PTFE and polystyrene, are made by polymerisation and recall the general properties of plastics.
- (g) explain the uses of given plastics in terms of their properties.
- (h) discuss and explain the environmental issues relating to the disposal of plastics, in terms of their non-biodegradability, increasing pressure on landfill for waste disposal, and how recycling addresses these issues as well as the need to carefully manage the use of natural resources such as oil.

7. THE EVER-CHANGING EARTH

Candidates should:

- (a) be able to briefly describe the theory of plate tectonics and know that it developed from Alfred Wegener's earlier theory known as continental drift.
- (b) appreciate that the earlier theory was not accepted by other scientists because Wegener could not explain how or why the continents moved.
- (c) describe the evidence, discovered at a later date, which led to the theory of plate tectonics being accepted by other scientists.
- (d) know that the distribution of major earthquakes and volcanoes can be used to identify plate boundaries.
- (e) know that the original atmosphere was formed by gases, including carbon dioxide and water vapour, being expelled from volcanoes.
- (f) understand how the composition of the atmosphere has changed over geological time and recall its approximate present day composition.
- (g) understand the roles of respiration, combustion and photosynthesis in the maintenance of the levels of oxygen and carbon dioxide in the atmosphere.
- (h) appreciate that there is much media debate on the issue of global warming and be aware that the vast majority of scientists attribute the main cause of global warming to the increase in carbon dioxide in the atmosphere caused by the combustion of fossil fuels.
- (i) explain the environmental effects and consequences of the emission of carbon dioxide and sulfur dioxide into the atmosphere through the combustion of fossil fuels.
- (j) **evaluate proposed solutions to the problems of global warming and acid rain e.g. 'carbon capture' and 'sulfur scrubbing'.**

SCIENCE A and PHYSICS

PHYSICS 1

Energy, radiation and the Universe

1. GENERATION OF ELECTRICITY

Candidates should:

- (a) be aware of the usefulness of electricity as a means of energy transfer.
- (b) be aware of the significance of commissioning costs, running costs (including fuel) and decommissioning costs for power stations and respond to data concerning these costs for fossil fuel, nuclear and non-thermal power stations.
- (c) compare the advantages and environmental impact of different forms of electrical power generation including micro-generation, e.g. using domestic wind turbines and roof-top photovoltaic cells.
- (d) use data to estimate the power output of power stations and micro generators e.g. from energy content of fuel and conversion efficiency.
- (e) experimentally determine the density of materials, including air and water, and use knowledge of density to inform discussion of the energy available from moving water and air.
- (f) select and use the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

2. TRANSMISSION OF ELECTRICITY

Candidates should:

- (a) understand the need for an electricity distribution system, in terms of maintaining a reliable energy supply which is capable of responding to a fluctuating demand.
- (b) describe the National Grid in terms of power stations, substations and power lines.
- (c) explain in terms of energy efficiency and safety, why electricity is transmitted at high voltages but used at low voltages in the home and hence the need for transformers in the national grid.

- (d) investigate the operation of step-up and step-down transformers, e.g. using demountable transformers, C-cores or computer models, in terms of the input and output voltage, current and power. [N.B The operation of a transformer in terms of electromagnetic induction and turns ratio will not be examined in this unit.]
- (e) **select and use the equation:**

$$\text{power} = \text{voltage} \times \text{current}; P = VI$$

in relation to the supply of power from power stations, its transmission and receipt by the end user.

3. ENERGY SUPPLY AND THE HOME

Candidates should:

- (a) distinguish between power and energy and select and use the equation:
energy transfer = power \times time ; $E = Pt$.
- (b) select and use the equations:
Units used (kWh) = power (kW) \times time (h)
cost = units used \times cost per unit
together with information on the power ratings of domestic electrical appliances and investigate the cost of using them.
- (c) use data to make comparisons of different sources of domestic energy, including cost comparisons of traditional sources, e.g. electricity, gas, oil and coal, and the cost-effectiveness and environmental implications of introducing alternative energy sources, e.g. domestic solar and wind energy equipment.

4. ENERGY TRANSFER

Candidates should:

- (a) use energy transfer (Sankey) diagrams and understand qualitatively the idea of energy efficiency in terms of input energy, useful output energy and wasted energy.
- (b) investigate the efficiency of energy transfer in electrical contexts, e.g. using an electrical energy meter and a kettle.
- (c) select and use the equation:

$$\% \text{ efficiency} = \frac{\text{useful energy [or power] transfer}}{\text{total energy [or power] input}} \times 100$$

in a range of contexts including electrical power generation and transmission.

- (d) understand the relevance of the efficiency of fossil-fuel power stations and the national grid to the environmental debate on carbon footprint and anthropogenic global warming.
- (e) explore experimentally how temperature differences lead to the thermal transfer of energy by conduction, convection and radiation – a particle explanation for conduction will **not** be examined, but candidates should be aware that density changes result in natural convection. See section 5 below for thermal radiation.
- (f) understand how energy loss from houses can be restricted and use data to compare the economics of domestic insulation techniques, e.g. loft insulation and double glazing.

5. THE CHARACTERISTICS OF WAVES

Candidates should:

- (a) characterise waves in terms of their wavelength, frequency, speed and amplitude.
- (b) select and apply the equations

wave speed = wavelength \times frequency; $c = \lambda f$, and

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

to the motion of waves, **including electromagnetic waves.**

- (c) investigate the speed of waves, e.g. of water waves in a storage tray, and compare the speed of sound waves in air and wood.
- (d) distinguish between the different regions of the electromagnetic spectrum [radio waves, microwaves, infra red, visible light, ultra violet, X rays and gamma rays] in terms of their wavelength and frequency and appreciate that they all travel at the same speed in a vacuum.
- (e) appreciate that all regions of the electromagnetic spectrum transmit information and energy.
- (f) identify thermal radiation with electromagnetic radiation, understanding how the nature of the surface influences the radiation emitted and absorbed, **and understanding qualitatively the relationship between the temperature of an object and the radiation emitted.**
- (g) **describe the greenhouse effect in terms of visible radiation from the Sun and infra-red radiation emitted from the Earth and absorbed and re-emitted from the atmosphere.**
- (h) compare the use of microwaves and infra-red radiation in long distance communication, including a consideration of geosynchronous satellites, mobile phone technology and intercontinental optical fibre links.
- (i) be aware of public concern about claimed health risks associated with mobile phone masts and respond to newspaper and other reports discussing this issue.

6. IONISING RADIATION

Candidates should:

- (a) apply the term "radiation" to both electromagnetic waves and to energy given out by radioactive materials.
- (b) characterise radioactive emissions and short-wavelength parts of the electromagnetic spectrum (ultra-violet, X-ray and γ -ray) as ionising radiation, able to interact with atoms and to damage cells by the energy they carry.
- (c) know that waste materials from nuclear power stations and nuclear medicine are radioactive and some of them will remain radioactive for thousands of years.
- (d) observe experiments and/or ICT simulations of experiments to investigate the penetrating power of nuclear radiation and understand that, in making measurements of radiation, an allowance for background radiation must be made.
- (e) be aware that the random nature of radioactive decay has consequences when undertaking experimental work, requiring repeat readings to be made or measurements over a lengthy period as appropriate.
- (f) distinguish between alpha (α), beta (β) and gamma (γ) radiation in terms of their penetrating power, **relate their penetrating powers to their potential for harm** and discuss the consequences for the long-term storage of nuclear waste.
- (g) be aware of natural and artificial sources of background radiation, respond to information about received dose from different sources (including medical X-rays) and discuss the reasons for the variation in radon levels.

7. THE SOLAR SYSTEM AND ITS PLACE IN AN EVOLVING UNIVERSE

Candidates should:

- (a) appreciate the range of distance scales appropriate when discussing the universe, from the scale of planets, the Solar System, the Milky Way galaxy and the observable universe.
- (b) know that atoms of a gas absorb light at specific wavelengths which are characteristic of the elements in the gas and use data to identify gases from an absorption spectrum.
- (c) know that scientists in the nineteenth century were able to reveal the chemical composition of stars by studying the absorption lines in their spectra.
- (d) recall that Edwin Hubble's measurements on the spectra of distant galaxies revealed that the wavelengths of the absorption lines are increased and that this "cosmological red shift" increases with increasing distance.

- (e) **account for the cosmological red shift in terms of the expansion of the universe since the radiation was emitted.**
- (f) recall that the Big-Bang model of the origin of the universe predicted the existence of background radiation, which was subsequently detected accidentally in the 1960s, and that the Cosmic Microwave Background radiation is the red-shifted remnant of radiation from the origin of the universe.
- (g) appreciate the role played by the cosmological red-shift and the microwave background radiation in establishing the Big-Bang model of the origin of the universe.

ADDITIONAL SCIENCE and BIOLOGY

BIOLOGY 2

Cells and metabolism, digestion and respiration, biodiversity

1. CELLS AND CELL PROCESSES

Candidates should:

- (a) investigate how the development of the microscope (light, electron, laser imaging) influenced the understanding of the structure of organisms and the proposal that the cell is the basic unit of life (cell theory). (Details of subcellular structures or resolution are not needed)
Possible investigations: view objects at different magnifications.
- (b) know that microbes include bacteria, viruses, fungi and unicellular algae. Know the structure of a bacterial cell. Bacteria reproduce asexually by dividing into two. Some bacteria are thought to be the earliest forms of life. Know the structure of an algal cell. (References to prokaryote and eukaryote are not required.)
- (c) know that yeasts are fungi. Know the structure of a yeast cell. Yeasts reproduce asexually by budding.
- (d) investigate the similarities and differences between plant and animal cells and the specialisation that results from being multicellular. Draw and label diagrams of plant and animal cells and understand the function of the following parts: cell membrane, cytoplasm, nucleus; plus cell wall, chloroplast, vacuole.
Possible investigations: view prepared slides of plant and animal cells and tissues; prepare wet mounts of algal or plant cells.
- (e) know the basic structure of a virus and that viruses are smaller than bacteria. Viruses can only reproduce inside a host cell. The release of new viruses results in the destruction of the host cell and the released new viruses can then attack new cells.
- (f) discuss whether 'cell theory', as proposed in the late 19th century, can still be accepted in the light of the discovery of viruses in the 1950s.
- (g) know that different proteins are composed of different amino acids linked together to form a chain which is then folded to form a specific shape. Proteins have a number of important functions e.g. enzymes, hormones and muscle tissue. The specific shape of an enzyme enables it to function. **The active site of an enzyme depends on shape which is held by chemical bonds.** (Reference to terms primary, secondary, tertiary structure, or type of bonding is not required.)

- (h) know that chemical reactions in cells are controlled by enzymes and that enzymes are proteins made by living cells. Enzymes speed up/catalyse the rate of chemical reactions. Each enzyme has its own optimum pH and temperature. Interpret enzyme activity in terms of molecular collisions. Boiling denatures most enzymes by altering their shape. Simple understanding of 'lock and key' modelling is required. **Understand that enzymes function by the formation of the enzyme - substrate complex at the active site.**
- (i) investigate the use of digestive enzymes, lipases, proteases and carbohydrases in biological washing powders to remove stains from textiles. Use of enzymes enables lower temperatures to be used which requires less energy. Possible investigations: removal of egg yolk stains from cloth by biological washing powders at different temperatures; investigating the effect of pH on amylase activity.
- (j) know that DNA is made up of two long chains of alternating sugar and phosphate molecules connected by bases and that this structure is twisted to form a double helix. Know that there are four bases, A, T, C and G, and that it is the order of these bases which forms a code. This code determines the order in which different amino acids are linked together to form different proteins. **Understand complementary base pairing between adenine and thymine, cytosine and guanine and the role of the triplet code during protein synthesis. (Role of RNA is not required.)** Possible investigations: visualisation of DNA structure and function of the code through physical models and computer simulations.
- (k) explore information about the discovery of the structure and function of DNA and the process of collaboration needed between scientists, using different techniques, to deduce the mechanism.
- (l) understand that cell division, by mitosis, enables organisms to grow, replace worn out cells and repair damaged tissues. The chromosome number remains constant and the genetic composition of the daughter cells is identical to the mother cell. Understand that cell division by meiosis halves the chromosome number for the formation of gametes. (Understanding of the processes of the divisions is not required.)
- (m) be able to compare the outcome of a mitotic and a meiotic division. Each mitotic division produces two cells that are genetically identical and have the same number of chromosomes as the mother cell. Each meiotic division produces four cells that are genetically different and have half the number of chromosomes of the mother cell. (Understanding of the stages of the processes is not required.)
- (n) know that plants and animals have different patterns of growth and development and consider the advantages and disadvantages. Animals tend to grow to a finite size more so than plants. Animals have a compact growth form whereas in general land plants have a spreading, branched growth form.

- (o) know that, in mature tissues cells have generally lost the ability to differentiate into different types of cells. There are some cells, both plant and animal, that do not lose this ability and these are called stem cells. These adult stem cells retain the ability to differentiate into some different types of cells and therefore have potential for replacing damaged tissue, as do embryonic stem cells. Discuss the future potential and possible ethical issues surrounding this technology including the implications for society e.g. the use of embryonic stem cells. Plants have stem cells in their shoot and root tips which retain their ability to differentiate into other cells throughout the life of the plant.

2. SUBSTANCES ENTER AND LEAVE CELLS THROUGH THE CELL MEMBRANE

Candidates should:

- (a) use modelling to show that diffusion is the movement of substances down a concentration gradient including the use of Visking tubing as a model of living material. Consider the role of the cell membrane in diffusion.
- (b) understand that diffusion does not require energy and only certain substances pass through the cell membrane in this way, most importantly oxygen and carbon dioxide.
- (c) be able to interpret experimental results of Visking tubing experiments in terms of membrane pore and particle size: the pore size is large enough to allow water molecules through but restricts the movement of solute molecules.
- (d) investigate experimentally the effect of solute concentration on living plant tissue such as the effect of concentration of blackcurrant squash on osmosis in chipped potatoes.
- (e) know that osmosis is the diffusion of water through a selectively permeable membrane, from a region of high water (low solute) concentration to a region of low water (high solute) concentration.
- (f) **understand active transport as an energy requiring process whereby substances can enter cells against a concentration gradient.**

3. PHOTOSYNTHESIS

Candidates should:

- (a) enquire and consider what plants, which consist of cells, require to support life processes and what sources of materials are available.
- (b) investigate experimentally the conditions needed for photosynthesis to take place and the factors which affect its rate, including temperature, carbon dioxide and light intensity. **Understand these as limiting factors.** Computer modelling and simulations should also be used to extend the investigation by exploring further data and graphical interpretations.

- (c) be familiar with practical techniques such as use of sodium hydroxide to absorb carbon dioxide, how to test a leaf for the presence of starch, and how oxygen and carbon dioxide sensors and data loggers could be used experimentally to investigate the composition of air in a container housing a plant and varying a variety of factors such as species, illumination level etc.
- (d) understand the importance of photosynthesis whereby green plants and other photosynthetic organisms use chlorophyll to absorb light energy and convert carbon dioxide and water into glucose, producing oxygen as a by-product. The chemical reactions of photosynthesis within the cell are controlled by enzymes. Know the word equation for photosynthesis. (Details of the enzymes involved in photosynthesis are not required.)
- (e) know the uses made by plant cells of the glucose produced in photosynthesis. Glucose produced in photosynthesis may be respired to provide energy, converted to starch for storage or used to make cellulose and proteins which make up the body of plants.

4. RESPIRATION

Candidates should:

- (a) understand that all cells require a constant supply of energy to carry out cell processes and so enable organs and systems to function, and that energy is released in cells by respiration.
- (b) investigate experimentally energy release as heat during respiration, by germinating peas, including the role of thermos flasks and disinfectants.
- (c) know that aerobic respiration occurs in cells when oxygen is available. During aerobic respiration which is (a series of) chemical reactions within the cell controlled by enzymes, glucose and oxygen are used, energy is released and carbon dioxide and water are produced. Some energy is lost as heat. Know the word equation for aerobic respiration.
- (d) **understand that in the absence of oxygen, anaerobic respiration may occur. This is less efficient than aerobic respiration. In humans energy is released from glucose and lactic acid is produced. An oxygen debt may occur. In yeast, energy is released from glucose and ethanol and carbon dioxide are produced. Know the word equation for anaerobic respiration in human cells and fermentation in yeast. Know that there is less energy released per molecule of glucose in anaerobic respiration than in aerobic respiration. (Reference to ATP is not required.)**

5. DIGESTION

Candidates should:

- (a) question why and understand that during digestion there is a need for the breakdown of large molecules into smaller molecules so they can be absorbed for use by body cells.
- (b) investigate experimentally the role of enzymes, such as lipase, in digestion including the effect of temperature on enzyme action and the importance of experimental design including biological controls. Understand that boiling denatures enzymes and that enzymes are specific for each type of molecule.
- (c) investigate, using Visking tubing as a model gut, how soluble substances can be absorbed through the wall of the small intestine and eventually into the bloodstream, and understand the limitations of the model.
(Knowledge of active transport is not required.)
- (d) know that fats, made up of fatty acids and glycerol, proteins, made up of amino acids, and starch (a carbohydrate), made up of a chain of glucose molecules, in our food are insoluble. They are broken down during digestion into soluble substances so that they can be absorbed. Know how to test experimentally for the presence of starch, using iodine solution, glucose using Benedict's reagent and protein using Biuret solution. Use chemical models to show how compounds can be broken down into smaller units.
- (e) recognise and label on a given diagram of the human digestive system and associated structures: the mouth, oesophagus/gullet, stomach, liver, gall bladder, bile duct, pancreas, small intestine, large intestine, anus and understand the role of the following organs in digestion: mouth, stomach, pancreas, small intestine, large intestine.
- (f) understand how food is moved by peristalsis and know the function of bile, secreted by the liver and stored in the gall bladder, in the breakdown of fats. Possible investigations: observe images (X-ray/CAT scans) showing peristalsis and use of detergent to investigate the action of bile.
- (g) understand that body cells need the digested products of fats, carbohydrates and proteins. Fatty acids and glycerol from fats and glucose from carbohydrate provide energy whilst amino acids from digested proteins are needed to build proteins in the body. (Knowledge of lymphatic system is not required.)

6. RESPIRATORY SYSTEM

Candidates should:

- (a) understand the need for and purpose of the respiratory system and recognise and label on a given diagram of a vertical section of the human respiratory system: nasal cavity, trachea, bronchi, bronchioles, alveoli, lungs, diaphragm, ribs and intercostal muscles. (Knowledge of pleural membranes is not required.)
Possible investigations: examination/dissection of lungs, bronchi etc.; observation of sections of lung tissue under the microscope.
- (b) use a bell jar model to illustrate inspiration and expiration, understand the limitations of this model and be able to explain the mechanism of inspiration and expiration in terms of changes in thoracic volume and pressure brought about by movements of the diaphragm and rib cage.
Possible investigations: computer modelling the human ventilation system.
- (c) be able to label on a given diagram of an alveolus and its blood supply: end of bronchiole, wall of alveolus, moist lining of alveolus, wall of capillary, red blood cells and plasma. (The term 'air sac' should not be used.)
- (d) understand the differences between inspired and expired air and how gases diffuse between alveolar air and capillaries and know the adaptations of alveoli for gas exchange. Understand the use of lime water to indicate presence of carbon dioxide during investigations and examine data about the gas content of inspired and expired air.
- (e) know the function of mucus and cilia and the effects of smoking on cilia and mucus and the consequences for the individual.
- (f) investigate the evidence for a link between tar from cigarette smoking and lung cancer and between cigarette smoking and emphysema, and understand the consequences of these conditions.
Possible investigations: 'Going up in smoke'.
- (g) discuss the controversy between the sometimes conflicting evidence about the effects of smoking from independent studies and those of vested interest groups. Discuss the need for unbiased interpretation of investigations, scientific validation of data and peer review. Discuss how attitudes to smoking have changed over time as evidence about its effects has been validated by scientists including the conflict between regulation and personal freedom and the cost–benefit considerations.

7. BIODIVERSITY AND ENVIRONMENT

Candidates should:

- (a) use quadrats to investigate the abundance of species e.g. a comparison of different sides of a hedge or mown and unmown grassland.
- (b) obtain first hand data to understand how transects can be used to measure changes in the abundance and distribution of species e.g. seashore.
Possible investigations: 'Biodiversity in your backyard'.

- (c) understand the principles of sampling, the need to collect sufficient data and use of appropriate statistical analysis. (Details of statistical tests are not required.) **Understand the principles of capture/recapture techniques including simple calculations on estimated population size.**
- (d) understand what is meant by biodiversity, the variety or number of different species in an area, and why it is important. Investigate the ways in which biodiversity and endangered species can be protected including issues surrounding the use of legislation. Understand the need for and issues associated with the collection of reliable data and ongoing environmental monitoring. Appreciate how mathematical modelling can be used to analyse environmental interactions and predict trends.
- (e) investigate the use of biological control agents and the introduction of alien species and their effects on local wildlife. Understand the issues surrounding the use of biological control agents and how the approach to using this method of control has changed as requirements for detailed research and scientifically based trials and analysis are now more fully understood. Possible investigations: evaluating methods of pest control.

ADDITIONAL SCIENCE and CHEMISTRY

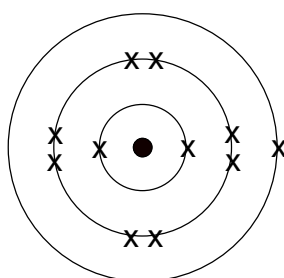
CHEMISTRY 2

Atoms, bonding and chemical change

1. ATOMIC STRUCTURE & THE PERIODIC TABLE

Candidates should:

- know that atomic nuclei are comprised of protons and neutrons.
- know the relative masses and relative charges of protons, neutrons and electrons.
- appreciate that the accepted model of an atom has developed over time as scientists made observations that could not be explained by contemporary ideas, and therefore proposed their own hypotheses to be tested by gathering further experimental evidence.
- understand that the atom as a whole has no electrical charge because the number of electrons in the shells is equal to the number of protons in the nucleus.
- understand the terms atomic number (proton number) and mass number (nucleon number).
- represent the electronic structures of any of the first 20 elements in diagrammatic form,
e.g. for sodium:



- use data given in the form ${}_{11}^{23}\text{Na}$ to give the number of protons, neutrons and electrons present in an atom.
- understand how the electronic structure of any element is related to its position in the Periodic Table (group and period) and understand that the chemical properties of each element is dependent upon its electronic structure.
- understand that some elements have two or more isotopes i.e. atoms with the same number of protons but different numbers of neutrons.

- (j) know that the mass of an atom of an element is measured on a scale which compares masses of atoms with each other – relative atomic masses (A_r).
- (k) be able to calculate the relative molecular (formula) mass (M_r) of a compound from its formula.

2. REACTIONS OF ALKALI METALS & HALOGENS

Candidates should:

- (a) investigate the reactions of Group 1 metals with
 - oxygen in the air (corrosion of newly exposed surface and burning)
 - water
 - Group 7 elementsin order to establish the trend in reactivity within the group.
- (b) describe what is observed when lithium, sodium and potassium react with water.
- (c) investigate the reactions of Group 7 elements with iron in order to establish the trend in reactivity within the group.
- (d) describe the trends in reactivity within Group 1 and Group 7 and be able to write and interpret word and balanced symbol equations for the above reactions.
- (e) **investigate the displacement reactions of Group 7 elements in order to confirm the trend in reactivity within the group, be able to make predictions based on this trend and write and interpret word and balanced symbol equations for the reactions.**
- (f) be able to use flame tests to detect the presence of lithium, sodium and potassium ions.
- (g) be able to use silver nitrate solution to detect the presence of chloride, bromide and iodide ions **and write and interpret ionic equations for the reactions.**
- (h) use the above tests in problem-solving situations where they plan and carry out procedures to identify substances.

3. CHEMICAL BONDING, STRUCTURE & PROPERTIES

Candidates should:

- (a) describe the properties of metals, ionic compounds, simple molecular covalent substances and giant covalent substances.
- (b) use the 'sea' of electrons/lattice of positive ions structural model for metals to explain their physical properties.

- (c) use their understanding of electronic structure to explain how ions are formed, and draw dot and cross diagrams to show how ionic bonding takes place in simple binary compounds formed from Group 1 or 2 elements and elements from Group 6 or 7.
- (d) use the accepted structural model for giant ionic structures to explain the physical properties of ionic substances.
- (e) use their understanding of electronic structure to explain how covalent bonds are formed, and draw dot and cross diagrams to show the covalent bonding in simple molecules, **including examples which contain double bonds**.
- (f) use the intermolecular bonding structural model for simple molecular structures to explain the physical properties of simple molecular substances.
- (g) describe the structures of diamond, graphite and carbon nanotubes.
- (h) describe and explain the properties of diamond and graphite, in terms of their bonding and structure, and relate their uses to these properties.
- (i) relate the properties and uses of carbon nanotubes to their bonding and structure.
- (j) know that thermochromic pigments, photochromic pigments, polymer gels, shape memory alloys and shape memory polymers are known as smart materials and have properties which change reversibly with a change in their surroundings.
- (k) know that the above materials change as follows:
- thermochromic pigments – change colour with changing temperature
 - photochromic pigments – change colour with changing light intensity
 - hydrogels – absorb/expel water and swell/shrink (up to 1000 times their volume) due to changes in pH or temperature
 - shape memory alloys – regain original shape when heated
 - shape memory polymers – regain original shape when heated.
- (l) relate the uses of smart materials to their properties.

4. RATE OF CHEMICAL CHANGE

Candidates should:

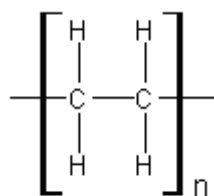
- (a) plan and carry out experiments to study the effect of any relevant factor on the rate of a chemical reaction, using appropriate technology e.g. a light sensor and data logger to follow the precipitation of sulfur during the reaction between sodium thiosulfate and hydrochloric acid.
- (b) analyse data collected in order to draw conclusions, and critically evaluate the method of data collection, the quality of the data and to what extent the data support the conclusion.

- (c) explore the particle theory explanation of rate changes, arising from changing concentration (pressure), temperature and particle size, using a range of sources including textbooks and computer simulations.
- (d) understand that a catalyst increases the rate of a chemical change while remaining chemically unchanged itself **and explain the effect in terms of the energy required for a collision to be successful.**
- (e) explain the economic and environmental importance of developing new and better catalysts, in terms of increasing yields, preserving raw materials, reducing energy costs etc.

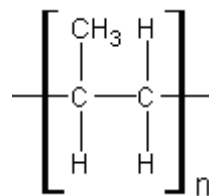
5. BASIC ORGANIC CHEMISTRY

Candidates should:

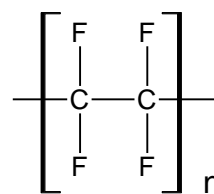
- (a) explain the principles involved in the fractional distillation of crude oil i.e. initial heating and evaporation, rising and cooling of vapour and condensation of fractions with similar boiling points at the same level within the column.
- (b) be able to name and write molecular and structural formulae for simple alkanes (C1-C4) and alkenes (C2-C3).
- (c) **know the addition reactions of ethene with hydrogen and bromine and write molecular and structural formulae for the products.**
- (d) describe and explain the addition polymerisation of ethene and be able to draw the repeating unit for the addition polymers polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene).



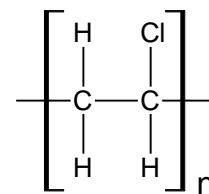
polythene



polypropene



PTFE



PVC

- (e) explain the different effect of heating on thermoplastics and thermosets in terms of the forces between their polymer chains.

6. CHEMICAL CALCULATIONS

Candidates should:

- (a) **collect experimental data, and use given data, in order to calculate the formula of a binary compound e.g. magnesium oxide.**
- (b) calculate the percentage composition of simple compounds.
- (c) **calculate the masses of reactants or products, from a balanced symbol equation for a reaction.**
- (d) be able to calculate the percentage yield of a reaction.
- (e) use given bond energy data to calculate the overall energy change for a reaction and to identify whether it is an exothermic or endothermic reaction.

7. WATER

Candidates should:

- (a) describe in outline the treatment of the public water supply using sedimentation, filtration and chlorination.
- (b) appreciate the importance of water conservation in domestic, commercial and industrial contexts.
- (c) understand that sea water can be desalinated to supply drinking water and discuss the sustainability of this process on a large scale.
- (d) describe and explain the method of separation of water and other miscible liquids, e.g. ethanol, by distillation.
- (e) describe how pigments such as inks can be separated using paper chromatography and explain the process in terms of differing solubilities.
- (f) analyse chromatogram data to identify components in a mixture and calculate R_f values for a solute.
- (g) **appreciate that gas chromatography is used by analytical chemists to identify and measure small amounts of certain chemicals e.g. pollutants in water or in the air, banned substances in the blood of athletes.**
- (h) draw and interpret solubility curves using given data on change of solubility with temperature.
- (i) know the causes of hardness in water and distinguish between hard and soft waters by their action with soap.
- (j) plan and carry out experiments to determine the type (temporary or permanent) and amount of hardness using soap solution.

- (k) analyse data collected in order to draw conclusions, and critically evaluate the method of data collection, the quality of the data and to what extent the data support the conclusion.
- (l) **explain how the methods of boiling, adding sodium carbonate and ion exchange work to soften water and discuss their advantages and disadvantages.**
- (m) describe the health benefits of hard water and its negative effects on boilers and water pipes.
- (n) **appreciate that atomic spectroscopy is used by analytical chemists to identify and find the concentrations of atoms or ions e.g. metal ions in water samples and biological tissues.**

ADDITIONAL SCIENCE and PHYSICS

PHYSICS 2

Electricity, forces and nuclear physics

1. SIMPLE ELECTRICAL CIRCUITS

Candidates should:

- (a) use voltmeters and ammeters to measure the voltage across and current through electrical components in electrical circuits.
- (b) know that, for components arranged in parallel, the voltage is the same across all components and the total current is equal to the sum of the currents through the individual components and appreciate how this relates to mains domestic circuits.
- (c) know that the current is the same for components in series.
- (d) use a circuit, which includes a variable resistor, to investigate how current changes with voltage for a component and recall the relationship for resistor (or wire) at constant temperature and a filament lamp.
- (e) understand qualitatively, the relationship between current, voltage and resistance.
- (f) select and use the equation:

$$\text{current} = \frac{\text{voltage}}{\text{resistance}}; \quad I = \frac{V}{R}$$

- (g) select and use the equations:

$$\text{power} = \text{voltage} \times \text{current}; \quad P = VI$$

and

$$\text{power} = \text{current}^2 \times \text{resistance}; \quad P = I^2R.$$

2. DISTANCE, SPEED AND ACCELERATION

Candidates should:

- (a) describe motion using speed, acceleration, velocity-time and distance-time graphs.
- (b) select and use the equations:

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{ and}$$

$$\text{acceleration [or deceleration]} = \frac{\text{change in velocity}}{\text{time}}; a = \frac{\Delta v}{t}$$

- (c) use velocity-time graphs to determine acceleration **and distance travelled**.

3. THE EFFECT OF FORCES

Candidates should:

- (a) investigate experimentally, e.g. using an air track and data logger, the effect of forces on the motion of an object.
- (b) understand the concept of inertia, that mass is an expression of the inertia of a body and recall, understand and apply Newton's first law of motion.
- (c) understand qualitatively how the momentum of a body depends upon its mass and its velocity, and select and use the equation:

$$\text{momentum} = \text{mass} \times \text{velocity}; \text{ momentum} = mv$$

- (d) understand that unbalanced forces produce a change in a body's motion and that the acceleration of a body is directly proportional to the resultant force and inversely proportional to the body's mass.
- (e) select and use Newton's second law of motion in the forms:

$$\text{resultant force} = \text{mass} \times \text{acceleration}; F = ma$$

and

$$\text{Force} = \frac{\text{change in momentum}}{\text{time}}; F = \frac{\Delta p}{t}$$

- (f) distinguish between the weight and mass of an object, use the approximation that the weight of an object of mass 1 kg is 10 N on the surface of the earth **and use data on gravitational field strength in calculations involving weight and gravitational potential energy**.
- (g) use knowledge of forces and their effects to explain the behaviour of objects moving through the air, including the concept of terminal speed.

4. INTERACTIONS BETWEEN OBJECTS

Candidates should:

- (a) state and use Newton's third law of motion.
- (b) know that when a force acts on a moving body, energy is transferred although the total amount of energy remains constant.
- (c) select and use the equation:

$$\text{work} = \text{force} \times \text{distance moved in the direction of the force} ; W = Fd$$

appreciating that work is a measure of the energy transfer, i.e. that

$$\text{work} = \text{energy transfer (in the absence of thermal transfer)}$$

- (d) appreciate that an object can possess energy because of its motion (kinetic energy) or position (potential energy)
- (e) **select and use the equations:**

$$\text{kinetic energy} = \frac{\text{mass} \times \text{velocity}^2}{2} ; \text{KE} = \frac{1}{2}mv^2$$

and

$$\text{change in potential energy} = \text{mass} \times \text{gravitational field strength} \times \text{change in height} ; \text{PE} = mgh.$$

- (f) investigate work and energy transfer experimentally, e.g. model crumple zones and using catapults to accelerate vehicles.
- (g) apply the principles of forces and motion to the safe stopping of vehicles, including knowledge of the terms reaction time, thinking distance, braking distance and overall stopping distance and discuss the factors which affect these distances.
- (h) apply the principles of forces and motion to an analysis of safety features of cars e.g. air bags and crumple zones.
- (i) apply their knowledge of the physics of motion together with presented data and opinions to discuss traffic control arising from (g) and (h) above, e.g. the need for speed limits and seat belts.

5. THE HALF LIFE OF RADIOACTIVE MATERIALS & THE NATURE OF NUCLEAR RADIATIONS

Candidates should:

- be aware of the random nature of radioactive decay and model the decay of a collection of atoms using a constant probability of decay, e.g. using a large collection of dice, coins or a suitably programmed spreadsheet.
- plot or sketch decay curves for radioactive materials, understand that a given radioactive material has a characteristic half life and determine the half life of a material from the decay curve.
- express the activity of a radioactive source in Becquerel.
- perform simple calculations involving the activity and half life of radioactive materials in a variety of contexts, e.g. carbon dating.
- respond to information describing uses of radioactive materials, relating to the half life, penetrating power and biological effects of the radiation e.g. radioactive tracers and cancer treatment.
- identify alpha radiation as a helium nucleus, beta radiation as a high-energy electron and gamma radiation as electromagnetic, **and recall and use the symbols** ${}^4_2\text{He}$, ${}^0_{-1}\text{e}$ **for alpha and beta particles.**
- know that radioactive emissions from unstable atomic nuclei arise because of an imbalance between the numbers of protons and neutrons.

6. NUCLEAR STRUCTURE, FISSION AND FUSION

Candidates should:

- understand the terms nucleon number(A), proton number(Z) and isotope and relate them to the number of protons and neutrons in an atomic nucleus.
- understand and use nuclear symbols of the form ${}^A_Z\text{X}$ in the context of transformations including radioactive decay, nuclear fission and nuclear fusion, and use data **to produce and** balance nuclear equations.
- know that the absorption of slow neutrons can induce fission in ${}^{235}_{92}\text{U}$ nuclei, releasing energy, and that the emission of neutrons from such fission can lead to a sustainable chain reaction.
- understand the roles of the moderator and control rods in a nuclear fission reactor.
- appreciate that nuclear fission products are unstable with a wide range of half lives.
- know that high energy collisions between light nuclei, especially isotopes of hydrogen, can result in fusion which releases energy.
- discuss the problems of containment in fission and fusion reactors including neutron and gamma shielding and pressure containment in fusion reactors and maintaining a high temperature in fusion reactors.

BIOLOGY

BIOLOGY 3

Transport in plants and animals, homeostasis, microorganisms and disease

1. PLANTS, WATER AND NUTRIENTS

Candidates should:

- (a) understand why water is important to plants and its use in photosynthesis, transport of minerals and support. (Reference to pressure potential is not required.)
Possible investigations: effects of lack of water on plant support.
- (b) investigate water loss in plants, for instance using a bell jar, and use of a simple potometer to investigate the effect of different environmental conditions on the rate of transpiration from a plant cutting.
- (c) observe root hairs and understand their significance increasing the area for absorption. Understand the role of osmosis in the uptake and movement of water through a plant **and understand that mineral salts are taken up by root hairs by active transport.**
Possible investigations: tracking active uptake of minerals by plant roots.
- (d) carry out an investigation into the movement of a dye through a flowering plant and know the role of xylem in transport of water within plants.
Understand the role of transpiration in the movement of water through a plant.
- (e) recognise and label on a given diagram of a T.S. leaf: cuticle, epidermis, stomata, palisade layer, spongy layer, xylem and phloem. Structure of stomata to include guard cells and stoma. Understand that stomata can open and close to regulate transpiration. (No details of the mechanism of opening and closing are required.)
Possible investigations: investigate distribution of stomata using nail varnish replicas and examine photomicrographs of plant structure.
- (f) investigate plant nutrient requirements and the effects of deficiencies on plant growth. Understand that lack of nitrates results in poor growth, deficiency of potassium results in yellowing of the leaf and deficiency of phosphate results in poor root growth and understand the use of KPN fertilisers.
- (g) know that phloem carries sugar from the photosynthetic areas to other parts of the plant. Sugar is moved to other parts of the plant for use in respiration and converted into starch for storage. The transport of sugar is not fully understood so it is still being investigated by plant scientists. (Knowledge of mass flow is not required.)

2. BLOOD AND CIRCULATION

Candidates should:

- (a) investigate and discuss the scientific approach of Harvey, in the 17th century, which showed, beyond all reasonable doubt, that blood circulates around the mammalian body.
- (b) be able to draw and label diagrams of a white blood cell (phagocyte only) and a red blood cell and know the differences between these cells; know the functions of the four main parts of the blood: red cells, platelets, plasma, white cells. (Details of haemoglobin or clotting mechanism are not required.)
- (c) know that a double circulatory system involves one to the lungs and one to the other organs of the body, and be able to recognise this on a diagram. Only the names of the following blood vessels are required: pulmonary artery, pulmonary vein, vena cava and aorta.
- (d) know that the heart pumps blood around the body and that it is made of muscle. Know that the heart has its own blood supply through the coronary vessels and that the blood flows to the organs through arteries and returns to the heart through veins. (Structure of arteries and veins is not required.)
- (e) recognise and label on a given diagram of the heart: the left and right atria and ventricles, valves, pulmonary artery, pulmonary vein, aorta and vena cava. (Names of individual valves are not required.)
- (f) be able to describe the passage of blood through the heart including the functions of the valves in preventing backflow of blood.
- (g) observe a dissected/model of the heart, to include coronary arteries and internal structure, and examine prepared slides of blood smears. Possible investigations: structure of a lamb's heart or model; effect of exercise on heart rate.
- (h) know that in the organs blood flows through very small blood vessels called capillaries. Substances needed by cells pass/diffuse out of the blood to the tissues, and substances produced by the cells pass/diffuse into the blood, through the walls of the capillaries. The thin walls of the capillaries are an advantage for diffusion. Capillaries form extensive networks so that every cell is near to a capillary carrying blood.

3. NERVOUS SYSTEM

Candidates should:

- (a) recognise and label on a given diagram of a vertical section through the eye the following parts and understand their functions: sclera, cornea, pupil, iris, lens, choroid, retina, blind spot and optic nerve. Possible investigations: observe changes in pupil size under different light intensities.
- (b) understand that the brain, spinal cord and nerves form the nervous system and the central nervous system consists of the brain and spinal cord.

- (c) know that some responses in animals are reflex actions. These reactions are fast and automatic and some are protective, as exemplified by the withdrawal reflex, blinking and pupil size.
Possible investigations: knee jerk reflex (which helps to keep us upright).
- (d) **know that a reflex arc involves stimulus, receptor, coordinator and effector. Recognise and label a given diagram of a reflex arc to show: receptor, sensory neurone, relay neurone in spinal cord, motor neurone, effector and synapses.**

4. ROLE OF THE KIDNEY IN HOMEOSTASIS

Candidates should:

- (a) know that the kidneys regulate the water content of the blood and remove waste products from the blood and understand why this is necessary.
- (b) recognise and label a given diagram of the human excretory system to show kidneys, renal arteries, renal veins, aorta, vena cava, ureters, bladder, urethra and be able to indicate the direction of blood flow in the blood vessels associated with the kidney.
- (c) recognise and label a given diagram of a section through a kidney to include: renal artery, renal vein, cortex, medulla, pelvis, ureter. **Know the position of nephrons.**
Possible investigations: observe gross structure of a section through a kidney to locate the cortex, medulla, pelvis and ureter.
- (d) **recognise and label a given simplified diagram of a nephron and its associated blood supply to show: capillary knot, Bowman's capsule, tubule, collecting duct, capillary network, arteriole to and from capillary knot.**
- (e) **interpret data about changes in the level of substances present due to passage through the kidney, understand the process of filtration under pressure and know that selective reabsorption of glucose, some salts, and much of the water takes place in the tubule.**
- (f) know that the waste, a solution containing urea and excess salts called urine, passes from the kidneys in the ureters to the bladder where it is stored before being passed out of the body. Understand that the presence of blood or cells in the urine indicates disease in the kidney.
- (g) know that the kidneys regulate the water content of the blood by producing dilute urine if there is too much water in the blood or concentrated urine if there is a shortage of water in the blood. **Role of anti-diuretic hormone (ADH).**
- (h) know that kidney failure may be treated by dialysis. **Understand how a dialysis machine works.**

- (i) know that a diseased kidney may be replaced by a healthy one by transplant from a donor of a similar 'tissue type' to the recipient. The donor kidney may be rejected by the body, attacked by the immune system, unless drugs are taken which suppress the immune response.
- (j) understand the advantages and disadvantages of the use of dialysis and transplants and discuss the ethical issues involved.

5. MICROORGANISMS AND DISEASE

Candidates should:

- (a) understand that most microorganisms are harmless and many perform vital functions however some microorganisms, called pathogens, cause diseases. Intact skin forms a barrier against microorganisms. The body also defends itself by: blood clots to seal wounds; white cells in the blood ingest microorganisms and produce antibodies and antitoxins. Pathogens must also compete with the body's natural population of microorganisms.
- (b) understand that vaccination can be used to protect humans from infectious disease. Discuss the deductive process and possible issues surrounding the work by Jenner on vaccination. Consider the factors influencing parents in decisions about whether to have children vaccinated or not, including the need for sound scientific evidence and the effect of the media and public opinion. Understand that science can only provide a statistically based 'balance of probability' answer to such issues.
- (c) know that an antigen is a molecule that is recognised by the immune system. Foreign antigens trigger a response by some white blood cells, lymphocytes, which secrete antibodies specific to the antigen. Know the function of antibodies.
- (d) know that a vaccine contains antigens (or parts of antigens) derived from a disease-causing organism. A vaccine will protect against infection by that organism by stimulating the white blood cells to produce antibodies to that antigen. Vaccines may be produced which protect against bacteria and viruses.
- (e) **assess data showing how, after an antigen has been encountered, memory cells remain in the body and antibodies are produced very quickly if the same antigen is encountered a second time. This memory provides immunity following a natural infection and after vaccination. The response is highly specific to the antigen involved.**
- (f) **understand why most people suffer from measles only once, but could suffer from flu many times during their lives.**
- (g) investigate the effect of penicillin on bacteria growing on agar plates. Antibiotics, including penicillin, were originally medicines produced by living organisms, such as fungi. Antibiotics help to cure bacterial disease by killing the infecting bacteria or preventing their growth. Possible investigations: investigate the effect of antimicrobial agents in cut wells, chimneys or filter paper discs on bacteria growing on agar plates.

- (h) understand that antibiotics may kill some bacteria but not viruses. Some resistant bacteria, such as MRSA, can result from the over use of antibiotics. Know effective control measures for MRSA.

6. MICROORGANISMS AND THEIR APPLICATIONS

Candidates should:

- (a) understand the safe use of basic aseptic techniques involved in inoculating, plating and incubating microorganisms.
Possible investigations: aseptic techniques; incubating and viewing plates; pouring an agar plate.
- (b) investigate the presence of bacteria in milk using agar plates. Understand the link between the number of bacterial colonies on the agar and the number of bacteria in the original sample.
Possible investigations: investigate bacterial numbers in different types of milk; making yoghurt from a starter culture.
- (c) investigate experimentally and explore information about the effect of temperature on the growth of bacteria and understand its application in food storage. (Growth curve is not required.)
Possible investigations: investigate bacterial numbers in food or milk kept in different storage conditions.
- (d) know that the fungus *Penicillium* is grown industrially in a fermenter and understand the factors which influence its growth. The penicillin is extracted from the surrounding medium by filtration.
- (e) know that there are advantages to using microorganisms for food production e.g. in the production of mycoprotein.
- (f) understand that microorganisms have an important role in decay and also have potential benefits for the environment. Investigate information about the uses of microorganisms, research and methods involved, such as cleaning up pollution, breaking down waste such as some plastics and producing biofuels.

CHEMISTRY

CHEMISTRY 3

The chemical industry and analysis

1. ADDITIONAL ORGANIC CHEMISTRY

Candidates should:

- (a) investigate patterns in the molecular formulae of alkanes, alkenes and alcohols.
- (b) be able to name and write molecular and structural formulae for straight chain alkanes (C1-C5) and alkenes (C2-C3).
- (c) **be able to write structural formulae for the chain isomers of C₄H₁₀ and C₅H₁₂.**
- (d) be able to **name and** write molecular and structural formulae for alcohols (C1-C3), **including the positional isomers of propanol.**
- (e) understand that enzymes are catalysts produced by living cells and investigate how the rates of enzyme catalysed reactions are affected by temperature.
- (f) describe how ethanol is made from sugars by the process of fermentation, the conditions used and the method of obtaining ethanol from the reaction mixture.
- (g) be able to write and interpret word **and balanced symbol** equations to represent fermentation.
- (h) know that ethanol is present in alcoholic drinks, and discuss the social and economic impact of these drinks.
- (i) know that ethanol is used as a solvent and as a fuel.
- (j) understand the social, economic and environmental factors that affect the development of ethanol as a fuel.
- (k) apply their understanding of the fire triangle to methods of fire prevention.
- (l) know that ethanol undergoes microbial oxidation to ethanoic acid (vinegar).
- (m) know that ethanoic acid is a weak acid and compare its reactions with those of dilute sulfuric acid.

2. REVERSIBLE REACTIONS, INDUSTRIAL PROCESSES & IMPORTANT CHEMICALS

Candidates should:

- (a) describe how ammonia is made by the reversible reaction of nitrogen and hydrogen in the Haber process and be able to write and interpret the word and balanced symbol equation for the reaction.
- (b) know that an iron catalyst is used during the Haber process, **and explain the choice of temperature and pressure employed** and the importance of recycling unreacted nitrogen and hydrogen.
- (c) **know that ammonia can be oxidised to give nitric acid.**
- (d) describe the stages in the Contact process for the manufacture of sulfuric acid and know that vanadium(V) oxide is used as a catalyst for the reversible formation of sulfur trioxide.
- (e) be able to write and interpret word and balanced symbol equations for the formation of sulfur trioxide.
- (f) know how nitrogenous fertilisers such as ammonium sulfate and ammonium nitrate are obtained by neutralising ammonia solution with sulfuric acid and nitric acid respectively.
- (g) describe and explain the benefit of nitrogenous fertilisers for crop growth and the problems that arise when they are washed into rivers.
- (h) evaluate the advantages and disadvantages of using nitrogenous fertilisers for individuals, communities and the environment.
- (i) know that concentrated sulfuric acid can remove the elements of water from substances such as sugar and hydrated copper(II) sulfate.

3. TITRATION & MOLE CALCULATIONS

Candidates should:

- (a) **know that the relative molecular (formula) mass of a compound, in grams, is equivalent to one mole of that substance.**
- (b) **be able to calculate the molar mass of a compound whose formula is given.**
- (c) **be able to convert the mass to amount of a substance in moles and vice versa, given formulae and relative atomic and molecular (formula) masses.**
- (d) **be able to calculate the concentration of a solution in mol dm⁻³, given the amount of substance and volume of solution.**
- (e) **be able to calculate the number of moles or mass of a substance in a solution of given volume and concentration (mol dm⁻³).**

- (f) be able to carry out a titration using an indicator and use titration data to compare the relative concentrations of solutions.
- (g) **perform calculations involving neutralisation reactions in solution, using a balanced equation.**
- (h) use titration method to prepare pure solutions of soluble salts, such as sodium chloride, from alkalis and evaporate to give crystals.

4. LIMESTONE

Candidates should:

- (a) investigate the thermal decomposition of the carbonates of calcium, copper and sodium and be able to write and interpret word and balanced symbol equations for any reactions that occur.
- (b) investigate the reaction of quicklime with water to produce slaked lime and be able to write and interpret word and balanced symbol equations for the reaction.
- (c) be able to write word and balanced symbol equations for the reaction of limewater and carbon dioxide.
- (d) know that limestone is used in the production of iron and steel, in road-building, to neutralise soil acidity and to make cement.
- (e) evaluate the social, economic and environmental effects of limestone quarrying.

5. CHEMICAL ANALYSIS

Candidates should:

- (a) be able to describe chemical tests for the gases hydrogen, oxygen, carbon dioxide and ammonia.
- (b) be able to use flame tests to distinguish between Na^+ , K^+ , Ca^{2+} and Cu^{2+} ions and describe the test to identify NH_4^+ ions by addition of $\text{NaOH}(\text{aq})$.
- (c) be able to describe the precipitation reactions of $\text{NaOH}(\text{aq})$ with aqueous Fe^{2+} , Fe^{3+} and Cu^{2+} and write and interpret word **and balanced symbol** equations for the reactions that occur (**including ionic equations**).
- (d) **appreciate that atomic spectroscopy is used to identify and find the concentrations of atoms or ions e.g. by a forensic scientist trying to identify a paint sample.**
- (e) be able to describe chemical tests to identify Cl^- , Br^- , I^- , CO_3^{2-} and SO_4^{2-} and write and interpret word **and balanced symbol** equations for the reactions that occur (**including ionic equations for precipitation reactions**).

- (f) be able to describe chemical tests used to distinguish between an alkene, **an alcohol** and a carboxylic acid.
- (g) use the above tests in problem-solving situations where they plan and carry out procedures to identify substances.
- (h) **appreciate that infrared spectroscopy is used to identify the presence of certain bonds in organic molecules and use data to identify alkanes, alkenes, alcohols and carboxylic acids.**
- (i) **be aware that the breathalyser used to take readings of alcohol concentration in the breath is an infrared-based test.**

PHYSICS

PHYSICS 3

Electromagnetism, waves, kinetic theory, nucleosynthesis

1. ELECTROMAGNETISM

Candidates should:

- (a) investigate the magnetic fields and recall the field patterns of bar magnets, straight wires, plane coils and solenoids.
- (b) investigate the motor effect **and relate the direction of the force on a current-carrying wire to the directions of the current and magnetic field.**
- (c) interpret and label a diagram of a simple d.c. motor, **predicting its direction of rotation** and understand qualitatively the effect on increasing the current, magnetic field strength and number of turns.
- (d) investigate the conditions in which a current is induced in circuits by changes in magnetic fields and the movement of wires.
- (e) use knowledge of electromagnetic induction to explain the operation of a simple a.c. electric generator including the factors upon which its output depends.
- (f) **relate the direction of the induced current in a generator to the direction of the magnetic field and the direction of rotation of the coil.**
- (g) investigate model transformers experimentally, e.g. using linked C-cores or demountable transformers, know qualitatively how the output voltage depends upon the number of turns on the coils and explain their operation qualitatively by reference to electromagnetic induction.
- (h) **select and use the equation:**

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

in the context of 100% efficient step-up and step-down transformers, and the equation:

$$P = VI$$

to the primary and secondary coils.

2. THE PROPERTIES OF WAVES AND THEIR USE IN INVESTIGATING THE STRUCTURE OF THE EARTH

Candidates should:

- (a) distinguish between transverse and longitudinal waves in terms of the direction of oscillation and the direction of propagation, appreciating that sound waves and P-waves are longitudinal and that electromagnetic waves and S-waves are transverse.
- (b) investigate experimentally the refraction of light at a plane boundary and the conditions under which total internal reflection occurs.
- (c) understand how endoscopes and optical fibres rely on total internal reflection for their operation. [NB monomode optical fibres will not be examined.]
- (d) explain refraction in terms of the speed of waves on either side of a refracting boundary.
- (e) **draw** and interpret diagrams of plane waves being reflected or refracted at plane boundaries, e.g. as shown in a ripple tank.
- (f) understand the properties of seismic P-waves, S-waves and surface waves, in terms of their nature, speed and ability to penetrate different materials.
- (g) **appreciate qualitatively how the speed of a wave depends upon the density and rigidity of the material through which it propagates.**
- (h) appreciate that earthquakes result from P, S and surface waves generated by the release of energy stored in rocks on either side of a fault.
- (i) interpret simplified seismic records, including the identification of the lag time between the arrival of the P and S waves and **use the seismic records from several stations to locate the epicentre of an earthquake.**
- (j) **interpret and sketch diagrams of the path of P and S-waves through the earth, relating their paths to the properties of the Earth's mantle and core.**
- (k) **know how the study of seismic records, including the identification of P and S-wave shadow zones, has enabled geo-physicists to investigate the structure of the earth, leading to a model of a solid mantle and a liquid core.**

3. MOTION

Candidates should:

- (a) select and use the equation

$$\text{speed} = \frac{\text{distance}}{\text{time}} \text{ for unaccelerated motion.}$$

- (b) appreciate that the motion of objects can be modelled using the equations:

$$x = \frac{1}{2}(u + v)t$$

$$v = u + at$$

$$v^2 = u^2 + 2ax$$

$$x = ut + \frac{1}{2}at^2$$

understand the condition under which these equations are valid and select and use these equations to solve problems including simple questions involving motion under gravity, without frictional forces.

- (c) explore experimentally, or using IT simulations, the collisions of objects under conditions in which externally applied forces are negligible, to develop an appreciation of the significance of the momentum of a body.
- (d) recall the law of conservation of momentum and relate it to Newton's third law of motion.
- (e) appreciate the law of conservation of momentum qualitatively and use it quantitatively to perform calculations involving collisions or explosions, **including selecting and using the equation:**

$$\text{kinetic energy} = \frac{1}{2}mv^2$$

to compare the kinetic energy before and after an interaction.

4. KINETIC THEORY

Candidates should:

- (a) understand qualitatively the concept of pressure and select and use the relationship:

$$\text{pressure} = \frac{\text{force}}{\text{area}}; \quad p = \frac{F}{A}$$

- (b) investigate the behaviour of a fixed quantity of gas under conditions of varying pressure, volume and temperature.
- (c) **appreciate how the behaviour of gases leads to the concepts of absolute zero and an absolute scale of temperature.**
- (d) express temperatures in kelvin and use the relationship

$$T / \text{K} = \theta / ^\circ\text{C} + 273$$

- (e) **use the relationship**

$$\frac{pV}{T} = \text{constant}$$

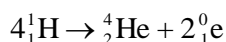
for gases, including circumstances in which one of the three variables remains constant.

- (f) explain the variation of the pressure of gases with volume and temperature qualitatively by applying a model of molecular motion and collisions.
- (g) explain the transfer of energy by conduction in solids, liquids and gases using a model of molecular motion and account for the better conduction in metals by the presence of mobile electrons.
- (h) explain convection in liquids and gases in terms of molecular behaviour and variations in volume and density.

5. THE ORIGIN OF THE CHEMICAL ELEMENTS

Candidates should:

- (a) recall that the Big-Bang model suggests an initial elemental composition for the universe of hydrogen (roughly 75%) and helium (roughly 25%) with very small quantities of other light elements.
- (b) recall the main observable stages in the life-cycle of stars of different masses, using the terms brown dwarf, red dwarf, main sequence, white dwarf, red giant, supernova, neutron star and black hole.
- (c) appreciate that the stability of stars depends upon a balance between gravitational force and a combination of gas and radiation pressure.
- (d) appreciate that main sequence stars generate their energy by the fusion of hydrogen to helium, according to the equation



where $\text{}^0_1\text{e}$ is a positron, the antiparticle of an electron which will subsequently annihilate together with an electron, $\text{}^0_{-1}\text{e}$, releasing further energy. [Recall of details of the fusion processes, either the proton-proton chain or the CNO cycle, will not be required, but candidates may be required to interpret information about nuclear reactions in stars which may be presented in the form of nuclear equations.]

- (e) know that Hoyle and colleagues were able to use the results of nuclear research to account for the production of all elements heavier than helium in the process of nucleosynthesis in stars.
- (f) use information to construct and interpret nuclear equations in the context of fusion processes in stars.
- (g) **describe the processes in post main-sequence stars in terms of the production of increasingly heavier elements, up to iron-56, in shells around the core of a star and recall that the limit of this depends upon the mass of the star.**
- (h) **recognise a simplified binding energy per nucleon curve and understand its relationship to energy release in nuclear fission and fusion.**
- (i) **recall that in fission and fusion processes which release energy, the mass of the products is less than that of the reactants, and that the energy release can be calculated using the mass-energy relationship:**

$$E = mc^2$$

- (j) relate the final stages in the life cycle of solar-mass and giant stars to the cessation of nuclear fusion and the existence of heavier elements in the interstellar medium to their ejection during the death of massive stars.
- (k) appreciate that the production by fusion of elements heavier than iron requires energy, that these elements, including uranium, are only produced from the energy released during the gravitational collapse of massive stars and that our ability to use uranium in a fission reactor is because of the release of this element in a supernova.

3

ASSESSMENT

3.1 Scheme of Assessment

Assessment for GCSE Sciences is tiered, i.e. externally assessed components/units are targeted at the grade ranges of A*-D (higher tier) and C-G (foundation tier), while controlled assessments cater for the full range of ability. Questions and tasks will be designed to enable candidates to demonstrate what they know, understand and can do.

A candidate may enter for one tier only at any particular examination sitting:

Tier	Grades Available
Higher	A*, A, B, C, D
Foundation	C, D, E, F, G

Candidates who narrowly fail to achieve Grade D on the higher tier will be awarded Grade E.

Candidates entering for the **GCSE Science A** qualification should complete 3 external, tiered units, plus an internal, untiered, teacher-marked assessment selected from two provided annually.

The **GCSE Additional Science** qualification consists of another 3 externally assessed, tiered units plus one further internal, untiered, teacher-assessed task selected from one of biology, chemistry or physics, provided annually.

The units comprising the assessment plus their weightings within each qualification are summarised in the table below:

Qualification	External Assessments (% weighting)			Internal Assessments
	Biology	Chemistry	Physics	
Science A	Biology 1 (25%)	Chemistry 1 (25%)	Physics 1 (25%)	Controlled Assessment (25%)
Additional Science	Biology 2 (25%)	Chemistry 2 (25%)	Physics 2 (25%)	Controlled Assessment (25%)

The qualifications in Biology, Chemistry and Physics each consist of the relevant subject units and a further externally-assessed, tiered unit for each subject, plus practical assessment selected from two provided annually for each subject.

Biology		Chemistry		Physics	
External	Internal	External	Internal	External	Internal
Biology 1 (25%)	Controlled Assessment (25%)	Chemistry 1 (25%)	Controlled Assessment (25%)	Physics 1 (25%)	Controlled Assessment (25%)
Biology 2 (25%)		Chemistry 2 (25%)		Physics 2 (25%)	
Biology 3 (25%)		Chemistry 3 (25%)		Physics 3 (25%)	

Note that units 1 and 2 are, in each case, common with the Science A and Additional Science units.

The raw mark allocations for each of the different assessments, at both foundation and higher tier, are as follows:

Qualification	External Assessments			Internal (total per qualification)
	Biology	Chemistry	Physics	
Science A	60	60	60	63
Additional Science, Biology, Chemistry, Physics	60	60	60	48

The examination papers for all externally-assessed units are of 60 minutes duration.

Short answer and objective questions account for no more than two-thirds of the total credit assigned to the externally-assessed written components. Candidates are provided with opportunities for extended writing. Questions target three levels of demand with some questions, targeting grades C and D, common to the foundation and higher tier papers as shown below:

	Tier	Grades targeted by questions			Total
		E, F, G	C, D	A*, A, B	
Marks available	Foundation	36	24		60
	Higher		24 + 6	30	60

Currently the external assessments take the form of paper-based examinations. However, in future years, an option may be available for some external assessments to be taken in electronic format as on-screen assessment.

Controlled Assessment

Science A

Candidates must complete a set task comprising **three short exercises** based upon the subject content of the GCSE Science A specification and submit written work based on each of the three exercises.

Exercise 1 – Research skills and use of information

Candidates will be provided with a topic, related to the Science A specification, to research using sources of information. They then write a report to answer the question provided and based upon their research findings.

Exercise 2 – Practical work and hypothesis testing

Candidates are provided with a scenario from which they will be required to test an hypothesis and answer a scientific question based upon the content of the Science A specification. They use equipment or apparatus to obtain results, then analyse and evaluate their findings.

Exercise 3 – Experimental techniques and safety

Candidates are shown one or more sequences via DVD/video depicting aspects of experimental work from the content of the Science A specification. They analyse safety aspects and may be asked to comment on and/or take measurements from the sequence.

Additional Science/Biology/Chemistry/Physics

Candidates must complete **one investigation** based upon the subject content of the GCSE Additional Science specification **or one for each** of Biology, Chemistry and Physics.

The structure of the assessed tasks is as follows:

1. Introductory experimental work. The candidates undertake a piece of practical work based upon the appropriate subject content. The carrying out of the introductory/background work is not assessed but the experience of carrying it out and, possibly the results, are needed in the subsequent stages.
2. Investigatory planning and research. The candidates undertake research and planning on the specified topic which arises from and is based upon their experience in the introductory work.
3. The candidates carry out their investigatory work, review it, analyse their findings and present a report on their work.

Skills

Centres should develop the skills for all controlled assessment tasks as an integral part of the delivery of subject content for the science course. Controlled assessment is seen as the natural outcome of the teaching and learning process and not necessarily additional to content delivery.

Provision of Assessments

Science A: For each of the Science tasks (i.e. a set of three exercises), WJEC will provide a choice of 2 comparable versions from which centres can select which they wish to use with their candidates. The exercises cannot be mixed between tasks.

Additional Science: WJEC will provide one task for the Additional Science content for each of Biology, Chemistry and Physics. Only one assessment is required for Additional Science, so centres can select which one they wish to use with their candidates.

Biology/Chemistry/Physics: WJEC will provide one additional task for each of Biology, Chemistry and Physics. Centres can select which one they wish to use with their candidates from either this task or the Additional Science task in each of Biology, Chemistry and Physics. One assessment from the two provided is required for each of Biology, Chemistry and Physics.

WJEC will publish the list of tasks annually, prior to the start of the academic year, with the details available to centres via the WJEC secure website.

Centres may contextualise the tasks if necessary to allow for availability of resources.

For each task it is permissible for the centre to set all candidates the same version.

WJEC will publish a Teachers' Guide to clarify how to develop candidates' investigatory work in an appropriate manner for the controlled assessment. This will be enhanced through the CPD programme delivered annually.

An Adviser, appointed by WJEC, will provide support, where needed, on the introduction of the chosen tasks within the parameters stated.

Details of administration for controlled assessment are given in section 5.

Marking

Teachers, at the centre, mark the controlled assessments using the generic marking criteria provided by WJEC. However, further interpretation in relation to the specific tasks will also be provided annually.

Generic marking criteria are printed in the pages which follow.

Science A

The three exercises are marked individually. For each exercise a candidate is awarded a mark for each Assessment Objective (AO).

A single mark out of 63 is submitted.

AO1 – recall, select and communicate knowledge and understanding of science

Descriptor	Mark range
0 marks if no evidence presented relating to scientific hypothesis and method. Candidates recall, select and communicate some facts relating to a scientific question, hypothesis and methods. They communicate basic ideas with limited clarity and coherence, limited use of scientific and technical terminology and with significant weaknesses in spelling, punctuation and grammar and form of presentation.	0-1
Candidates recall, select and communicate some knowledge and understanding relating to a scientific question, hypothesis and methods. They communicate ideas with some coherence, using some scientific and technical terminology appropriately, with few errors in spelling, punctuation and grammar and presentation.	2-3
Candidates recall, select and communicate precise knowledge and detailed understanding relating to a scientific question, hypothesis and methods. They communicate complex ideas coherently and logically using scientific and technical terminology appropriately and consistently, with hardly any errors in spelling, punctuation and grammar and well presented.	4-5

AO2 – apply skills, knowledge and understanding of science in practical and other contexts

Descriptor	Mark Range
0 marks if no evidence presented of planning and data collection. Candidates apply limited skills and knowledge in planning to answer a simple scientific question or test a hypothesis. They select a simple method for data collection and manage risks when carrying out practical work. They collect and record some relevant primary and secondary data, presenting it in an understandable manner, and make a limited connection between the evidence collected and their conclusion.	0-2
Candidates apply appropriate skills, knowledge and understanding in planning to answer a scientific question or test a hypothesis. They select appropriate methods to collect numerical and other data and adequately assess and manage risks when carrying out practical work. They collect, record and process primary and secondary data in a logical manner, presenting it clearly, and make straightforward links between the evidence collected and their conclusion.	3-5
Candidates independently apply skills, knowledge and understanding in planning to answer a scientific question or test a hypothesis. They select appropriate methods to collect numerical and other data with reasonable accuracy and competently assess and manage risks when carrying out practical work. They systematically collect, record and process high-quality primary and secondary data, presenting it in an appropriate style, and demonstrate a comprehensive understanding of the relationship between the evidence collected and their conclusion.	6-8

AO3 – analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence

Descriptor	Mark Range
0 marks if no evidence presented of analysis evaluation and concluding. Candidates interpret and evaluate some qualitative and quantitative data and information from a limited range of sources. They can draw elementary conclusions having collected limited evidence.	0-2
Candidates analyse, interpret and evaluate quantitative and qualitative data and information. They understand the limitations of evidence and develop arguments with supporting explanations. They draw conclusions consistent with the available evidence.	3-5
Candidates analyse, interpret and critically evaluate quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.	6-8

Summary of Assessment Objective Allocation

	Total Mark	% of Controlled Assessment	% of Award
AO1	15	23.8	6.0
AO2	24	38.1	9.5
AO3	24	38.1	9.5

Additional Science/Biology/Chemistry/Physics

A candidate is awarded a mark in each of the following fields:

Hypothesising and planning
 Collecting, reviewing and processing data
 Analysing and reviewing procedure
 Analysing data and concluding.

A single mark out of 48 is submitted.

Hypothesising and planning	
Description	Mark range
No evidence of planning presented.	0
Candidates work from a given hypothesis and make a plan to collect some relevant data without necessarily controlling variables. They take some account of safety in their plan.	1-3
Candidates make a simple hypothesis relating the independent and dependent variables. Plan identifies independent and dependent variables without necessarily identifying controlled variables explicitly. They identify any significant hazards relating to the investigation.	4-6
Candidates make a hypothesis relating the variables to be investigated and discuss it in terms of scientific knowledge or the results of their preliminary research. Plan identifies the variables which need to be controlled and includes ranges and intervals of variables and appropriate numbers of repeats. They use the experience of previous work to produce a simple risk assessment for the investigation.	7-9
Candidates additionally use the results of scientific knowledge, preliminary work and research to justify the hypothesis. They explain how they control variables and justify the need to control specific variables in terms of a valid investigation (or discuss the limitations of the investigation where variables cannot be controlled). They discuss and use the results of preliminary work to inform details of the plan, e.g. in terms of ranges and number of repeats and any relevant safety issues.	10-12

Assessment Objective Allocation

AO1: 3

AO2: 6

AO3: 3

Total 12

Collecting, reviewing and processing data	
Description	Mark range
No evidence of collected data presented.	0
Candidates work safely, collect some data relevant to the investigation and display the collected data.	1-3
Candidates collect sufficient relevant data which enables an initial assessment of the validity of the hypothesis to inform the plan. They select simple forms and styles of presentation of the data including a simple table, graph, chart or diagram which enables data to be interpreted; they process some data mathematically, e.g. by averaging.	4-6
Candidates collect sufficient valid data which enables them to make a judgement on a simple hypothesis and review details of the plan in the light of results. Using standard forms and styles of presentation appropriate to the task, they display data systematically, including detailed graph or chart; they use judgement in the selection and mathematical processing of data which they display appropriately.	7-9
Candidates collect sufficient high-quality valid data which enables them to make a good judgement of a detailed hypothesis and they discuss the sufficiency of the data, reflecting upon the plan. They select and effectively use high-level forms and styles of presentation appropriate to the task; they process data appropriately and accurately producing a high-level display of the data.	10-12

Assessment Objective Allocation

AO1: 3

AO2: 6

AO3: 3

Total 12

Analysing and reviewing procedure	
Description	Mark range
No evidence of analysis or review presented.	0
Candidates make simple comments about techniques in the procedure and on the quality of the evidence produced. They make a simple statement referring to other data, e.g. in the preliminary work or research.	1-3
Candidates make detailed, relevant comments about techniques in the procedure and use the spread/trend of their raw data to comment on the repeatability of the data produced. They make a detailed statement referring to other data, e.g. in the preliminary work or research.	4-6
Candidates suggest changes to the techniques in the procedure. They justify improvements in terms of the repeatability of the measurements or justify an assertion that no improvement is necessary. They comment on other data, e.g. in the preliminary work or research.	7-9
Candidates discuss the limitations of the investigation. They relate the outcome of the investigation with information discovered in the candidate's research, making a detailed comparison.	10-12

Assessment Objective Allocation

AO1: 0

AO2: 0

AO3: 12

Total 12

Analysing data and concluding	
Description	Mark range
No relevant analysis or conclusion presented.	0
Candidates make a simple, relevant statement about the data possibly identifying some trends or patterns in the data. The presentation may have major inaccuracies of spelling, punctuation and grammar; little use of scientific vocabulary.	1-3
Candidates give a detailed, accurate description of the trends or patterns in the data relating the trends to information discovered in the candidate's research. The presentation has inaccuracies in spelling, punctuation and grammar; use of scientific vocabulary is limited.	4-6
Candidates identify the relationship(s) between variables revealed in the data, relating this to the hypothesis. They make a comparison of the outcome of the investigation with information discovered in the candidate's research. The presentation has no major inaccuracies in spelling, punctuation and grammar; use of scientific vocabulary is good.	7-9
Candidates produce a valid conclusion from the data collected. They discuss the extent to which the data support the hypothesis (including whether an alternative hypothesis is supported). They discuss the extent to which more/improved quality of the data would improve their confidence in the conclusion. The presentation has good spelling, punctuation and grammar; use of scientific vocabulary is appropriate and of a high standard.	10-12

Assessment Objective Allocation

AO1: 3

AO2: 0

AO3: 9

Total 12

Summary of Assessment Objective Allocation

	Total Mark	% of Controlled Assessment	% of Award
AO1	9	18.75	4.69
AO2	12	25.0	6.25
AO3	27	56.25	14.06

3.2 Assessment Objectives

Candidates will be required to demonstrate their ability to:

AO1: Recall, select and communicate their knowledge and understanding of science.

AO2: Apply skills, knowledge and understanding of science in practical and other contexts.

AO3: Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence.

The weighting of assessment objectives across examination components is as follows:

Science A

	AO1	AO2	AO3	Total
Units 1-3	30%	26.3%	18.7%	75%
Controlled Assessment	6.0%	9.5%	9.5%	25%
Total Weighting	36%	35.8%	28.2%	100%

Additional Science

	AO1	AO2	AO3	Total
Units 1-3	30%	30%	15%	75%
Controlled Assessment	4.69%	6.25%	14.06%	25%
Total Weighting	34.69%	36.25%	29.06%	100%

Biology/Chemistry/Physics

	AO1	AO2	AO3	Total
Unit 1	10%	8.75%	6.25%	25%
Unit 2	10%	10%	5%	25%
Unit 3	10%	10%	5%	25%
Controlled Assessment	4.69%	6.25%	14.06%	25%
Total Weighting	34.69%	35%	30.31%	100%

3.3 Quality of Written Communication

For components involving extended writing (all units) candidates will be assessed on the quality of their written communication within the overall assessment of that component.

Mark schemes for these components include the following specific criteria for the assessment of written communication:

- legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning;
- selection of a form and style of writing appropriate to purpose and to complexity of subject matter;
- organisation of information clearly and coherently; use of specialist vocabulary where appropriate.

The marking criteria for controlled assessment contain specific references to these aspects as do the mark schemes for external assessments. The questions in external assessments which include these aspects are noted on the front of each examination paper.

4 AWARDING, REPORTING AND RE-SITTING

GCSE qualifications are reported on an eight point scale from A* to G, where A* is the highest grade. The attainment of pupils who do not succeed in reaching the lowest possible standard to achieve a grade is recorded as U (unclassified) and they do not receive a certificate.

This is a linear specification in which all assessments must be taken at the end of the course. Where candidates wish to re-sit, external components must be re-taken. The controlled assessment component may also be re-taken according to guidelines given in 'Administration of Controlled Assessment'. Alternatively, the UMS mark for this component may be carried forward for aggregation with the external components when these are re-taken.

Individual unit results are reported on a uniform mark scale (UMS) with the following grade equivalences:

GRADE	MAX.	A*	A	B	C	D	E	F	G
Each Unit	80	72	64	56	48	40	32	24	16
Subject Award	320	288	256	224	192	160	128	96	64

For the externally-assessed units, which are tiered, the maximum uniform mark available on the foundation tier of the assessment will be 55 [i.e. 1 mark less than the minimum mark needed to achieve a grade B on that unit]. As the internal assessments are not tiered, the full range of uniform marks is available in these units.

5 ADMINISTRATION OF CONTROLLED ASSESSMENT

Scheme of Assessment

The WJEC GCSE Science A/Additional Science/Biology/Chemistry/Physics specifications meet all the regulations for controlled assessment as laid down by the regulatory authorities. The controlled assessment is worth 25% of the total marks available for each specification.

Science A

The controlled assessment tests all the assessment objectives for GCSE Science contributing to overall weightings within those specified by the regulatory authorities.

Assessment Objective		% Weighting in Controlled Assessment	% Weighting in Science A
AO1	Recall, select and communicate knowledge and understanding of science	24	6
AO2	Apply skills, knowledge and understanding of science in practical and other contexts	38	9.5
AO3	Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence	38	9.5

Additional Science/Biology/Chemistry/Physics

The controlled assessment tests all the assessment objectives for GCSE Additional Science/Biology/Chemistry/Physics contributing to overall weightings within those specified by the regulatory authorities.

Assessment Objective		% Weighting in Controlled Assessment	% Weighting in Additional Science Biology/Chemistry/Physics
AO1	Recall, select and communicate knowledge and understanding of science	18.8	4.7
AO2	Apply skills, knowledge and understanding of science in practical and other contexts	25.0	6.3
AO3	Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence	56.3	14.1

(Note: Figures rounded to 1 decimal place.)

LEVELS OF CONTROL

The regulation of controlled assessment in GCSE Sciences is split into three stages:

- task setting
- task taking
- task marking

For each stage, the regulatory authorities have specified a certain level of control to ensure reliability and authenticity.

TASK SETTING

Overall this aspect has a high level of control therefore WJEC will provide tasks annually.

Science A: Candidates must complete **three short exercises** based upon the subject content of the GCSE Science specification.

The structure of the tasks is as follows:

1. Research and use of information.
2. Practical work and hypothesis testing.
3. Experimental techniques and safety.

Additional Science: Candidates must complete **one scientific investigation** based upon the subject content of the GCSE Additional Science specification.

or

Biology/Chemistry/Physics: Candidates must complete **one scientific investigation** based upon the subject content of **each** of the GCSE Biology/Chemistry/Physics specifications.

The structure of the tasks is as follows:

1. Introductory/background experimental work.
2. Investigatory planning and research.
3. The candidates carry out their investigatory work, and present a report.

TASK TAKING

The controlled assessment criteria recognise two phases of task taking, each with its specified level of control.

- (A) Research/data collection
A limited level of control is specified.
- (B) Analysis and evaluation
A high level of control is specified.

(A) Research/data collection

Research is carried out under limited control.

Authenticity control

Activities such as introductory experimental work, research, investigatory planning and data collection should be supervised by the teacher who may also give guidance regarding the appropriate sources of research that are applicable for the investigation chosen. It is permissible for some research to be carried out outside the classroom.

It is sometimes necessary for the teacher to provide some research material to all pupils. This is because gaining access to such material may be problematic for pupils. In these instances, the teacher must record and keep examples of any pieces of research material that are given to all pupils.

Feedback control

Teachers can comment on the research / planning work being undertaken by candidates e.g. on the nature and suitability of the approach. Substantial support, both oral and written, given to candidates should be dated and logged. It should indicate clearly the nature of the advice. This information should be taken into account when making the final assessment, as credit is only given for the candidate's own input.

Feedback on practical activities should be limited to answering technical questions on the nature of the task.

*Time control***Science A**

Exercise 1: It is recommended that the whole period available for research is limited to **no more than 2 weeks**.

Exercise 2: It is recommended that the complete exercise should occupy **two 45 minute lessons of classroom time of which one is fit for the data collection**.

Exercise 3: The whole exercise should occupy **no more than 45 minutes of classroom time**.

Additional Science/Biology/Chemistry/Physics

The initial part of the task, the Introductory/background experimental work falls partly outside the research/data collection phase of the controlled assessment and no duration is stipulated for this. There are two parts of the controlled assessment which fall within this phase.

Research: It is recommended that approximately **1 hour** of supervised time be allocated to this plus a 1 week period for candidates to pursue their own research.

Data collection: This is the experimental stage of the task. The duration of this phase should normally be up to **2 hours**.

Extra allowances

These recommended time spans may be increased to accommodate the needs of those candidates who need extra time due to, for example, learning difficulties or disabilities. In addition, centres may make any suitable adaptations to methods or equipment in order to allow such candidates access to the marks.

Collaboration control

Candidates may collaborate on their research activities and when collecting data in practical situations; however, they should undertake their own planning. Candidates must ultimately produce individual responses.

Resource control

Candidates' access to resources is determined by those available to the centre. This includes laboratory apparatus and access to sources of information including the internet. Centres may adapt activities, if necessary, in order to allow candidates to complete the exercises. If this occurs, the moderator should be informed by annotation of the work.

(B) Analysis and evaluation

Overall this aspect has a high level of control.

Authenticity control

Candidates must complete all work under direct formal supervision, normally in lesson time. It is expected that candidates would complete the work in hand-written form but they may use ICT as long as the integrity of the work can be assured.

Feedback control

During the completion of the controlled assessment, teachers are allowed to communicate with candidates to clarify issues, but not to offer suggestions or solutions. Teachers can give help regarding technical issues such as the use of ICT equipment.

*Time control***Science A**

The analysis and evaluation phase of each assessment task should normally be completed within 45 minutes of formal supervised time. These should each be in one block. Preparatory material for the research and data collection phase must be collected in and kept with the response to the analysis and evaluation phase.

Additional Science/Biology/Chemistry/Physics

Two parts of the controlled assessment fall within the analysis and evaluation phase.

Planning: This part of the controlled assessment must normally be completed within 1½ hours of formal supervised time. This does not need to be in one block but may be spread over more than one session. Preparatory material and any written work left unfinished at the end of a session must be collected in and given out at the start of the next session. Redrafting of the work is not permitted.

Reporting: This part of the controlled assessment must normally be completed within 3 hours of formal supervised time. This does not need to be in one block but may be spread over more than one session. Preparatory material and any written work left unfinished at the end of a session must be collected in and given out at the start of the next session. Redrafting of the work is not permitted.

Extra allowances

These recommended time spans may be increased to accommodate the needs of those candidates who need extra time due to, for example, learning difficulties or disabilities. In addition, centres may make any suitable adaptations to methods or equipment in order to allow such candidates access to the marks.

Collaboration control

Candidates must complete the controlled assessment task independently.

Resource control

During the analysis and evaluation stage, candidates will be allowed to use only the material collected during the research and data collection stage to complete the controlled assessment.

TASK MARKING

Overall this aspect has a medium level of control.

Initial marking

When the work is completed, teachers at the centre mark the controlled assessment using the generic mark scheme provided by WJEC. The work should be annotated to indicate how the final mark has been achieved. The annotation should be addressed to the moderator.

Internal moderation

Internal moderation is the process whereby the assessment of the work of candidates in different teaching groups within a centre is checked for accuracy and consistency. This has to be done before the sample is chosen for the WJEC moderator. A teacher responsible for the course should check that the agreed standards of marking have been consistently applied and adjust the marks if necessary. Details of any internal moderation should be provided when the sample is sent to the WJEC moderator.

Authentication of Controlled Assessments

In line with JCQ requirements, candidates are required to sign that the work submitted is their own and teachers/assessors are required to confirm that the work assessed is solely that of the candidate concerned and was conducted under the required conditions. A copy of the authentication declaration, which forms part of the cover sheet for each candidate's work, will be provided by WJEC. (A copy is also provided in Appendix 7.) It is important to note that **all** candidates are required to sign this form, and not merely those whose work forms part of the sample submitted to the moderator. Malpractice discovered prior to the candidate signing the declaration of authentication need not be reported to WJEC but must be dealt with in accordance with the centre's internal procedures.

Before any work towards the controlled assessment is undertaken, the attention of candidates should be drawn to the relevant JCQ Notice to Candidates. (A copy is provided in Appendix 7.) This is available on the JCQ website (www.jcq.org.uk) and included in *Instructions for Conducting Controlled Assessments*.

External moderation

External moderation is the process whereby the marks awarded by the centre are checked for accuracy and consistency across centres. This involves a moderator appointed by WJEC checking a sample of the work from a centre. An internal assessment manual is available from WJEC each year which contains information about selecting a sample for external moderation and submission dates.

When selecting a sample, centres should ensure that:

- candidates from each teaching group should be represented
- in bilingual centres, work should be submitted in both Welsh and English.

Centres should also send to their appointed moderator the following documents:

- any relevant administration forms
- copies of any detailed interpretation of the mark schemes used, especially if work is contextualised
- any further information which may help the moderator when interpreting the work or marking
- signed authentication
- details of internal moderation (if applicable).

6

GRADE DESCRIPTIONS

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

Grade A

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

Grade A (continued)

Science	Physics	Biology	Chemistry	Additional Science
<p>They apply appropriate skills, including communication, mathematical and technological skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models to explain phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models, including mathematical models, to explain abstract ideas, phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models, including mathematical models, to explain abstract ideas, phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models, including mathematical models, to explain abstract ideas, phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including communication, mathematical and technological skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models to explain phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses.</p>
<p>Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.</p>	<p>Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.</p>	<p>Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.</p>	<p>Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.</p>	<p>Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations taking account of the limitations of the available evidence. They make reasoned judgments consistently and draw detailed, evidence-based conclusions.</p>

Grade C

Science	Physics	Biology	Chemistry	Additional Science
<p>Candidates recall, select and communicate secure knowledge and understanding of science. They demonstrate understanding of the nature of science, its laws, its applications and the influences of society on science and science on society. They understand how scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.</p>	<p>Candidates recall, select and communicate secure knowledge and understanding of physics. They demonstrate understanding of the nature of physics, its laws, principles and applications and the relationship between physics and society. They understand that scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.</p>	<p>Candidates recall, select and communicate secure knowledge and understanding of biology. They demonstrate understanding of the nature of biology and its principles and applications and the relationship between biology and society. They understand that scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.</p>	<p>Candidates recall, select and communicate secure knowledge and understanding of chemistry. They demonstrate understanding of the nature of chemistry, its laws, principles and its applications and the relationship between chemistry and society. They understand that scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.</p>	<p>Candidates recall, select and communicate secure knowledge and understanding of science. They demonstrate understanding of the nature of science, its laws, its applications and the influences of society on science and science on society. They understand how scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space.</p>

Grade C (continued)

Science	Physics	Biology	Chemistry	Additional Science
<p>They apply appropriate skills, including communication, mathematical and technological skills, knowledge and understanding in a range of practical and other contexts. They recognise, understand and use straightforward links between hypotheses, evidence, theories, and explanations. They use models to explain phenomena, events and processes. Using appropriate methods, sources of information and data, they apply their skills to answer scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They show understanding of the relationships between hypotheses, evidence, theories and explanations and use models, including mathematical models, to describe abstract ideas, phenomena, events and processes. They use a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They show understanding of the relationships between hypotheses, evidence, theories and explanations and use models, including mathematical models, to describe abstract ideas, phenomena, events and processes. They use a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They show understanding of the relationships between hypotheses, evidence, theories and explanations and use models, including mathematical models, to describe abstract ideas, phenomena, events and processes. They use a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and test hypotheses.</p>	<p>They apply appropriate skills, including communication, mathematical and technological skills, knowledge and understanding in a range of practical and other contexts. They recognise, understand and use straightforward links between hypotheses, evidence, theories, and explanations. They use models to explain phenomena, events and processes. Using appropriate methods, sources of information and data, they apply their skills to answer scientific questions, solve problems and test hypotheses.</p>
<p>Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and develop arguments with supporting explanations. They draw conclusions consistent with the available evidence.</p>	<p>Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They draw conclusions based on the available evidence.</p>	<p>Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They draw conclusions based on the available evidence.</p>	<p>Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They draw conclusions based on the available evidence.</p>	<p>Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and develop arguments with supporting explanations. They draw conclusions consistent with the available evidence.</p>

Grade F

Science	Physics	Biology	Chemistry	Additional Science
<p>Candidates recall, select and communicate their limited knowledge and understanding of science. They recognise simple inter-relationships between science and society. They have a limited understanding that advances in science may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.</p> <p>They apply skills, including limited communication, mathematical and technological skills, knowledge and understanding in practical and some other contexts. They show limited understanding of the nature of science and its applications. They can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas.</p>	<p>Candidates recall, select and communicate limited knowledge and understanding of physics. They recognise simple inter-relationships between physics and society. They show a basic understanding that scientific advances may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.</p> <p>They apply skills, including limited mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They recognise and use hypotheses, evidence and explanations and can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas.</p>	<p>Candidates recall, select and communicate limited knowledge and understanding of biology. They recognise simple inter-relationships between biology and society. They show a limited understanding that scientific advances may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.</p> <p>They apply skills, including limited mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They recognise and use hypotheses, evidence and explanations and can explain straightforward models of phenomena, events and processes. They use a limited range of methods, sources of information and data to address straightforward scientific questions, problems and hypotheses.</p>	<p>Candidates recall, select and communicate limited knowledge and understanding of chemistry. They recognise simple inter-relationships between chemistry and society. They show a limited understanding that scientific advances may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.</p> <p>They apply skills, including limited mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They recognise and use hypotheses, evidence and explanations and can explain straightforward models of phenomena, events and processes. They use a limited range of methods, sources of information and data to address straightforward scientific questions, problems and hypotheses.</p>	<p>Candidates recall, select and communicate their limited knowledge and understanding of science. They recognise simple inter-relationships between science and society. They have a limited understanding that advances in science may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space.</p> <p>They apply skills, including limited communication, mathematical and technological skills, knowledge and understanding in practical and some other contexts. They show limited understanding of the nature of science and its applications. They can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas.</p>

Grade F (continued)

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

7

THE WIDER CURRICULUM

Key Skills and Essential Skills Wales

GCSE Sciences will provide a range of opportunities for developing these skills. The following Key Skills/Essential Skills Wales can be developed through this specification at levels 1 and 2:

- Application of Number
- Communication
- Problem Solving
- Information and Communication Technology
- Working with Others
- Improving Own Learning and Performance

Mapping of opportunities for the development of these skills against appropriate criteria at Level 2 is provided in Exemplification of Key Skills/Essential Skills Wales, available on the WJEC website.

Opportunities for use of technology

This specification is designed to provide a range of opportunities for the use of ICT. The programmes of study in the specification content provide opportunities for the use of ICT in the delivery of the course. In addition, the centre-based element will provide further opportunities for candidates to use ICT in scientific investigations.

Through the teaching of investigative skills, candidates should be given opportunities to apply and develop their ICT capability. In particular, candidates could:

- use data-handling software to analyse data from fieldwork;
- use data-handling software to create, analyse and evaluate charts and graphs;
- use data loggers in investigations;
- use spreadsheets for data analysis;
- use the Internet or CD-ROM software as sources of secondary evidence.

Suitable relevant subject content includes ecological investigations, genetic variation, searching for alternative evidence using CD-ROM or the Internet e.g. for the impact on local communities caused by industrial activities and conservation, using data loggers to investigate photosynthesis and motion.

Spiritual, Moral, Ethical, Social and Cultural Issues

The specification provides a framework and includes specific content through which individual courses may address spiritual, moral, ethical, social and cultural issues. It aims to provide a stimulus for students to develop an understanding of the usefulness and limitation of scientific method and so appreciate its applicability in everyday life. An examination of scientific and contemporary issues is therefore an integral part of the course.

Contexts are provided to give the opportunity to:

- encourage candidates to discern, consider and discuss questions relating to the origin of the universe, the meaning of life, the nature of humanity and concepts such as infinity, proof, truth and certainty;
- consider scientific interpretations of the structures and development of the modern world;
- consider ethical, cultural and social issues resulting from scientific interpretations and advances in knowledge.

Sensitive Issues

It should also be noted that some aspects of the specification may raise contentious issues e.g. evolution, which should be treated with understanding.

In addition, the inclusion of human infections and diseases in the specification may raise difficulties for individuals, particularly those with personal involvement e.g. genetic disorders, therefore a sensitive approach is required.

Citizenship

The applications and implications of science in society, which are inherent in the science specifications, encourage the development of a responsible attitude to citizenship. An understanding that individuals have a collective responsibility is fostered in relation to various ethical issues included in the specifications such as genetic engineering and pollution.

Environmental Issues

WJEC has taken account of the following important issues in preparing this specification. It therefore provides opportunities to develop an awareness of environmental issues and controversies. Some relevant topics are listed below.

Environmental Issues
Energy efficiency Maintenance of biodiversity Exploitation of resources Air, water and pesticide pollution Energy and mineral recycling Aspects of the reprocessing and storage of radioactive materials The depletion of the ozone layer Global warming and its control Acid rain and its control Transmission of electrical energy

Health and Safety Consideration

At all times both teachers and candidates should be aware of health and safety issues arising from work both within and outside the centre. Risk assessments are required for all practical work whether it takes place in the laboratory or out in the field. The specifications require candidates to develop the relevant skills and awareness of health and safety issues.

The European Dimension

The approach used in constructing the specification lends itself to the establishment of links with other areas of study, particularly those involving economic and industrial understanding and environmental and health education. It may also be used to illustrate the European dimension and requires consideration of the issues posed by different perspectives.

The approach is exemplified by various sections regarding the need for international co-operation such as for effective pollution control, species protection, the finite nature of world resources, and regulation of food quality.

Appendix 1

Mathematical Demands

As required by the regulators, this specification provides learners with the opportunity to develop their skills in mathematics in scientific contexts. The assessment materials will contain opportunities for candidates to demonstrate scientific knowledge using appropriate mathematical skills as indicated on page 12.

The following areas of mathematics have been identified by the regulators as arising naturally from the science content in the subject criteria and are therefore expected of candidates.

Candidates at both **foundation** and **higher tiers** should be able to:

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

In addition, **higher tier** candidates should be able to

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

Candidates are permitted to use calculators in all assessments.

Appendix 2

Use of SI Units

Candidates are expected to use units appropriately. However, not all questions need to reward the appropriate use of units.

Candidates are expected to be familiar with and to use SI units and SI multipliers. They are expected to know the SI units of quantities in the specification, e.g. in Physics 1, the equation $\text{power} = \text{voltage} \times \text{current}$ is specified, so candidates will be expected to be familiar with watt, volt and amp and their symbols; W, V and A.

The non-SI units hour (h) and kilowatt hour (kWh) are also used in the context of energy supply and in measurement of blood pressure (mmHg).

Appendix 3

Lines of Best Fit

If there is a continuous relationship between the two variables plotted on a graph, a line of best fit should be drawn joining, or approximating to, the points. The line of best fit may be straight or curved and, in higher level work, it may be used to deduce a mathematical relationship between the variables.

In a great deal of scientific, especially biological, data there is no such continuous relationship. In this case a series of straight lines should be used to join successive points. The values between the points cannot be shown on the graph and cannot be deduced from the readings. A smooth curve should therefore only be used if there is good reason to think that the intermediate values would fall on that curve. Joining points by straight lines indicates that the points in between recorded points are unknown and, in addition, how they vary between recorded points is also unknown.

In some disciplines a 'line of best fit' is regarded as the norm and the possibility of straight line joining of points is not considered. Therefore, an awareness of the particular requirements for presenting biological data is required and the need for appropriate explanation to enable an understanding of why this difference occurs.

Appendix 4

Questions involving Equations in Physics Papers in GCSE Sciences

Question papers for Physics 1, Physics 2 and Physics 3 will include, as a separate section, the list of the equations from the physics units, in words and, where appropriate, in symbols. A list of SI multipliers will also be given in this section. Questions will be set which will require candidates to use these equations.

The following styles of questions will be set.

1. Use of a given equation: the equation to be used is presented in the question. Candidates will need to use data in the question and may need to select it from a table, a graph or from a passage.
2. Use of the list of equations: the equation (or equations) to be used is not presented in the question. Candidates will need to look at the data in the question and the quantity they need to determine and select from the equations in the list the most appropriate one(s) to use. It may be that there is more than one possible approach.

As stipulated in Appendix 1, questions on foundation tier papers will not require candidates to change the subject of an equation, though the data may need to be manipulated in other ways, e.g. by use of an SI multiplier.

Appendix 5

Chemical symbols

Candidates must ensure that chemical symbols are written using clearly recognisable upper case and lower case letters as appropriate. A copy of the Periodic Table will be printed on the back cover of each examination paper.

Chemical formulae

Candidates are required to write chemical formulae in each of units Chemistry 1, Chemistry 2 and Chemistry 3. They must ensure that upper case and lower case letters are clearly recognisable and that any numbers present are in subscript. A table including the formulae of ions used to determine the chemical formulae of simple compounds will be printed inside the back cover of each examination paper.

Appendix 6

Command Words and Phrases

The command words and phrases used in examination papers are listed below.

Calculate/work out ...	Implies that the candidate must produce a numerical answer.
Compare ...	Implies that that candidate needs to describe the similarities and/or differences in material arising from the specification content or in sets of data provided.
Complete ...	Implies that the candidate needs to enter the answer in spaces provided in a diagram, table etc.
Describe ...	Implies that the candidate must state in words, or as diagrams, the important points of the topic.
Draw a bar chart ...	Implies that: <ul style="list-style-type: none"> • for a graph where the axes are labelled and scaled the candidate needs to plot as bars a series of values; • for a graph where the axes are labelled and not scaled the candidate needs to add scales and plot as bars a series of values.
Draw a graph ...	Implies that: <ul style="list-style-type: none"> • for a graph where the axes are labelled and scaled the candidate needs to plot as points a series of values and then draw an appropriate line; • for a graph where the axes are labelled and not scaled the candidate needs to add scales, plot as points a series of values and then draw an appropriate line.
Explain how/why ...	Implies that the candidate must apply reasoning to the recall of theory. (This command phrase is not used if the answer required is no more than a list of reasons.)
Give a reason/how/why ...	Implies that a reason is needed which is an application of scientific knowledge.
Give/name/state/write down ...	Implies that a concise answer is required without supporting evidence.
List ...	Implies that a series of concise answers is required, each answer being written one after the other.

Predict ...	Implies that a considered answer is required without supporting evidence, and that the answer is based on the candidate making logical links between various pieces of information.
Sketch a graph ...	Implies that the candidate needs to draw a line on a grid indicating a trend or pattern without the need first to plot a series of points.
Suggest ...	Implies that there is no unique answer, and that candidates are expected to base the answer on scientific knowledge and/or scientific principles.
Use the information ...	Implies that the answer must be based on information provided within the context of the question.
Use your understanding/ideas of ... to ...	Implies the concept around which the answer should be framed.
What is meant by ...	Implies that a definition should be given, together with some relevant comment on the significance or context of the question.

Appendix 7



Controlled Assessment
GCSE Additional Science
GCSE Biology/Chemistry/Physics

Assessment Area	Mark Awarded
Hypothesising and planning/12	
Collecting, reviewing and processing data/12	
Analysing and reviewing procedure/12	
Analysing data and concluding/12	
Total Mark / 48	

Candidate Name

Centre Name **Centre Number** ..

Declaration by candidate
<p><i>I have read and understood the Notice to Candidates (GCSE and Principal Learning: Controlled Assessments). I have produced the attached work without assistance other than that which is acceptable under the scheme of assessment.</i></p> <p>Candidate's name:</p> <p>Candidate's signature: Date</p>

Declaration by teacher or lecturer
<p><i>I confirm that:</i></p> <ol style="list-style-type: none"> <i>the candidate's work was conducted under the conditions laid out by the specification;</i> <i>I have authenticated the candidate's work and am satisfied that, to the best of my knowledge, the work produced is solely that of the candidate.</i> <p>Teacher's name:</p> <p>Teacher's signature: Date</p>

Year



Controlled Assessment
GCSE Science A

Assessment Objective	Mark Awarded
AO1/15	
AO2/24	
AO3/24	
Total Mark / 63	

Candidate Name

Centre Name Centre Number

Declaration by candidate

*I have read and understood the **Notice to Candidates (GCSE and Principal Learning: Controlled Assessments)**. I have produced the attached work without assistance other than that which is acceptable under the scheme of assessment.*

Candidate's name:

Candidate's signature: **Date**

Declaration by teacher or lecturer

I confirm that:

1. *the candidate's work was conducted under the conditions laid out by the specification;*
2. *I have authenticated the candidate's work and am satisfied that, to the best of my knowledge, the work produced is solely that of the candidate.*

Teacher's name:

Teacher's signature: **Date**

Year



This notice has been produced on behalf of:

AQA, City & Guilds, CCEA, Edexcel, OCR and WJEC

Notice to Candidates

GCSE and Principal Learning: Controlled Assessments

This notice tells you about some things that you must, and must not, do when you are completing your work.

Before you submit any work for marking, you will be asked to sign an authentication statement confirming that you have read and followed these regulations.

If there is anything that you do not understand, you **must** ask your teacher or lecturer.

Controlled Assessment will provide you with an opportunity to do some independent research into a topic. The research you do may involve looking for information in published sources such as textbooks, encyclopedias, journals, TV, radio, and on the internet.

Using information from published sources (including the internet) as the basis for your assignment is a good way to demonstrate your knowledge and understanding of a subject, but you must take care how you use this material - you cannot copy it and claim it as your own work.

The regulations state that:

"the work which you submit for assessment must be your own";

"you must not copy from someone else or allow another candidate to copy from you".

If you use the same wording as a published source, you must place quotation marks around the passage and state where it came from. This is called "referencing". You must make sure that you give detailed references for everything in your work which is not in your own words. A reference from a printed book or journal should show the name of the author, the year of publication and the page number, for example: (Morrison, 2000, pg.29).

For material taken from the internet, your reference should show the date when the material was downloaded and must show the precise web page, not the search engine used to locate it. This can be copied from the address line. For example:
(<http://www.bbc.co.uk/schools/16/sosteacher/history/49766.shtml>), downloaded 12 February 2010.

You may be required to include a bibliography at the end of your work. Your teacher or lecturer will tell you whether a bibliography is necessary. Where required, your bibliography must list the full details of publications you have used in your research, even where these are not directly referred to, for example: Morrison, A. (2000) "Mary, Queen of Scots", London: Weston Press.

If you copy the words or ideas of others and don't show your sources in references and a bibliography, this will be considered as cheating.

Preparing your work – good practice

If you receive help and guidance from someone other than your teacher, you **must** tell your teacher who will then record the nature of the assistance given to you.

If you worked as part of a group on an assignment, for example, undertaking field research, you must each write up your own account of the assignment. Even if the data you have is the same, the description of how that data was obtained and the conclusions you draw from it should be in your own words.

You must meet the deadlines that your teacher gives you. Remember – your teachers are there to guide and assist you – showing them your work as it progresses will allow you and your teacher time to sort out any problems before it is too late.

Take care of your work and keep it safe. Don't leave it lying around where your classmates can find it. You must always keep your work secure and confidential whilst you are preparing it; do not share it with your classmates. If it is stored on the computer network, keep your password secure. Collect all copies from the printer and destroy those you don't need.

Don't be tempted to use essays from online essay banks – this is cheating. Electronic tools used by awarding bodies can detect this sort of copying.

Plagiarism

Plagiarism involves taking someone else's words, thoughts or ideas and trying to pass them off as your own. **It is a form of cheating which is taken very seriously.**

Don't think you won't be caught; there are many ways to detect plagiarism.

- Markers can spot changes in the style of writing and use of language.
- Markers are highly experienced subject specialists who are very familiar with work on the topic concerned – they may have read the source you are using (or even marked the essay you have copied from!).
- Internet search engines and specialised computer software can be used to match phrases or pieces of text with original sources and to detect changes in the grammar and style of writing or punctuation.

Penalties for breaking the regulations

If your work is submitted and it is discovered that you have broken the regulations, one of the following penalties will be applied:

- the piece of work will be awarded zero marks;
- you will be disqualified from that unit for that examination series;
- you will be disqualified from the whole subject for that examination series;
- you will be disqualified from all subjects and barred from entering again for a period of time.

Your awarding body will decide which penalty is appropriate.

REMEMBER – IT'S YOUR QUALIFICATION SO IT NEEDS TO BE YOUR OWN WORK

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