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Science A

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GCSE

Science A

Twenty First Century Science Suite

OCR GCSE in Science A J630

Foreword to the Second Edition

This Second Edition of the OCR GCSE Science A specification has been produced to correct minor errors found in the original edition (published in Dec 2005). There are no changes to actual content or the scheme of assessment. Centres should note however the grade descriptions in Appendix A have now been replaced with the correct versions.

Section 6.6 has been updated (amended in Oct 2007).

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1 About this Qualification

1.1 About the Twenty First Century Science Suite

The Twenty First Century Science suite comprises six specifications which share common material, use a similar style of examination questions and have a common approach to skills assessment. The qualifications available as part of this suite are:

GCSE Science A (J630)	which emphasises scientific literacy – the knowledge and understanding which candidates need to engage, as informed citizens, with science-based issues. As with other courses in the suite, this qualification uses contemporary, relevant contexts of interest to candidates, which can be approached through a range of teaching and learning activities.
GCSE Additional Science A (J631)	which is a concept-led course developed to meet the needs of candidates seeking a deeper understanding of basic scientific ideas. The course focuses on scientific explanations and models, and gives candidates an insight into how scientists develop scientific understanding of ourselves and the world we inhabit.
GCSE Additional Applied Science A (J632)	which meets the needs of candidates who wish to develop their scientific understanding through authentic, work related contexts. The course focuses on procedural and technical knowledge that underpins the work of practitioners of science and gives candidates an insight into what is involved in being a practitioner of science.
GCSE Biology A (J633) **GCSE Chemistry A (J634)** **GCSE Physics A (J635)**	each of which provides an opportunity for further developing an understanding of science explanations, how science works and the study of elements of applied science, with particular relevance to professional scientists.

This suite is supported by the Nuffield Curriculum Centre and The University of York Science Education Group.

1.2 About this Science Specification

This booklet contains OCR's GCSE specification in Science for teaching from September 2006 and first certification in June 2007.

This specification is designed as the primary Science qualification for all candidates at KS4. It aims to enhance candidates' 'scientific literacy', leading to better engagement with science. The course is designed to enable candidates to:

- recognise the impact of Science and technology on everyday life;
- make informed personal decisions about issues and questions that involve science;
- understand and reflect on the information included in (or omitted from) media reports and other sources of information.

To achieve this, candidates must have a broad understanding of the main scientific concepts that provide a framework for making sense of the world. These are referred to as 'Science Explanations'. But, candidates also need to be able to reflect on scientific knowledge itself, the practices that have produced it, the kinds of reasoning that are used in developing a scientific argument, and the issues that arise when scientific knowledge is put to practical use. These are referred to as 'Ideas about Science'. The specification content is based upon these two essential elements, which were developed by the University of York Science Education Group (UYSEG) as part of a project on 'Science in the 21st Century', commissioned by QCA. Together, the Science Explanations and Ideas about Science cover the KS4 Programme of Study for Science.

This specification comprises nine teaching modules which are assessed through five units.

Unit	Unit Code	Title	Duration	Weighting	Total Mark
1	A211	Science A Unit 1 – modules B1, C1, P1	40 mins	16.7%	42
2	A212	Science A Unit 2 – modules B2, C2, P2	40 mins	16.7%	42
3	A213	Science A Unit 3 – modules B3, C3, P3	40 mins	16.7%	42
4	A214	Science A Unit 4 – Ideas in Context	45 mins	16.7%	40
5	A219	Science A Unit 5 – Practical Data Analysis and Case Study	-	13.3%	16
			-	20%	24

Candidates take all five units. Alternatively, candidates can also achieve GCSE Science A by taking Unit 1 from each of Biology (A221), Chemistry (A321) and Physics (A331) plus Units 4 and 5 from this specification.

1.3 Qualification Titles and Levels

This qualification is shown on a certificate as OCR GCSE in Science.

This qualification is approved by the regulatory authority, QCA, as part of the National Qualifications Framework.

Candidates who gain grades G to D will have achieved an award at Foundation Level (Level 1 of the National Qualifications Framework).

Candidates who gain grades C to A* will have achieved an award at Intermediate Level (Level 2 of the National Qualifications Framework).

1.4 Aims

The aims of this GCSE specification are to encourage candidates to:

- acquire a systematic body of scientific knowledge, and the skills needed to apply this in new and changing situations;
- acquire an understanding of scientific ideas, of how they develop, of the factors which may affect their power, and of their limitations;
- consider and evaluate critically their own data and conclusions, and those obtained from other sources, using ICT where appropriate;

- evaluate, in terms of their scientific knowledge and understanding and their understanding of the processes of scientific enquiry and of the nature of scientific knowledge, the benefits and drawbacks of scientific and technological developments, including those related to the environment, personal health and quality of life, and considering ethical issues where these arise;
- select, organise and present information clearly and logically, using appropriate scientific terms and conventions, and ICT where appropriate;
- interpret and evaluate scientific data and conclusions from a variety of sources;
- use electronic (internet, CD ROMs, databases, simulations etc.) and/or more traditional sources of information (books, magazines, leaflets etc.) to collect data and ideas on a topic of scientific interest.

1.5 Prior Learning/Attainment

Candidates who are taking courses leading to this qualification at Key Stage 4 should normally have followed the corresponding Key Stage 3 programme of study within the National Curriculum.

Other candidates entering this course should have achieved a general educational level equivalent to National Curriculum Level 3.

2 Summary of Content

The specification content is based on a set of Science Explanations and the Ideas about Science. It is presented as nine modules which are listed below. Each module uses contexts that make it of clear and immediate relevance and interest to candidates. The contexts relate to candidates' everyday experiences and interests, for example, to issues often in the news, or to work and leisure.

A module defines the required teaching and learning outcomes. Ideas about Science should have a strong influence on the teaching of each module. Each module is designed to be taught in approximately half a term, in 10% of the candidates' curriculum time.

Module B1: You and Your Genes

- What are genes and how do they affect the way that organisms develop?
- Why can people look like their parents, brothers and sisters, but not be identical to them?
- How can and should genetic information be used? How can we use our knowledge of genes to prevent disease?
- What are stem cells, and why could they be useful in treating some diseases?

Module C1: Air Quality

- Which chemicals make up air, and which ones are pollutants? How do I make sense of data about air pollution?
- What chemical reactions produce air pollutants? What happens to these pollutants in the atmosphere?
- Is air pollution harmful to me, or to my environment?
- What choices can we make personally, locally, nationally or globally to improve air quality?

Module P1: The Earth in the Universe

- What do we know about the Earth and Space?
- How have the Earth's continents moved, and with what consequences?
- What is known about stars and galaxies?
- How do scientists develop explanations of the Earth and Space?

Module B2: Keeping Healthy

- How do our bodies resist infection?
- What are vaccines and how do they work?
- What are antibiotics, and why can they become less effective? How are new drugs developed and tested?
- What factors increase the risk of heart disease?

Module C2: Material Choices

- What different properties do different materials have?
- Why is crude oil important as a source of new materials such as plastics and fibres?
- Why does it help to know about the molecular structure of materials such as plastics and fibres?
- When buying a product, what else should we consider besides its cost and how well it does its job? How should we manage the wastes that arise from our use of materials?

Module P2: Radiation and Life

- What types of electromagnetic radiation are there? What happens when radiation hits an object?
- Which types of electromagnetic radiation harm living tissue and why?
- How does electromagnetic radiation make life on Earth possible?
- What is the evidence for global warming? Why might it be occurring, and how serious a threat is it?
- What ideas about risk do citizens and scientists use?

Module B3: Life on Earth

- How did life on Earth begin and evolve?
- How have scientists developed explanations of evolution?
- How did humans evolve? How are our nervous systems organised?
- Why do some species become extinct, and does it matter? What is the importance of biodiversity?

Module C3: Food Matters

- What is the difference between intensive and organic farming?
- Why are chemicals deliberately added to food?
- How can we make sure that our food does not contain chemicals that may be harmful to health?
- Why does what we eat affect our health?

Module P3: Radioactive Materials

- Why are some materials radioactive?
- How can radioactive materials be used and handled safely, including wastes?
- How can electricity be generated? What can be done with nuclear wastes?
- What are the health risks from radioactive materials?

3 Content

Layout of Module Content

The content is displayed as nine modules B1, B2, B3, C1, C2, C3, P1, P2 and P3. Each module has an overview page summarising the content and providing a context, as shown below.

Issues for citizens	Questions that science might help to answer
e.g. Is it safe to use microwave ovens and mobile 'phones?	e.g. Which types of radiation harm living tissues and why?
Science explanations	Ideas about Science
e.g. SE 12 Radiation	e.g. IaS 2.5–2.8 Correlation and cause

The overview identifies:

- issues which are likely to be uppermost in the minds of citizens when considering the module topic, whatever their understanding of science;
- questions about the topic that science may be able to address, which could reasonably be asked of a scientifically literate person;
- those Science Explanations and Ideas about Science which are introduced or further developed in the module.

Some symbols and fonts are provided to give teachers additional information, expressed in abbreviated form, about the way in which the content is linked to other parts of the specification, and the table below summarises this information.

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

MODULE B1: YOU AND YOUR GENES – OVERVIEW

The inheritance of detailed information from each generation to the next is a fundamental story in science. For each of us, inheritance also raises questions about our own development. In this module candidates learn basic concepts of inheritance: genes as units of inheritance, the interplay between genes and environment, sexual reproduction as a source of variation.

These concepts are sufficiently detailed for candidates to make sense of related ideas in other GCSE Science modules. More complex ideas, such as mechanisms for protein synthesis and cell division, are not required, and are covered in GCSE Additional Science, module B5 Growth and Development.

Throughout the module, candidates are introduced to genetic technologies that open up new possibilities for individuals and society. In doing so, they present significant ethical issues for citizens. Candidates explore some of the ideas people use to make ethical decisions. This enables them to engage with issues which regularly appear in the media, such as genetic testing, gene therapy and cloning research.

Issues covered in this module may be very sensitive for candidates.

Issues for citizens	Questions that science may help to answer
How do my genes affect my appearance, my body, and my health?	What are genes and how do they affect the way that living organisms develop? Why can people look like their parents, brothers or sisters, but not be identical to them?
How and why do people find out about their genes? What decisions do people make with this information?	How can and should genetic information be used?
Can we change our genes, and should this be allowed?	How can we use our knowledge of genes to prevent disease?
What is cloning, and should it be allowed?	What are stem cells, and why could they be useful in treating some diseases?
Science Explanations	**Ideas about Science**
SE 8 The gene theory of inheritance SE 6b Cells as the basic units of living things	IaS 6.4-6.7 Making decisions about science and technology

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, the use of the internet to disseminate scientific findings about health issues to the public.

Use of ICT in teaching and learning can include:

- animated journey through a cell to illustrate the relationship between the nucleus, chromosomes, genes and DNA and a simple explanation of protein synthesis;
- interactive animation of genetic crosses;
- video clips of relevant media reports.

MODULE B1: YOU AND YOUR GENES

B1.1 What are genes and how do they affect the way that organisms develop?

1. recall that instructions for how an organism develops are found in the nucleus of its cells;
2. understand that genes are instructions for a cell that describe how to make proteins, **which may be structural or enzymes;**
3. understand that genes are sections of very long DNA molecules that make up chromosomes in the nuclei of cells.

B1.2 Why can people look like their parents, brothers and sisters, but not be identical to them?

1. recall that sex cells have only a copy of one chromosome from each pair;
2. understand that the occurrence of chromosomes (and hence genes) in pairs relates to their origin from each parent's sex cells;
3. recall that chromosomes in a pair carry the same genes in the same place, but that there are different versions of genes called alleles;
4. understand that a person may have two alleles the same or two different alleles for any gene;
5. interpret (through family trees or genetic diagrams) the inheritance of normal single gene characteristics with a dominant and recessive allele;
6. understand that offspring may have some similarity to their parents because of the combination of maternal and paternal alleles in the fertilised egg;
7. understand why different offspring from the same parents can differ from each other;
8. recall that human males have sex chromosomes XY and females have sex chromosomes XX;
9. **recall that sex of a human embryo is determined by a gene on the Y chromosome;**
10. **understand the link between this gene and the development of sex organs into either ovaries or testes.**

MODULE B1: YOU AND YOUR GENES

B1.3 How can and should genetic information be used? How can we use our knowledge of genes to prevent disease?

1. understand that most characteristics are determined by several genes working together, for example, height;
2. understand that most characteristics are also affected by environmental factors, for example, lifestyle factors contributing to disease;
3. recall that a small number of disorders are caused by alleles of a single gene, limited to Huntington's disorder and cystic fibrosis;
4. recall the symptoms of Huntington's disorder and cystic fibrosis;
5. understand why a person with one recessive allele will not show the associated characteristic, but is a carrier and can pass the allele to their children;
6. interpret (through family trees or genetic diagrams) the inheritance of a single gene disorder, including the risk of a child being a carrier;
7. understand the implications of testing adults and fetuses for alleles which cause genetic disease, for example:
   - whether or not to have children at all;
   - whether or not a pregnancy should be terminated.
8. understand the implications of testing embryos for embryo selection **(pre-implantation genetic diagnosis)**;
9. **understand the implications of the use of genetic testing by others, (for example for genetic screening programmes, by employers and insurance companies.);**
10. understand that gene therapy may make it possible to treat certain genetic diseases;
11. in the context of genetic testing (when provided with additional information about the reliability and risks of genetic tests) or gene therapy be able to:
    - distinguish questions which could be addressed using a scientific approach, from questions which could not;
    - say clearly what the issue is;
    - summarise different views that may be held;
    - identify and develop arguments based on the ideas that:
      - the right decision is the one which leads to the best outcome for the majority of people involved;
      - certain actions are never justified because they are unnatural or wrong;
12. **in the context of use of genetic testing by others can:**
    - **distinguish what can be done (technical feasibility), from what should be done (values);**
    - **explain why different courses of action may be taken in different social and environmental contexts.**

MODULE B1: YOU AND YOUR GENES

B1.4 What are stem cells, and why could they be useful in treating some diseases?

1. recall that bacteria, plants and some animals can reproduce asexually to form clones (with identical genes to their parent);
2. understand that any differences between clones are likely to be due only to environmental factors;
3. understand how clones of animals occur:
   - naturally, when cells of an embryo separate (identical twins);
   - **artificially, when the nucleus from an adult body cell is transferred to an empty unfertilised egg cell;**
4. recall that embryonic stem cells are unspecialised cells that can develop into any type of cell;
5. understand that there is the potential to use stem cells to treat some illnesses;
6. recall that the cells of multicellular organisms become specialised during the early development of the organism;
7. in the context of cloning embryos to produce large numbers of stem cells to treat illnesses, can:
   - say clearly what the issue is;
   - summarise different views that may be held;
   - identify and develop arguments based on the ideas that:
     - o the right decision is the one which leads to the best outcome for the majority of people involved;
     - o certain actions are never justified because they are unnatural or wrong.

MODULE C1: AIR QUALITY – OVERVIEW

The quality of air is becoming a major world concern. In this module, candidates explore environmental and health consequences of certain air pollutants, and options for improving air quality in the future. The emphasis is on health issues arising from burning fuels, rather than global issues such as climate change, which is covered in P2, Radiation and life.

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

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

Issues for citizens	Questions that science may help to answer
How do I make sense of data about air pollution?	What chemicals make up air, and which ones are pollutants?
Where do pollutants come from?	What chemical reactions produce air pollutants?
Is air pollution harmful to me or my environment?	What happens to pollutants in the atmosphere?
How can we improve air quality?	What choices can we make personally, locally, nationally or globally to improve air quality?
Science Explanations	**Ideas about Science**
SE 1 Chemicals SE 2 Chemical change	IaS 1 Data and its limitations IaS 2.1, 2.3 – 2.5 Correlation and cause IaS 4.2 The scientific community IaS 6.3 Making decisions about science and technology

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

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

Use of ICT in teaching and learning can include:

- internet to research local air quality data;
- animation to illustrate chemical change during reactions;
- simulation to model effects of local government policy decisions on air quality.

MODULE C1: AIR QUALITY

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

1. recall that the Earth is surrounded by an atmosphere made up mainly of nitrogen, oxygen and argon, plus small amounts of water vapour, carbon dioxide, and other gases;
2. recall that the relative proportions of gases in the atmosphere are about 78% nitrogen, 21% oxygen and 1% argon;
3. recall that human activity adds small amounts of carbon monoxide, nitrogen oxides and sulfur dioxide to the atmosphere;
4. recall that human activity also adds extra carbon dioxide and small particles of solids (e.g. carbon) to the atmosphere;
5. recall that some of these substances, called pollutants, are directly harmful to humans and some are harmful to the environment and so cause harm to humans indirectly;
6. when using their own and given data relating to measured concentrations of atmospheric pollutants, or the composition of the atmosphere:
   - uses data rather than opinion in justifying an explanation;
   - can suggest reasons why a measurement may be inaccurate;
   - can suggest reasons why several measurements of the same quantity may give different results;
   - when asked to evaluate data, makes reference to its reliability (i.e. is it repeatable?);
   - can calculate the mean of a set of repeated measurements;
   - from a set of repeated measurements of a quantity, uses the mean as the best estimate of the true value;
   - can explain why repeating measurements leads to a better estimate of the quantity;
   - can make a sensible suggestion about the range within which the true value of a measured quantity probably lies;
   - **can justify the claim that there is/is not a ‘real difference’ between two measurements of the same quantity;**
   - can identify any outliers in a set of data, and give reasons for including or discarding them.

MODULE C1: AIR QUALITY

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

1. recall that coal is mainly carbon;
2. recall that petrol, diesel fuel and fuel oil are mainly compounds of hydrogen and carbon (hydrocarbons);
3. recall that, when fuels burn, atoms of carbon and/or hydrogen from the fuel combine with atoms of oxygen from the air to produce carbon dioxide and/or water (hydrogen oxide);
4. recall that atoms are rearranged during a chemical reaction;
5. interpret representations of the rearrangement of atoms during a chemical reaction;
6. understand that during the course of a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants;
7. understand that the conservation of atoms during combustion reactions has implications for air quality;
8. recall that the properties of the reactants and products are different;
9. understand how sulfur dioxide is produced if the fuel contains any sulfur;
10. understand how burning fossil fuels in power stations and for transport pollutes the atmosphere with:
    - carbon dioxide and sulfur dioxide,
    - carbon monoxide and particulate carbon (from incomplete burning),
    - nitrogen oxides (from the reaction between atmospheric nitrogen and oxygen at the high temperatures inside engines);
11. relate the formulas for carbon dioxide CO_2, carbon monoxide CO, sulfur dioxide SO_2, nitrogen monoxide NO, nitrogen dioxide NO_2, and water H_2O, to visual representations of their molecules;
12. **recall that nitrogen monoxide NO, is formed during the combustion of fuels in air, and is subsequently oxidised to nitrogen dioxide NO_2 .(NO and NO_2 are jointly referred to as 'NOx');**
13. understand that atmospheric pollutants cannot just disappear, they have to go somewhere:
    - particulate carbon is deposited on surfaces, making them dirty;
    - sulfur dioxide and nitrogen dioxide react with water and oxygen to produce acid rain;
    - carbon dioxide is used by plants in photosynthesis;
    - carbon dioxide dissolves in rain water and in sea water.

ⓘ Candidates are not required to write word or symbol equations.

MODULE C1: AIR QUALITY

C1.3 Is air pollution harmful to me, or to my environment?

1. when given data relating to affect of air quality:
   - can identify the absence of replication as a reason for questioning a scientific claim;
   - **can explain why scientists regard it as important that a scientific claim can be replicated by other scientists;**
   - can identify the outcome and the factors that may affect it;
   - can suggest how an outcome might be affected when a factor is changed;
   - can give an example from everyday life of a correlation between a factor and an outcome;
   - uses the ideas of correlation and cause appropriately when discussing historical events or topical issues in science;
   - **can explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and can give an example to illustrate this;**
   - can suggest factors that might increase the chance of an outcome, but not invariably lead to it;
   - can explain that individual cases do not provide convincing evidence for or against a correlation.

C1.4 What choices can we make personally, locally, nationally or globally to improve air quality?

1. understand how atmospheric pollution caused by power stations which burn fossil fuels can be reduced by:
   - using less electricity;
   - removing sulfur from natural gas and fuel oil;
   - removing sulfur dioxide and particulates (carbon and ash) from the flue gases emitted by coal-burning power stations;
2. understand that the only way of producing less carbon dioxide is to burn less fossil fuels;
3. understand how atmospheric pollution caused by exhaust emissions from motor vehicles can be reduced by:
   - burning less fuel by having more efficient engines;
   - using low sulfur fuels;
   - using catalytic converters, which convert nitrogen monoxide to nitrogen and oxygen and carbon monoxide to carbon dioxide;
   - adjusting the balance between public and private transport;
   - having legal limits to emissions (which are enforced by the use of MOT tests).
4. in the context of emissions of pollutants into the atmosphere:
   - shows awareness that scientific research and applications are subject to official regulations and laws.

MODULE P1: THE EARTH IN THE UNIVERSE – OVERVIEW

Scientific discoveries in the Solar System and beyond continue to inspire popular culture and affect our understanding of our place in the Universe. In this module, candidates learn about the life cycle of a star and its implications for the Sun and Earth. They also explore the scale of the Universe and its past, present and future, and consider whether we are alone or there might be life elsewhere.

Closer to home, candidates consider both long and short term changes in the Earth's crust, and how these changes impact on human life. A theme running through the module is natural disasters: earthquakes, volcanoes and asteroid impact – explaining them, predicting them and coping with or averting them.

Across the whole module, candidates encounter many examples showing relationships between data and explanations. Through these contexts they learn about the way scientists communicate and develop new explanations.

Issues for citizens	Questions that science may help to answer
Is there life elsewhere in the Universe?	What do we know about the Earth and space?
Why do mountains come in chains, in particular places? Can we predict earthquakes, especially those that are likely to cause most damage?	How have the Earth's continents moved, and with what consequences?
Could the human race be destroyed by an asteroid colliding with the Earth? What will happen to the Earth and the Sun?	What is known about stars and galaxies?
What do we know about the Universe? Where do the elements of life come from?	How do scientists develop explanations of the Earth and space?
Science Explanations	**Ideas about Science**
SE 14 a, b The Earth SE 15 The Solar System SE 16 The Universe	IaS 3 Developing explanations IaS 4 The scientific community

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- computer modelling of galaxies in collision;
- processing data on movements of the Earth's lithosphere (to confirm the theory of plate tectonics);
- creating a 3D model of the large-scale structure of the Universe from individual galaxy observations.

Use of ICT in teaching and learning can include:

- animations to illustrate continental drift and movement at tectonic plates margins;
- internet to research particular geohazard.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.1 What do we know about the Earth and Space?

1. recall that rocks provide evidence for changes in the Earth (erosion and sedimentation, fossils, folding, radioactive dating, craters);
2. understand that continents would be worn down to sea level, if mountains were not being continuously formed;
3. understand that the rock processes seen today can account for past changes;
4. understand that the Earth must be older than its oldest rocks, **which are about 4 thousand million years old**;
5. label on a given diagram of the Earth its crust, mantle and core;
6. recall that the solar system was formed over very long periods from clouds of gases and dust in space, **about 5 thousand million years ago**;
7. distinguish between planets, moons, the Sun, comets, asteroids and be aware of their relative sizes and motions;
8. recall that fusion of hydrogen **nuclei** is the source of the Sun's energy;
9. understand that all chemical elements larger than helium were made in earlier stars;
10. discuss the probability and possible consequences of an asteroid colliding with the Earth, including the extinction of the dinosaurs;
11. in relation to the above, or when provided with relevant additional information:
    - can identify statements which are data and statements which are (all or part of) an explanation;
    - can recognise data or observations that are accounted for by (or conflict with) an explanation;
    - can identify imagination and creativity in the development of explanations;
    - can justify accepting or rejecting a proposed explanation on the grounds that it:
        - accounts for observations;
        - **and/or provides an explanation that links things previously thought to be unrelated;**
        - **and/or leads to predictions that are subsequently confirmed.**
12. recall that light travels at a high but finite speed, **300 000 km/s;**
13. understand that the speed of light means distant objects are observed as younger than they are now;
14. recall a light-year is the distance travelled by light in a year;
15. compare the relative ages of the Earth, the Sun and the Universe;
16. compare the relative diameters of the Earth, the Sun and the Milky Way;
17. relate uncertainty in the distance of stars and galaxies to the difficulty of observations.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.2 How have the Earth’s continents moved, and with what consequences?

1. recall Wegener’s theory of continental drift and his evidence for it (geometric fit of continents and their matching fossils, mountain chains, and rocks);
2. understand how Wegener’s theory accounted for mountain building;
3. recall reasons for the rejection of Wegener’s theory by geologists of his time (movement of continents not detectable, Wegener an outsider to the community of geologists, too big an idea from limited evidence, simpler explanations of the same evidence);
4. understand that seafloor spreading is a consequence of movement of the solid mantle;
5. **recall that seafloors spread by about 10 cm a year;**
6. **understand how seafloor spreading produces a pattern in the magnetism recorded in ocean floors, limited to reversals of the Earth’s magnetic field and solidification of molten magma at oceanic ridges;**
7. recall that earthquakes, volcanoes and mountain building generally occur at the edges of tectonic plates;
8. **understand how the movement of tectonic plates causes earthquakes, volcanoes, mountain building and contributes to the rock cycle;**
9. recall some actions that public authorities can take to reduce damage caused by geohazards.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.3 What is known about stars and galaxies?

1. understand that what we know about distant stars and galaxies comes only from the radiation astronomers can detect;
2. understand that distance to stars can be measured using the relative brightness of stars or parallax (qualitative idea only);
3. understand that light pollution interferes with observations of the night sky;
4. recall that the Sun is a star in the Milky Way galaxy;
5. recall that there are thousands of millions of galaxies, each containing thousands of millions of stars, and that all of these make up the Universe;
6. recall that all stars have a life cycle;
7. recall that astronomers have detected planets around some nearby stars;
8. understand that, if even a small proportion of stars have planets, many scientists think that it is likely that life exists elsewhere in the Universe;
9. recall that no evidence of alien life (at present or in the past) has so far been detected;
10. recall that distant galaxies are moving away from us;
11. **relate the distance of galaxies to the speed at which they are moving away; (Hubble's law, but not redshift)**
12. **understand why the motions of galaxies suggests that Space itself is expanding;**
13. recall that the Universe began with a 'big bang' about 14 thousand million years ago;
14. understand why the ultimate fate of the Universe is difficult to predict.

MODULE P1: THE EARTH IN THE UNIVERSE

P1.4 How do scientists develop explanations of the Earth and Space?

1. in relation to movements of the Earth's continents (P1.2) or what is known about stars and galaxies (P1.3), or when provided with relevant additional information:
   - can identify statements which are data and statements which are (all or part of) an explanation;
   - can recognise data and observations that are accounted for by, (or conflict with), a given explanation;
   - can identify imagination and creativity in the development of an explanation;
   - can describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists;
   - can recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well established ones;
2. in relation to movements of the Earth's continents (P1.2), or when provided with relevant additional information:
   - can justify accepting or rejecting a proposed explanation on the grounds that it:
     - accounts for observations;
     - **and/or provides an explanation that links things previously thought to be unrelated;**
     - **and/or leads to predictions that are subsequently confirmed;**
   - can draw valid conclusions about the implications of given data for a given explanation, e.g.
     - recognises that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct**;
     - recognises that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong, **and that this may decrease our confidence in the explanation**;
   - can identify a scientific question for which there is not yet an agreed answer, **and suggest a reason why**;
   - can identify absence of replication as a reason for questioning a scientific claim;
   - **can explain why scientists regard it as important that a scientific claim can be replicated by other scientists;**
   - can suggest plausible reasons why scientists involved in a scientific event or issue disagree(d);
   - **can suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it.**

MODULE B2: KEEPING HEALTHY – OVERVIEW

Keeping healthy involves maintaining a healthy lifestyle, practicing good hygiene to avoid infection, and using medication when necessary. This module illustrates these principles through prevention of infectious diseases and heart disease.

Candidates learn about the immune system, and how vaccines work. They consider the causes of heart disease, and how individuals can minimise this risk. The module explores how new drugs are developed, including the stages of testing for safety and efficiency. Candidates also learn about the increase of 'superbugs', and how correct use of antibiotics can help to reduce their prevalence.

In the contexts of vaccination policy and the study of clinical trials, candidates explore ideas of correlation and cause, and how peer review by the scientific community strengthens the reliability of scientific claims. They also consider particular ethical issues arising in modern medicine, for example, the right of individual choice versus social policy, illustrated through vaccination policy.

Issues for citizens	Questions that science may help to answer
Why do I catch some diseases but not others?	How do our bodies resist infection?
Why are we encouraged to have vaccinations?	What are vaccines, and how do they work?
Why won't the doctor give me an antibiotic when I catch a cold? What are 'superbugs'?	What are antibiotics, and why can they become less effective?
How do drug companies make sure a new drug is as safe as possible?	How are new drugs developed and tested?
How can my lifestyle affect my health?	What factors increase the risk of heart disease?
Science Explanations	**Ideas about Science**
SE 7c Maintenance of life SE 10 The germ theory of disease	IaS 2.3–2.7 Correlation and cause IaS 4.1–4.2 Scientific community IaS 6.5–6.7 Making decisions about science and technology

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- storing and displaying magnified images from microscopes;
- storing and displaying data from studies of factors which may, or may not, cause disease.

Use of ICT in teaching and learning can include:

- animation to illustrate immune response;
- animation to illustrate development of antibiotic-resistant bacterial populations;
- video clips to illustrate smallpox vaccination programmes;
- video clips of interviews with patients who have heart disease;
- video clips illustrating how epidemiological research is carried out and reported.

MODULE B2: KEEPING HEALTHY

B2.1 How do our bodies resist infection?

1. recall that there are natural barriers to reduce the risk of harmful microorganisms entering the body (limited to the skin, chemicals in tears, sweat and stomach acid);
2. understand that in suitable conditions (such as inside the body) these microorganisms can reproduce rapidly;
3. understand that symptoms of a disease are caused by damage done to cells by the microorganisms or the poisons (toxins) they produce;
4. recall that our bodies have immune systems to defend themselves against the invading microorganisms;
5. understand that white blood cells can destroy microorganisms by engulfing and digesting them, or by producing antibodies;
6. understand that a different antibody is needed to recognise each different type of microorganism;
7. understand that once the body has made the antibody to recognise a particular microorganism it can make that antibody again very quickly, therefore protecting against that particular microorganism.

B2.2 What are vaccines and how do they work?

1. understand that microorganisms may enter the body and cause illness before the immune system can destroy them;
2. understand that vaccinations provide protection from microorganisms by establishing antibodies before infection;
3. recall that a vaccination contains a usually safe form of a disease-causing microorganism;
4. understand that vaccination can never be completely safe, since individuals have varying degrees of side-effects from a vaccine;
5. **understand why, to prevent epidemics of infectious diseases, it is necessary to vaccinate a high percentage of a population;**
6. understand that there is a conflict between a person's right to decide about vaccination for themselves or their children, and what is of benefit to society as a whole;
7. understand that new vaccines against influenza have to be developed regularly because the virus changes very quickly;
8. **understand that it is difficult to develop an effective vaccine against the HIV virus (which causes AIDS) because the virus damages the immune system and has a high mutation rate;**
9. With respect to vaccination policy can:
   - say clearly what the issue is;
   - summarise different views that may be held;
   - **distinguish what can be done (technical feasibility) from what should be done (values);**
   - **explain why different courses of action may be taken in different social and economic contexts;**
   - identify, and develop, arguments based on the ideas that:
     - the right decision is the one which leads to the best outcome for the majority of people involved;
     - certain actions are never justified because they are unnatural or wrong.

MODULE B2: KEEPING HEALTHY

B2.3 What are antibiotics, and why can they become less effective? How are new drugs developed and tested?

1. recall that we can kill bacteria and fungi, but not viruses, using chemicals called antibiotics;
2. recall that over a period of time bacteria and fungi may become resistant to antibiotics;
3. **understand that random changes (mutations) in the genes of these microorganisms sometimes lead to varieties which are less affected by the antibiotic;**
4. understand that to reduce antibiotic resistance we should only use antibiotics when necessary and always complete the course;
5. recall that new drugs are first tested for safety and effectiveness using human cells grown in the laboratory and animals;
6. recall that human trials may then be carried out:
    - on healthy volunteers to test for safety;
    - on people with the illness to test for safety and effectiveness.
7. **describe and explain the use of 'blind' or 'double-blind' human trials in the testing of a new medical treatment;**
8. **understand why placebos are not commonly used in human trials.**

MODULE B2: KEEPING HEALTHY

B2.4 What factors increase the risk of heart disease?

1. understand why heart muscle cells need their own blood supply;
2. explain how the structure of arteries and veins is related to their function;
3. understand how fatty deposits in the blood vessels supplying the heart muscle can produce a ‘heart attack’;
4. recall that heart disease is usually caused by lifestyle factors and/or genetic factors, not microorganisms;
5. recall that these lifestyle factors include poor diet, stress, cigarette smoking, excessive alcohol intake;
6. understand that heart disease is more common in the UK than in non-industrialised countries;
7. recall that regular moderate exercise reduces the risk of developing heart disease;
8. in the context of how lifestyle factors that can increase the risk of heart disease are identified, via epidemiological studies:
    - can give an example from everyday life of a correlation between a factor and an outcome;
    - uses the ideas of correlation and cause appropriately;
    - **can explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this;**
    - can suggest factors that might increase the chance of an outcome but not invariably lead to it;
    - can explain that individual cases do not provide convincing evidence for or against a correlation;
    - can evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched;
    - **can use data to develop an argument that a factor does/does not increase the chance of an outcome;**
    - **can identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link;**
    - can describe in broad outline the ‘peer review’ process, in which new scientific claims are evaluated by other scientists;
    - can recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well-established ones;
    - can identify absence of replication as a reason for questioning a scientific claim;
    - **can explain why scientists regard it as important that a scientific claim can be replicated by other scientists.**

MODULE C2: MATERIAL CHOICES – OVERVIEW

Our way of life depends on a wide range of materials produced from natural resources. This module considers how measurements of the properties of materials can inform the choice of material for a particular purpose. By taking their own measurements, candidates explore some of the issues which arise when trying to establish accurate and meaningful data.

Key ideas in this module are illustrated through polymers. Candidates learn how the particles (e.g. molecules) that make up a material fit together and how strongly they hang on to each other, providing an explanation of the properties of materials. This provides an example of a scientific explanation which makes sense of a wide range of observations.

Through conducting a life cycle assessment, candidates learn that in selecting a product for a particular job we should assess not only its 'fitness for purpose' but also the total effects of using the materials that make up the product over its complete life cycle, from its production from raw materials to its disposal.

Issues for citizens	Questions that science may help to answer
How can we pick a suitable material for a particular product or task?	What different properties do different materials have?
	Why is crude oil important as a source of new materials such as plastics and fibres?
	Why does it help to know about the molecular structure of materials such as plastics and fibres?
When buying a product, what else should we consider besides its cost and how well is does its job?	How should we manage the wastes that arise from our use of materials?
Science Explanations	**Ideas about Science**
SE 3 Materials and their properties	IaS 1 Data and its limitations IaS 2.2 Correlation and cause IaS 6.1–6.4, 6.7 Making decisions about science and technology

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, logging data, storing it and displaying it in a variety of formats for analysis and evaluation

Use of ICT in teaching and learning can include:

- spreadsheet to record and display measurements of the properties of materials;
- video clips to illustrate main stages from extraction of oil to production of synthetic plastic or fibre;
- still images and diagrams to create presentations to show how the properties of a material depend on its molecular structure;
- simulation to explore the impact of choices made during the life cycle of a product;
- internet to explore case studies of the sustainable use of materials.

MODULE C2: MATERIAL CHOICES

C2.1 What different properties do different materials have?

1. interpret information about how solid materials can differ with respect to properties such as:
   - melting points;
   - strength (in tension or compression);
   - stiffness;
   - hardness;
   - density;
2. relate properties to the uses of materials such as plastics, rubbers and fibres;
3. relate the effectiveness and durability of a product to the materials used to make it;
4. interpret information about the properties of materials such as plastics, rubbers and fibres to assess the suitability of these materials for particular purposes;
5. with respect to data from the measurement of properties of materials:
   - uses data rather than opinion in justifying an explanation;
   - can suggest reasons why a measurement may be inaccurate;
   - can suggest reasons why several measurements of the same quantity may give different results;
   - when asked to evaluate data, makes reference to its reliability (i.e. is it repeatable?);
   - can calculate the mean of a set of repeated measurements;
   - from a set of repeated measurements of a quantity, uses the mean as the best estimate of the true value;
   - can explain why repeating measurements leads to a better estimate of the quantity;
   - can make a sensible suggestion about the range within which the true value of a measured quantity probably lies;
   - **can justify the claim that there is/is not a 'real difference' between two measurements of the same quantity;**
   - can identify any outliers in a set of data, and give reasons for including or discarding them;
   - can identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive feature, or the fact that they are not as a design flaw;
   - **can explain why it is necessary to control all factors thought likely to affect the outcome other than the one being investigated.**

MODULE C2: MATERIAL CHOICES

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

1. recall that the materials we use are chemicals or mixtures of chemicals, and state examples;
2. recall that materials can be obtained or made from living things, and give examples such as cotton, paper, silk and wool;
3. understand that there are synthetic materials which are alternatives to materials from living things;
4. interpret representations of rearrangements of atoms during a chemical reaction;
5. understand that during the course of a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants;
6. recall that crude oil consists mainly of hydrocarbons which are chain molecules of varying lengths made from carbon and hydrogen atoms only;
7. recall that only a small percentage of crude oil is used for chemical synthesis;
8. recall that the petrochemical industry refines crude oil to produce fuels, lubricants and the raw materials for chemical synthesis;
9. understand that some small molecules can join together to make very long molecules called polymers and that the process is called polymerisation;
10. understand that by using polymerisation, a wide range of materials may be produced;
11. recall an example of a material that has replaced an older material because of its superior properties.

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

1. understand how the properties of solid materials depend on how the particles they are made from are arranged and held together;
2. relate the strength of the forces between the particles to the amount of energy needed for them to break out of the solid structure, and to the temperature at which the solid melts;
3. understand how modifications in polymers produce changes to their properties (see C2.1), to include modifications such as:
   - increased chain length;
   - cross-linking;
   - the use of plasticizers;
   - **increased crystallinity.**

MODULE C2: MATERIAL CHOICES

C2.4 When buying a product, what else should we consider besides its cost and how well is does its job? How should we manage the wastes that arise from our use of materials?

1. recall the key features of a life cycle assessment (LCA) including:
   - the main requirements for energy input;
   - the environmental impact and sustainability of making the material from natural resources;
   - the environmental impact of making the product from the material;
   - the environmental impact of using the product;
   - the environmental impact of disposing of the product by incineration, landfill or recycling;
2. **understand how the outcomes of a Life Cycle Assessment (LCA) for a particular material will depend on which product is made from the material;**
3. when given appropriate information relating to a Life Cycle Assessment (LCA), compare and evaluate:
   - the use of different materials for the same job;
   - the use of the same material for different jobs;
4. in the context of a Life Cycle Assessment:
   - can distinguish questions which could be addressed using a scientific approach, from questions which could not;
   - can identify the groups affected and the main benefits and costs of a course of action for each group;
   - can explain the idea of sustainable development, and apply it to specific situations;
   - shows awareness that scientific research and applications are subject to official regulations and laws;
   - **can distinguish between what can be done (technical feasibility) and what should be done (values);**
   - **can explain why different courses of action may be taken in different social and economic contexts.**

MODULE P2: RADIATION AND LIFE – OVERVIEW

The possible health risks of radiation, both in nature and from technological devices, are becoming of increasing concern. In some cases, misunderstanding the term 'radiation' generates unnecessary alarm. By considering the need to protect the skin from sunlight, candidates are introduced to a general model of radiation travelling from the source to a receiver. They learn about the electromagnetic spectrum and the harmful effects of some radiation. Through an investigation of evidence, concerning the possibly harmful effects of low intensity microwave radiation from devices such as mobile phones, candidates learn to evaluate reported health studies and interpret levels of risk. The greenhouse effect and photosynthesis illustrate how radiation from the Sun is vital to life, whilst the ozone layer is shown to be a natural protection from harmful radiation. Finally, candidates study evidence of global warming and its relationship to the carbon cycle. Possible consequences and preventative actions are explored.

Issues for citizens	Questions that science may help to answer
What is radiation?	What types of electromagnetic radiation are there? What can happen when radiation hits an object?
Is it safe to use mobile 'phones? Is it safe to sunbathe?	Which types of electromagnetic radiation harm living tissues and why? What ideas about risk do citizens and scientists use?
Are there any benefits from radiation?	How does electromagnetic radiation make life on Earth possible?
What is global warming, and what can be done to prevent or reduce it?	What is the evidence for global warming, why might it be occurring, and how serious a threat is it?
Science Explanations	**Ideas about Science**
SE 12 Radiation SE 5a The chemical cycles of life SE 14c The Earth	IaS 2.1, 2.3–2.7 Correlation and cause IaS 5 Risk

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- computer climate modelling;
- displaying data on stratospheric ozone concentrations as a false colour map.

Use of ICT in teaching and learning can include:

- PowerPoint slides to illustrate evidence of climate change;
- video clip to illustrate infrared imaging;
- animation to model Sun's radiation and greenhouse effect;
- animation to model effect of carbon dioxide levels on global temperature;
- computer climate models.

MODULE P2: RADIATION AND LIFE

P2.1 What types of electromagnetic radiation are there? What happens when radiation hits an object?

1. recall that light is one of a family of radiations, the electromagnetic spectrum;
2. understand that a beam of electromagnetic radiation delivers energy in ‘packets’ called photons;
3. list the electromagnetic radiations in order of the energy delivered by each photon – radio waves, microwaves, infrared, $^{\text{red}}$ light $^{\text{violet}}$, ultraviolet, X-rays, gamma rays;
4. interpret a situation in which one object affects another some distance away in terms of the general model of electromagnetic radiation:
    - one object (a source) emits radiation;
    - the radiation travels from the source and can be reflected, transmitted or absorbed by materials on its journey;
    - radiation may be absorbed by another object (a detector) some distance away;
5. understand that the energy deposited by a beam of electromagnetic radiation depends on both the number of photons arriving and the energy that each photon delivers;
6. recall that the intensity of electromagnetic radiation is the energy arriving at a surface each second;
7. understand that the intensity of a beam of electromagnetic radiation decreases with distance **and be able to explain why**;
8. understand that ionising radiation is able to break molecules into bits (called ions), **which can then take part in other chemical reactions**;
9. recall that ionising radiation includes:
    - ultraviolet radiation;
    - X-rays;
    - gamma rays;
10. understand that microwaves heat materials containing particles that the microwaves can vibrate;
11. relate the heating effect of non-ionising radiation to its intensity **and duration**;
12. recall an example of the way in which each of infrared, microwaves and radio waves are used for transmitting information.

MODULE P2: RADIATION AND LIFE

P2.2 Which types of electromagnetic radiation harm living tissue and why?

1. recall that the heating effect of absorbed radiation can damage living cells;
2. recall that low intensity microwave radiation, for example from mobile phone hand sets and masts, may be a health risk, but this is disputed;
3. recall that ionising radiation can damage living cells;
4. recall examples of how exposure to different amounts of ionising radiation can affect living cells;
5. recall that the metal cases and door screens of microwave ovens protect users from the radiation;
6. recall that physical barriers protect people from ionising radiation, for example, sun-screens and clothing can be used to absorb most of the ultraviolet radiation from the Sun.

P2.3 How does electromagnetic radiation make life on Earth possible?

1. recall that the Earth is surrounded by an atmosphere which allows light radiated from the Sun to pass through;
2. recall that this radiation:
   - provides the energy for photosynthesis;
   - warms the Earth's surface;
3. recall that photosynthesis removes carbon dioxide from the atmosphere and adds oxygen, and that this reverses the effect of respiration;
4. understand that the Earth emits electromagnetic radiation that is absorbed by some gases in the atmosphere, so keeping the Earth warmer than it would otherwise be. This is called the greenhouse effect;
5. understand that the ozone layer absorbs ultraviolet radiation, **producing reversible chemical changes in that part of the atmosphere**;
6. understand that the ozone layer protects living organisms, especially animals, from the harmful effects of ultraviolet radiation.

MODULE P2: RADIATION AND LIFE

P2.4 What is the evidence for global warming, why might it be occurring, and how serious a threat is it?

1. recall that one of the greenhouse gases in the Earth's atmosphere is carbon dioxide, present in small amounts;
2. **recall that other greenhouse gases include methane, present in trace amounts, and water vapour;**
3. interpret simple diagrams representing the carbon cycle;
4. use the carbon cycle to explain:
   - why for thousands of years the amount of carbon dioxide in the Earth's atmosphere was approximately constant;
   - how decomposers play an important part in the recycling of carbon;
   - that during the past two hundred years, the amount of carbon dioxide in the atmosphere has been steadily rising;
   - that the rise in atmospheric carbon dioxide is largely the result of:
     - burning increased amounts of fossil fuels as an energy source;
     - burning forests to clear land;
5. **understand that computer climate models provide evidence that human activities are causing global warming;**
6. understand that global warming could result in:
   - climate change and how this could make it impossible to continue growing some food crops in particular regions;
   - extreme weather conditions in some regions;
   - rising sea levels due to melting continental ice and expansion of water in the oceans, which would cause flooding of low-lying land.

MODULE P2: RADIATION AND LIFE

P2.5 What ideas do citizens and scientists have about risk?

1. when provided with necessary additional information about alleged health risks due to radiation (P2.2) or global warming (P2.4) can:
   - identify examples of risk which arise from new scientific or technological advances;
   - suggest ways of reducing specific risks;
   - interpret and discuss information on the size of risks, presented in different ways;
   - **discuss a given risk, taking account of both the chance of it occurring and the consequences if it did;**
   - **identify, or propose, an argument based on the precautionary principle;**
   - use the ideas of correlation and cause appropriately when discussing historical events or topical issues in science;
   - **explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this;**
   - suggest factors that might increase the chance of an outcome, but not invariably lead to it;
   - explain that individual cases do not provide convincing evidence for or against a correlation;
   - **use data to develop an argument that a factor does/does not increase the chance of an outcome;**
   - **identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link.**

2. when provided with necessary additional information about alleged health risks due to radiation emitted from technological devices, or ultraviolet radiation from the Sun (P2.2), can:
   - explain why it is impossible for anything to be completely safe;
   - suggest benefits of activities with known risk;
   - offer reasons for peoples willingness (or reluctance) to accept the risk of a given activity;
   - discuss personal and social choices in terms of a balance of risk and benefit;
   - **distinguish between actual and perceived risk, when discussing personal and social choices;**
   - **suggest reasons for given examples of differences between actual and perceived risk;**
   - **explain what the ALARA (as low as reasonably achievable) principle means, and how it applies in a given situation;**
   - identify the outcome and the factors that may affect it;
   - suggest how an outcome might be affected when a factor is changed;
   - give an example from everyday life of a correlation between a factor and an outcome;
   - evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched.

MODULE B3: LIFE ON EARTH – OVERVIEW

Theories for the origin of life on Earth often feature in the media and popular culture. Candidates consider different explanations for life on Earth, and its subsequent evolution. These contexts illustrate how explanations arise and become accepted, and the role of the scientific community in this process. Natural selection is introduced as the mechanism for evolution.

Evolution of multicellular organisms has led to complex body communication systems, both nervous and hormonal. Through the context of human evolution, candidates consider implications of data for given theories.

Living organisms are dependent on their environment and each other for survival. Biodiversity is recognised as an important natural resource, which is increasingly threatened by human activity. Candidates consider causes of extinction, and whether extinctions should be a global concern.

Issues for citizens	Questions that science may help to answer
Where did life on Earth come from?	How did life on Earth begin and evolve?
Is evolution 'just a theory'?	How have scientists developed explanations of evolution?
How do some species survive? Why do some species become extinct, and does it matter?	How did humans evolve? How are our nervous systems organised? What is the importance of biodiversity

Science Explanations	Ideas about Science
SE 4b,c The interdependence of living things SE 7e Maintenance of life SE 9 The theory of evolution by natural selection	IaS 3 Developing explanations IaS 4.3–4.4 The scientific community

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- recording and displaying the results of DNA analysis;
- monitoring and recording human and animal behaviour.

Use of ICT in teaching and learning can include:

- video clips to illustrate varied ecosystems;
- internet to research endangered plant or animal;
- presentation to show how understanding of evolution develops as new evidence is discovered.

MODULE B3: LIFE ON EARTH

B3.1 How did life on Earth begin and evolve?

1. recall that the many different species of living things on Earth (and many species that are now extinct) evolved from very simple living things;
2. recall that life on Earth began about 3500 million years ago;
3. understand that evidence for evolution is provided by fossils and from analysis of similarities and differences in DNA of organisms;
4. recall that the first living things developed from molecules that could copy themselves;
5. understand that these molecules were produced by the conditions on Earth at that time, or may have come from elsewhere;
6. recall that evolution happens due to natural selection;
7. understand the process of natural selection in terms of variation, competition, increased chance of survival and reproduction, and increased number of individuals displaying certain characteristics in later generations;
8. understand that variation is caused by both environment and genes, but only genetic variation can be passed on;
9. explain the difference between natural selection and selective breeding;
10. **interpret data on changes in a species in terms of natural selection;**
11. **recall that changes can occur in genes (mutations);**
12. **understand that mutated genes in sex cells can be passed on to offspring and may occasionally produce new characteristics;**
13. **understand that the combined effect of mutations, environmental changes and natural selection can produce new species;**
14. understand that if the conditions on Earth had, at any stage, been different from what they actually were, evolution by natural selection could have produced different results.

MODULE B3: LIFE ON EARTH

B3.2 How have scientists developed explanations of evolution?

1. when provided with information about alternative views on the origin of life on Earth, or the evolutionary process:
   - can identify statements which are data and statements which are (all or part of) an explanation;
   - can recognise data or observations that are accounted for by (or conflict with) an explanation;
   - can identify imagination and creativity in the development of an explanation;
   - can justify accepting or rejecting a proposed explanation on the grounds that it:
     - accounts for observations;
     - **and/or provides an explanation that links things previously thought to be unrelated;**
   - can identify a scientific question for which there is not yet an agreed answer **and suggest a reason why;**
   - can suggest plausible reasons why scientists involved in a scientific event or issue disagree(d);
   - **can suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it.**

MODULE B3: LIFE ON EARTH

B3.3 How did humans evolve? How are our nervous systems organised?

1. recall that the evolution of multicellular organisms has led to nervous and hormonal communication systems;
2. recall that sensor (receptor) cells detect stimuli and effector cells produce responses to stimuli;
3. recall that nervous systems are made up of nerve cells (neurones) linking receptor cells (e.g. in eyes, ears and skin) to effector cells (in muscles/glands);
4. recall that in humans and other vertebrates the nervous system is coordinated by a central nervous system (spinal cord and brain);
5. understand that nervous systems use electrical impulses for fast, short-lived responses;
6. recall that hormones are chemicals which travel in the blood and bring about slower, longer-lasting responses;
7. recall two examples, in humans, of each of nervous and hormonal communication;
8. **recall that nervous and hormonal communication systems are involved in maintaining a constant internal environment (homeostasis);**
9. recall that the evolution of a larger brain gave some early humans a better chance of survival;
10. understand human evolution in terms of a common ancestor, divergence of hominid species, extinction of all but one of these species;
11. when provided with additional information about human evolution:
    - can draw valid conclusions about the implications of given data for a given theory, for example:
        - o recognises that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct**;
        - o recognises that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong, **and that this may decrease our confidence in the explanation**.

MODULE B3: LIFE ON EARTH

B3.4 Why do some species become extinct, and does it matter? What is the importance of biodiversity?

1. understand that living organisms are dependent on the environment and other species for their survival;
2. understand that there is competition for resources between different species of animals or plants in the same habitat;
3. relate changes affecting one species in a food web to the impact on other species that are part of the same food web;
4. understand that a rapid change in the environment may cause a species to become extinct, for example, if:
   - the environmental conditions change;
   - a new species that is a competitor, predator or disease organism of that species is introduced;
   - another organism in its food web becomes extinct;
5. understand that species have become extinct (or are in danger of becoming extinct) and that this is likely to be due to human activity;
6. recall two examples of modern extinctions caused by direct human activity, and two caused by indirect human activity;
7. explain why maintaining biodiversity is an important part of using the environment in a sustainable way;
8. understand that biodiversity may be important for the future development of food crops and medicines.

MODULE C3: FOOD MATTERS – OVERVIEW

This module follows the commercial 'food chain' from farm to plate. Intensive and organic farmers use different methods to maintain soil fertility by recycling chemicals. Farmers also use a range of techniques to combat loss of crop yields by competition from weeds, or attack by pests and diseases.

There may be harmful or toxic chemicals in the food we eat. Some occur naturally. Some are deliberate additives. The added chemicals may be to preserve foods or to improve their colour, texture and flavour. These chemicals need not be harmful in small amounts. Their effects depend on how much we eat. To determine the safe levels of chemicals in food it is necessary to carry out a risk assessment. Regulators ensure that food does not contain any chemicals known to be unsafe.

Our bodies digest the food we eat. Digestion breaks down natural polymers such as starch and protein. The smaller molecules produced can be absorbed into the bloodstream. Some processed foods contain a high level of sugar which enters the bloodstream quickly. Insulin is available to treat people with diabetes who cannot control blood sugar levels normally.

Issues for citizens	Questions that science may help to answer
Is organic food better for us?	What is the difference between intensive and organic farming?
What are food additives, and why are they used?	Why are chemicals deliberately added to food?
Are food additives safe to eat?	How can we make sure that our food does not contain chemicals that may be harmful to health?
Why can it be harmful to eat too much sugary food?	Why does what we eat affect our health?
Science Explanations	**Ideas about Science**
SE 5b,c The chemical cycles of life SE 7a,d Maintenance of life	IaS 5.1–5.5 Risk IaS 6.1–6.3, 6.7 Making decisions about science and technology

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, disseminating scientific findings to the public in forms which allow individuals to make decisions about the issues related to food safety.

Use of ICT in teaching and learning can include:

- internet to research particular food additives;
- modelling software to display small and large biological molecules;
- animation to illustrate key stages in the nitrogen cycle.

MODULE C3: FOOD MATTERS

C3.1 What is the difference between intensive and organic farming?

1. recall that many chemicals in living things are natural polymers (limited to carbohydrates and proteins);
2. recall that cellulose, starch and sugars are carbohydrates which consist of carbon, hydrogen and oxygen;
3. recall that amino acids and proteins consist mainly of carbon, hydrogen, oxygen and nitrogen;
4. understand that there is continual cycling of elements through consumption of living organisms and decay;
5. **describe the main stages of the nitrogen cycle;**
6. understand that where crops are harvested, elements such as nitrogen, **potassium and phosphorus**, are lost from the soil so that the land becomes less fertile unless these elements are replaced;
7. recall and explain the methods used by organic and intensive farmers to maintain the fertility of soils used to grow crops;
8. understand that yields from crops may be reduced by pests and disease;
9. understand that organic and intensive farmers use different methods to protect crops against pests and diseases, and that these can have different effects on the environment;
10. understand that farmers have to follow the UK national standards if they want to claim that their products are organic;
11. when provided with information about the methods used in farming:
    - can identify the groups affected and the main benefits and costs of a course of action for each group;
    - can explain the idea of sustainable development, and apply it to specific situations;
    - show awareness that scientific research and applications are subject to official regulations and laws;
    - **can distinguish between what can be done (technical feasibility) from what should be done (values);**
    - **can explain why different courses of action may be taken in different social and economic contexts.**

MODULE C3: FOOD MATTERS

C3.2 Why are chemicals deliberately added to food?

1. recall that food colours can be used to make processed food look more attractive;
2. recall that flavourings enhance the taste of food;
3. understand that artificial sweeteners help to reduce the amount of sugar in processed foods and drinks;
4. recall that emulsifiers and stabilisers help to mix ingredients together that would normally separate, such as oil and water;
5. understand that preservatives help to keep food safe for longer by preventing the growth of harmful microbes;
6. understand that antioxidants are added to foods containing fats or oils to prevent them deteriorating by reaction with oxygen in the air;
7. understand that additives with an E number have passed a safety test and been approved for use in the UK and the rest of the EU;
8. understand that there are health concerns about the use of some additives.

ⓘ Understanding of how emulsifiers and stabilisers function is not required.

MODULE C3: FOOD MATTERS

C3.3 How can we make sure that our food does not contain chemicals that may be harmful to health?

1. recall examples of natural chemicals in plants which may be toxic, cause harm if not cooked properly, or may give rise to allergies in some people (for example, poisonous mushrooms, uncooked cassava, gluten in wheat, peanut allergy);
2. recall an example of a harmful chemical in food, produced by moulds that contaminate crops during storage (for example aflatoxin in nuts and cereals);
3. understand that chemicals used in farming such as pesticides and herbicides may remain in the products we eat;
4. understand that harmful chemicals may form during food processing and cooking;
5. understand the steps that people can take to reduce their exposure to harmful chemicals;
6. understand how food labelling can help consumers decide which products to buy;
7. understand the role of the scientific advisory committees which carry out risk assessments to determine the safe levels of chemicals in food;
8. understand the role of the Food Standards Agency as an independent food safety watchdog set up by an Act of Parliament to protect the public's health and consumer interests in relation to food;
9. in the context of stages in the 'food chain':
    - show awareness that scientific research and applications are subject to official actions and laws;
    - can explain why it is impossible for anything to be completely safe;
    - can identify examples of risk which arise from new scientific or technological advances;
    - can suggest ways of reducing specific risks;
    - can interpret and discuss information on the size of risks, presented in different ways;
    - **can identify, or propose, an argument based on the precautionary principle.**

MODULE C3: FOOD MATTERS

C3.4 Why does what we eat affect our health?

1. understand that digestion breaks down natural polymers to smaller, soluble compounds that are absorbed and transported in the blood (illustrated by the breakdown of starch to glucose sugar and proteins to amino acids);
2. recall that cells grow by building up amino acids from the blood into new proteins;
3. recall that these parts of the body consist mainly of protein: muscle, tendons, skin, hair, haemoglobin in blood;
4. recall that excess amino acids are broken down in the liver to form urea, which is excreted by the kidneys in urine;
5. understand that high levels of sugar, common in some processed foods, are quickly absorbed into the blood stream, causing a rapid rise in the blood sugar level;
6. recall that there are two types of diabetes (type 1 and type 2), and that it is particularly late-onset diabetes (type 2) which is more likely to arise because of poor diet;
7. understand that obesity is one of the risk factors for type 2 diabetes;
8. understand that type 1 diabetes arises when the pancreas stops producing enough of the hormone, insulin; but that type 2 diabetes develops when the body no longer responds to its own insulin or does not make enough insulin;
9. recall that type 1 diabetes is controlled by insulin injections and that type 2 diabetes can be controlled by diet and exercise;
10. In the context of diet and health:
    - **can discuss a given risk, taking account of both the chance of it occurring and the consequences if it did;**
    - can suggest benefits of activities that have a known risk;
    - can offer reasons for people’s willingness (or reluctance) to accept the risk of a given activity;
    - can discuss personal and social choices in terms of a balance of risk and benefit.

MODULE P3: RADIOACTIVE MATERIALS – OVERVIEW

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

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

The UK Government may soon consult with the public about building new nuclear power stations. A key argument is that generating electricity from nuclear fission does not produce carbon dioxide. On the other hand, there is still no solution to the long-term problem of disposing of nuclear wastes. Renewable energy sources may not generate sufficient electricity to replace existing nuclear stations when these reach the end of their lifetimes.

Candidates consider different ways that electricity could be generated, and different ways that nuclear wastes could be disposed of. These case studies illustrate that public decisions must be made by weighing up benefits against costs. Factors to consider include both technical feasibility and likely social and environment impact, now and in the future.

Issues for citizens	Questions that science may help to answer
What does ‘radioactive’ mean?	Why are some materials radioactive?
If radiation from radioactive materials is dangerous, how can it help to cure cancer?	What are the health risks from radioactive materials? How can radioactive materials be used and handled safely, including wastes?
Do we need nuclear power?	How can electricity be generated? What can be done with nuclear waste?
Science Explanations	**Ideas about Science**
SE 11a,b,e Energy sources and uses SE 13 Radioactivity	IaS 5 Risk IaS 6.1–6.3, 6.7 Making decisions about science and technology

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

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

Use of ICT in teaching and learning can include:

- datalogging to show decay of protactinium;
- animation to illustrate atomic structure and decay;
- video clips to illustrate key ideas of risk in context of radioactive materials;
- animation to illustrate key processes in power stations.

MODULE P3: RADIOACTIVE MATERIALS

P3.1 Why are some materials radioactive?

1. recall that some elements emit ionising radiation all the time and are called radioactive;
2. understand that radioactive elements are naturally found in the environment, emitting background radiation;
3. recognise, in given text, the terms electron, proton, neutron and nucleus;
4. **understand that an atom has a nucleus, made of protons and neutrons;**
5. **understand that every atom of any element has the same number of protons but the number of neutrons may differ;**
6. understand that the behaviour of radioactive materials cannot be changed by chemical or physical processes;
7. recall three types of ionising radiation (alpha, beta and gamma) emitted by radioactive materials;
8. recall the penetration properties of each type of radiation;
9. **describe radioactive materials in terms of the instability of the nucleus, radiation emitted and the element left behind;**
10. understand that, over time, the activity of radioactive sources decreases;
11. understand the meaning of the term half-life;
12. understand that radioactive elements have a wide range of half-life values;
13. **carry out simple calculations involving half-life.**

MODULE P3: RADIOACTIVE MATERIALS

P3.2 How can radioactive materials be used and handled safely, including wastes?

1. understand that ionising radiation can damage living cells;
2. understand that ionising radiation is able to break molecules into bits (called ions), **which can then take part in other chemical reactions;**
3. understand that when ionising radiation strikes living cells these may be killed or may become cancerous;
4. recall how ionising radiation can be used to:
   - treat cancer;
   - sterilise surgical instruments;
   - sterilise food;
5. recall that radiation dose (in sievert) (based on both amount and type of radiation) is a measure of the possible harm done to your body;
6. interpret given data on risk related to radiation dose;
7. understand that radioactive materials expose people to risk by irradiation and contamination;
8. understand that we are irradiated and contaminated all the time and name some sources of this background radiation;
9. relate ideas about half life and background radiation to the time taken for a radioactive source to become safe;
10. recall categories of people who are regularly exposed to risk of radiation and that their exposure is carefully monitored.

MODULE P3: RADIOACTIVE MATERIALS

P3.3 How can electricity be generated? What can be done with nuclear wastes?

1. understand why electricity is called a secondary energy source;
2. understand that electricity is convenient because it is easily transmitted over distances and can be used in many ways;
3. label a block diagram showing the basic steps by which electricity is generated;
4. interpret a Sankey diagram of electricity generation and distribution to include the efficiency of energy transfers;
5. recall two examples to show that we can use renewable energy sources instead of fuels to generate electricity;
6. recall that power stations which burn carbon fuels will produce carbon dioxide;
7. understand that a nuclear fuel is one where energy is released from changes in the nucleus;
8. **know that in nuclear fission a neutron splits a large and unstable nucleus (limited to uranium) into two smaller parts, roughly equal in size, releasing more neutrons;**
9. **compare the amount of energy released during nuclear fission with that released in a chemical reaction;**
10. **understand how the nuclear fission process in nuclear power stations is controlled, and use the terms chain reaction, fuel rod, control rod and coolant;**
11. understand that nuclear power stations produce radioactive waste;
12. understand that nuclear wastes are categorised as high level, intermediate level and low level, and relate this to disposal methods;
13. interpret and evaluate information about different energy sources for generating electricity, considering efficiency, economic and environmental costs, **power output** and **lifetime**.

MODULE P3: RADIOACTIVE MATERIALS

P3.4 What are the health risks from radioactive materials?

1. when provided with additional information on the health risks associated with radioactive materials, and the steps taken to limit these:
   - can explain why it is impossible for anything to be completely safe;
   - can identify examples of risks which arise from new scientific or technological advances;
   - can suggest ways of reducing specific risks;
   - can interpret and discuss information on the size of risks, presented in different ways;
   - **can discuss a given risk, taking account of both the chance of it occurring and the consequences if it did;**
   - can suggest benefits of activities with known risk;
   - can offer reasons for people’s willingness (or reluctance) to accept the risk of a given activity;
   - can discuss personal and social choices in terms of a balance of risk and benefit;
   - **can identify, or propose, an argument based on the ‘precautionary principle’;**
   - **can distinguish between actual risk and perceived risk, when discussing personal and social choices;**
   - **can suggest reasons for given examples of differences between actual and perceived risk;**
   - **can explain what the ALARA (as low as reasonably achievable) principle means and how it applies to the issue in question;**
2. in the context of health risks associated with radioactive materials:
   - can identify the groups affected and the main benefits and costs of a course of action for each group;
   - can explain the idea of sustainable development, and apply it to specific situations;
   - shows awareness that scientific research and applications are subject to official regulations and laws;
   - **can distinguish what can be done (technical feasibility), from what should be done (values);**
   - **can explain why different courses of action may be taken in different social and economic contexts.**

4 Scheme of Assessment

4.1 Units of Assessment

GCSE Science A (J630)	
Unit 1: Science A Unit 1 – modules B1, C1, P1 (A211)	
16.7% of the total GCSE marks 40 minutes written paper 42 marks	This question paper: • is offered in Foundation and Higher Tiers; • focuses on modules B1, C1 and P1; • uses objective style questions throughout (there is no choice of questions); • assesses knowledge and understanding of the specification content and application of that knowledge and understanding; • assesses Ideas about Science in familiar and unfamiliar contexts.
Unit 2: Science A Unit 2 – modules B2, C2, P2 (A212)	
16.7% of the total GCSE marks 40 minutes written paper 42 marks	This question paper: • is offered in Foundation and Higher Tiers; • focuses on modules B2, C2 and P2; • uses objective style questions throughout (there is no choice of questions); • assesses knowledge and understanding of the specification content and application of that knowledge and understanding; • assesses Ideas about Science in familiar and unfamiliar contexts.
Unit 3: Science A Unit 3 – modules B3, C3 and P3 (A213)	
16.7% of the total GCSE marks 40 minutes written paper 42 marks	This question paper: • is offered in Foundation and Higher Tiers; • focuses on modules B3, C3 and P3; • uses objective style questions throughout (there is no choice of questions); • assesses knowledge and understanding of the specification content and application of that knowledge and understanding; • assesses Ideas about Science in familiar and unfamiliar contexts.

Unit 4: Science A Unit 4 – Ideas in Context (A214)	
16.7% of the total GCSE marks 45 minutes written paper 40 marks	This question paper: • incorporates pre-release material;
	• assesses knowledge and understanding of the specification content and application of that knowledge and understanding;
	• assesses Ideas about Science in familiar and unfamiliar contexts;
	• uses structured questions throughout (there is no choice of questions);
	• includes some marks for communication skills.

Unit 5: Science A Unit 5 – Practical Data Analysis and Case Study (A219)	
33.3% of the total GCSE marks skills assessment 40 marks (16 + 24)	• This skills assessment unit comprises two elements: the critical analysis of primary data and a case study of a topical (scientific) issue.
	• Opportunities for both elements should arise naturally during the course.
	• This unit is assessed by teachers, internally standardised and then externally moderated by OCR.

4.2 Unit Options

To claim the qualification GCSE Science (J630) candidates can:

- take Units 1 to 5 as above (i.e. Units A211, A212, A213, A214 and A219);

or

- take Unit 1 from each of Biology, Chemistry and Physics plus Units 4 and 5 from this specification (i.e. Units A221, A321, A331, A214 and A219).

4.3 Tiers

Units 1, 2, 3, 4 are set in one of two tiers: Foundation Tier and Higher Tier. Foundation Tier papers assess Grades G to C and Higher Tier papers assess Grades D to A*. An allowed grade E may be awarded on the Higher Tier components. Candidates are entered for either the Foundation Tier or the Higher Tier using option codes F and H. Unit 5 (skills assessment) is not tiered.

Candidates may enter Units 1, 2, 3 and 4 at different tiers, so for example, a candidate may take A211F, A212F and A213H, A214F.

4.4 Assessment Availability

There are two examination sessions each year, in January and June.

	Unit 1 (A211)	Unit 2 (A212)	Unit 3 (A213)	Unit 4 (A214)	Unit 5 (A219)
January 2007	✓	✓	–	–	–
June 2007	✓	✓	✓	✓	✓

After June 2007, Units 1, 2 and 3 will be available in the January and June sessions. The Ideas in Context paper Unit 4 and skills assessment, Unit 5, will only be available in the June sessions.

The Foundation and Higher Tier papers covering the same unit will be timetabled on the same day, and will commence at the same time. The papers timetabled simultaneously will contain common questions, or part questions, targeting the overlapping grades C and D.

4.5 Assessment Objectives

The Assessment Objectives describe the intellectual and practical skills which candidates should be able to demonstrate, in the context of the prescribed content. Candidates should demonstrate communication skills, including ICT, using scientific conventions (including chemical equations) and mathematical language (including formulae).

Assessment Objective 1 (AO1): Knowledge and understanding of science and how science works

Candidates should be able to:

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

Assessment Objective 2 (AO2): Application of skills knowledge and understanding

Candidates should be able to:

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

Assessment Objective 3 (AO3): Practical, enquiry and data-handling skills

Candidates should be able to:

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

Weighting of Assessment Objectives

Assessment Objectives	Weighting
AO1: Knowledge and understanding	29.5%
AO2: Application of knowledge and understanding, analysis and evaluation	36.6%
AO3: Enquiry	33.9%

The relationship between the units and the assessment objectives is shown in the following grid.

	Assessment Objective Weightings by Unit			
	AO1	AO2	AO3	Total
A211, A212, A213	22.5%	24.1%	3.5%	50.1%
A214	5.0%	6.5%	5.2%	16.7%
A219	2%	6%	25.2%	33.2%
Overall	29.5%	36.6%	33.9%	100%

All figures given are for guidance only and have a tolerance of ±3%.

4.6 Quality of Written Communication

Candidates are expected to:

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

Candidates' quality of written communication is assessed in the Ideas in Context paper, Unit 4, and by the Case Study.

5 Skills Assessment

5.1 Nature of Skills Assessment

Rationale

The skills assessment comprises two elements: the critical analysis of primary data, and a Case Study on a topical (scientific) issue.

First-hand experience of the problems of collecting valid and reliable data can give candidates a better sense of what the difficulties really are, a 'feel' for how great they are in specific cases, and provide a context for beginning to understand how to tackle and perhaps overcome them. Analysis and interpretation of data teaches how scientists use experimental evidence to develop and test theories. Evaluation of procedures and data shows how the reliability of scientific findings can be assessed.

The Case Study is designed to motivate candidates and give them an insight into how science is reported to the public, and how they can explore the validity of underlying research and claims or recommendations based on this research.

Skills assessment should arise naturally out of teaching, so that it can be assessed by teachers, internally standardised and then externally moderated by OCR.

Introduction

The skills assessment accounts for 33.3% of the marks for this specification. There are two elements to the work which make up each candidate's portfolio. Portfolio work is assessed by teachers, internally standardised and then externally moderated. Centres should note that marks for both elements of Unit A219 must be submitted in the same examination session.

Element 1: Data Analysis: Marks submitted out of 16

Candidates either singly or collaboratively take part in a practical procedure in order to collect primary data. Candidates are assessed on their ability to analyse and evaluate the data collected and the limitations of the techniques used. It is not essential for candidates to collect all of the data which is to be used in this exercise. Their own first hand data may be supplemented with extra data from other candidates or classes, demonstrations or other sources.

Marks are awarded for two strands, Interpretation (Strand I) and Evaluation (Strand E). The two marks which make up the assessment total for this element of skills assessment must both come from the same activity.

The skills to be assessed for this component are also assessed in GCSE Additional Science A. To avoid unnecessary duplication of practical work, the same marks which are counted in GCSE Additional Science may also be used for this element in this specification, provided that data collected from candidates' own practical work are used.

Element 2: Case Study: Marks submitted out of 24

This assignment should arise naturally from work on the course or from an issue that arises while candidates are following the course. It should be related to an aspect of science that involves an element of controversy, in terms either of the interpretation of evidence, or of the acceptability of some new development. Topics for study should be selected by candidates in discussion with teachers, and should be seen as an extension or consolidation of studies undertaken as a normal part of the course. The work should be capable of being completed within approximately 4-6 hours over a period of time, for example, one lesson per week for half a term, with some non-contact time.

5.2 Marking Internally Assessed Work

Arrival at Strand Marks

The method of marking the skills assessment is the same across this Science suite.

The award of marks is based on the professional judgement of the science teacher, working within a framework of descriptions of performance. Within each strand, each line in the marking grids represents a different aspect of performance. For each of these, a series of four descriptions of performance illustrates what might be expected for candidates working at different levels.

Marking decisions should be recorded on marking grids. A master copy is provided in the skills assessment guidance booklet. The completed grid serves as a cover-sheet for the work if it is required for moderation.

Candidates may not always report their work in a particular order. So, evidence of achievement in a strand may be located almost anywhere in the work. Thus, it is necessary to look at the whole piece of work for evidence of each strand in turn.

Within any one strand, each aspect should be considered in turn. A tick on the grid should be used to indicate the performance statement that best matches the work.

Where the maximum mark is 8, intermediate marks 1, 3, 5 or 7 can be used where performance exceeds that required by one statement, but does not adequately match that required by the next higher statement (e.g. if the work significantly exceeds what is required for 4 marks, but does not reach the standard for 6, then the tick should be placed on the dividing line between the 4 and 6 mark boxes).

Where a decision is based partly on the teacher' observation of the candidate at work, the work should be annotated to record this at an appropriate point on the report.

In some cases, in order to allow credit for the widest possible variety of activities, an aspect of performance is represented by two (or more) rows of mark descriptors. In such cases, where a row is not relevant or appropriate for a particular activity, it should be left blank and excluded from the 'best-fit' marking judgement and the more appropriate alternative row used.

When each aspect of the performance within a strand has been assessed in this way, the pattern of achievement is interpreted by a 'best-fit' judgement to give a mark for that strand.

This method of marking can be applied even where there is a wide variation between performance in different aspects. Thus, weak performance in one aspect need not depress marks too far if other aspects show better performance.

Recording and Submitting Marks

Skills Assessment Forms will be provided for centres to record marks submitted. The final mark should be submitted to OCR on form MS1 by 15th May in the year of entry for Unit 5. These forms are produced and despatched at the relevant time based on entry information provided by the centre.

All assessed work which has contributed to candidates' final totals must be available for moderation.

Unit 5 (A219), Element 1: Practical Data Analysis (13.3%)

There are two strands in this element: Interpreting Data and Evaluation. The descriptors for each strand are identical to those found in the Additional Science specification.

Marks for each strand must come from a single data analysis activity. It is expected that candidates will attempt more than one data analysis task during the course. The total for the assessment should be the highest total for one data analysis task. It is not permitted to aggregate marks from two or more different pieces of work.

Marking Criteria – Practical Data Analysis

Strand I: Interpreting Data

Candidates are expected to be able to:

- present or process a set of data in such a manner as to bring out any ‘patterns’[1] that are present (IaS1.4, 2.1, 2.3–4);
- state conclusions based on these patterns (IaS 2.4);
- relate their conclusions to scientific theories or understanding (IaS 3.1, 3.3, 3.4).

In the following table, each row represents increasing achievement in a different aspect of performance.

Aspect of Performance	Strand I Mark			
	2	4	6	8
a graphical or numerical processing of data	Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line (normally a line of best fit) or construct complex charts or diagrams (e.g. stacked histograms, species distribution maps).	Additionally, indicate the spread of data (e.g. through scatter-graphs or error bars) and give clear keys for displays involving multiple data sets.
	Select individual results as a basis for conclusions.	Carry out simple calculations (e.g. correct calculation of averages from repeated readings).	Use mathematical comparisons between results to support a conclusion.	Use complex processing to reveal patterns in the data (e.g. statistical methods, use of inverse relationships or calculation of gradient of graphs).
b summary of evidence	Note differences between situations/ cases, or compare individual results.	Identify trends or general correlations in the data.	Describe formal or statistical relationships within the cases/situations studied.	Review the extent of, or limitations to, formal conclusions in relation to the scatter evident in the data.
c explanations suggested	Link the outcomes to previous experience or ‘common sense’.	Relate the conclusion to scientific ideas/ explanations.	Justify the conclusion by reference to relevant scientific knowledge and understanding.	Use detailed scientific knowledge to explain all aspects of the given conclusion.

[redacted]

[1] ‘Patterns’ here means similarities, or differences, or the presence or absence of a relationship (e.g. a correlation between a factor and an outcome, or a trend linking two variables)

Strand E: Evaluation

Candidates are expected to be able to look back at the experiment they have carried out, show what they have learned from doing it and explain how they would modify it in the light of this, were they to carry it out again. These suggestions may demonstrate understanding of:

- difficulties in collecting valid and reliable data (IaS 1.1–3);
- weaknesses in the design of the data set collected, such as imperfect control of other variables, or the size and matching of samples compared (IaS 2.3, 2.6–7);
- assessing the level of confidence that can be placed in these conclusions (IaS 2.2–3, 2.6–7).

In the following table each row represents increasing achievement in a different aspect of performance.

Aspect of Performance	Strand E Mark			
	2	4	6	8
a evaluation of procedures	Make a relevant comment about how the data was collected and safety procedures.	Comment on the limitations to accuracy or range of data imposed by the techniques and equipment used.	Suggest improvements to apparatus or techniques, or alternative ways to collect the data, but without sufficient practical detail.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement.
b reliability of evidence	Make a claim for accuracy or reliability, but without appropriate reference to the data.	Note the presence or absence of results that are beyond the range of experimental error.	Use the general pattern of results or degree or scatter between repeats as a basis for assessing accuracy and reliability.	Consider critically the reliability of the evidence, accounting for any anomalies.
c reliability of conclusion	Relate judgement of the reliability (or otherwise) of the conclusions only to techniques used, not to data collected.	Link confidence in the conclusion to the apparent reliability of the data collected.	Discuss the precision of apparatus and techniques, the range covered and reliability of data to establish a level of confidence in the conclusions.	Identify weaknesses in the data and give a detailed explanation of what further data would help to make the conclusion more secure.

Unit 5 (A219), Element 2: Case Study (20%)

The candidate presents one Case Study, a report based on detailed study of a chosen topic.

Choosing a topic

In everyday life, citizens most often become aware of science-related issues through reports in the media: newspapers, teenage magazines, television, etc. This component of the assessment is designed to help candidates develop strategies for evaluating such information, and to increase awareness of appropriate ways of making decisions about such issues.

Ideally, the study should arise from such a media source. Suitable topics involve some degree of controversy, or disagreement, either about the interpretation of the scientific evidence, or about how individuals or society should respond. The title for a Case-Study is best phrased as a question to be answered by careful balancing of evidence and opinions from a variety of sources.

Suitable topics often fall into one of three main types.

- Evaluating claims where there is uncertainty in scientific knowledge (e.g. “Is there life elsewhere in the Solar System?” or “Does using mobile phones cause risk of brain damage?”) Controversies of this type focus attention on the relationship between data and explanations in science, and on the quality of research which underlies competing claims.
- Contributing to decision making on a science-related issue (e.g. “Should a shopping street be pedestrianised to reduce air pollution?” or “Should the government restrict research into human cloning?”) Studies in this category are more likely to involve elements of personal choice, values and beliefs, and may involve balancing of risks and benefits of any proposed action.
- Personal or social choices (e.g. “Should my child receive the triple MMR vaccine?”). Ethical and personal issues are likely to figure in such studies, but it is important to evaluate these in relation to what is known about the science which underlies the issue.

In all cases, an important factor in choice of subject should be the availability of information giving a variety of views in forms that can be accessed by the candidate. Candidates may be provided with the initial stimulus for the study, but should be encouraged to search for a range of opinions in order to reach a balanced conclusion.

The subject need not be restricted to topics studied in the course. However, it is necessary for the candidate to apply some relevant scientific knowledge and understanding to discussion of the issues raised. This is most likely to be the case if the study arises naturally during normal work on the course.

Candidates need not all study the same, or related, topics. Motivation is greatest if they are given some degree of autonomy in the choice of topic. This may be achieved by allowing choice of different issues related to a general topic (e.g. different aspects of air pollution when studying Air Quality) or by encouraging candidates to identify topics of interest and begin collecting resource materials over an extended period. At a time chosen by the centre, candidates then complete their Case Study, and may each be working on a different topic.

Presentation of the Case Study

Candidates will find it helpful to have a clear sense of audience in their writing – perhaps candidates in year 9, to encourage them to explain the basic science behind the topic.

The Case Study will often take the form of a 'formal' written report. However, candidates should not be discouraged from other styles of presentation, for example:

- a newspaper or magazine article;
- a PowerPoint presentation;
- a poster or booklet;
- a teaching/learning activity such as a game;
- a script for a radio programme or a play.

In all cases, sufficient detail must be included to allow evaluation in all of the performance areas. Some types of presentation would require supporting notes.

A Case Study represents a major piece of work and it is not expected that candidates will attempt more than one during the course. If a candidate has attempted more than one case study, then the total for the assessment should be the highest total for any one case study.

It is not permitted to aggregate marks from two or more different pieces of work, nor to add marks obtained from separate, limited range tasks, exercises or part-studies.

Marking Criteria – Case Study

Marks are awarded under four headings, A, B, C and D.

Because of the risk of some studies becoming excessively long, it is important to link marks to the quality of the work done, rather than the quantity.

The four strands to be awarded credit are:

A: Quality of selection and use of information, on a scale of 0–4 marks

Here candidates should show an awareness of sources of information such as their own notes, text books or encyclopedias, or the internet. They should consider the reliability of any sources used. All sources should be credited, and it should be clear where each piece of information has come from. Credit is given for being selective in choosing only relevant material. Direct quotations should be acknowledged.

B: Quality of understanding of the case, on a scale of 0–8 marks

Candidates should describe the basic science which helps understanding of the topic, and apply it to evaluate the reliability of claims made. In many cases, they may follow a topic beyond the normal limits of the specification, and credit should be awarded for understanding whether within or beyond the specification.

C: Quality of conclusions, on a scale of 0–8 marks

Different evidence, arguments or views should be compared and evaluated and used as a basis for a balanced conclusion or proposal for action.

D: Quality of presentation, on a scale of 0–4 marks

Communication skills should be rewarded for effective presentation including use of different forms for presenting different types of information (e.g. pictures, tables, charts, graphs, etc.).

Strand A: Quality of Selection and Use of Information

Candidates will select and organise information from a variety of sources, bearing in mind both relevance to the study and the apparent reliability of the sources. It is expected that centres will make at least a basic selection of resources available for candidates to work from. A survey of the units included in the course will identify topics which are likely to be relevant, topical and of interest to candidates. In addition to standard textbooks and library books, resources are available from industry, from environmental groups and in popular science magazines, as well as through the internet.

Candidates should be encouraged to seek out their own additional resources, but should not be completely dependent on this, and in particular, should not be dependent on home or out of school support.

Credit will be given for selection of appropriate material from the available resources, rather than indiscriminate copying. It will also be given for judgement shown in selecting from a variety of sources to give a balanced view of the topic. Good work is characterised by the ability of the candidate to adapt and re-structure information to suit the purpose of the study.

In some cases, candidates may wish to collect information about the public acceptability of an idea or perception of risk through questionnaires (administered to classmates or other groups) or to test media claims through experimental work. Whilst relevant work of these types may be credited, it should not dominate the study.

In all cases, candidates should record the sources of information they have used. The assignment can be used as an introduction to the value of crediting sources in scientific communication.

Marks are awarded on a scale of 0 to 4 by matching the work to performance descriptors.

Candidates should show awareness of the variety of sources of information relevant to science-based issues, and some understanding that the reliability of sources may vary.

This aspect of the work is linked to understanding of Ideas about Science 4: The Scientific Community (mainly IaS 4.1, 4.2, 4.3 and 4.4).

Aspect of Performance	Strand A Mark			
	1	2	3	4
a planning the use of sources of information	Very little information is given beyond that provided by the original stimulus material.	Information from a limited range of additional sources is included, although some may be irrelevant or inappropriate to the study.	Relevant information is selected from a variety of sources.	Sources of information are assessed for reliability as a basis for selection of relevant information from a wide variety of sources.
b acknowledgement of sources used		Sources are identified by incomplete or inadequate references.	References to sources are clear, but limited in detail.	References to these sources are clear and fully detailed.
c linking information to specific sources		Direct quotations are rarely indicated as such.	Direct quotations are generally acknowledged.	The sources of particular opinions are indicated at appropriate points in the text of the report.

Strand B: Quality of Understanding of the Case

Where possible, candidates should make reference to explanatory scientific theory to help them understand the significance of the information they are dealing with. However, controversies in science often arise in areas where there is no (GCSE level) descriptive theory to provide a basis for understanding and evaluating the issues involved. In such cases, candidates should draw on Ideas about Science, especially IaS 2 (Correlation and cause), to justify the conclusions they reach about the information they have collected.

Note that these studies should not be used to extend or assess the candidate's knowledge of basic academic theory related to the topic, but rather to encourage them to see how the science knowledge they have can be related to topical issues to help them reach valid judgements. Some candidates may wish to go beyond what they have been taught in class and, if they find and correctly apply theory which is directly relevant to the Case Study, this can help to raise their mark. However, credit should not be given to uncritical copying of large amounts of theory from texts.

Candidates should provide some background to the case study in relation to relevant scientific theory. They should also evaluate how well-founded are links between the available evidence and claims or views made on the basis of the evidence. Where little explanatory theory is available at this level, candidates should draw on Ideas about Science 2, 3 and 4 to help them evaluate the evidence they find.

This aspect of the work depends on understanding of:

- Ideas about Science 1: Data and its limitations (mainly 1.2, 1.3 and 1.4);
- Ideas about Science 2: Correlation and cause (mainly 2.1, 2.2, 2.4–2.7).

Aspect of Performance	Strand B Mark			
	2	4	6	8
a making use of science explanations	Only superficial mentions of science explanations, often not correctly applied to the case.	Provides a basic outline of the main scientific ideas which are relevant to the case.	Provides a detailed review of the scientific knowledge needed to understand the issues studied.	Considers how different views described in the study can be supported by detailed scientific explanations.
b recognition and evaluation of scientific evidence	Sources are uncritically quoted without distinguishing between scientific evidence and unsupported claims.	Science content and data in sources is recognised.	Claims and opinions are linked to the scientific evidence they are based on.	The quality of scientific evidence in sources is evaluated in relation to the reliability of any claims made.

Strand C: Quality of Conclusions

The work should take account of different views or opinions which are represented in the information collected. Credit will be given for discussion of the perceived benefits and associated risks of any proposed actions, and for judgements of the acceptability of any conclusions reached.

The case studied should be such that there is scope for taking views about the acceptability of some view or course of action.

Work on this aspect of the Case Study will be linked to understanding of:

- Ideas about Science 1: Data and its limitations (mainly parts 1.2 and 1.4);
- Ideas about Science 5: Risk (mainly parts 5.1, 5.2, 5.4, 5.6 and 5.7);
- Ideas about Science 6: Making decisions about science and technology (mainly parts 6.3, 6.4, 6.5 and 6.6).

Aspect of Performance	Strand C Mark			
	2	4	6	8
a comparing opposing evidence and views	Information is unselectively reported without taking any clear view about any course of action.	Claims for a particular idea, development or course of action are reported without critical comment.	Claims and arguments for and against are reported, but with little attempt to compare or evaluate them.	Details of opposing views are evaluated and critically compared.
b conclusions and recommendations	A conclusion is stated without reference to supporting evidence.	A conclusion is based on evidence for one view only.	Some limits or objections to the conclusion are acknowledged.	Alternative conclusions are considered, showing awareness that different interpretations of evidence may be possible.

Strand D: Quality of Presentation

Candidates should be encouraged to be creative and imaginative in their choice of method and media for communicating their findings. The report may be in a variety of forms, including formal written reports, newspaper articles, PowerPoint presentations, posters, scripts for a radio programme or play etc. Whatever form of presentation is chosen, it should be supported by sufficient documentation to allow assessment of all four qualities. It should also be remembered that the work may need to be posted to a moderator towards the end of the course. Where electronic media are included, a paper print-out must be provided for moderation purposes.

Note that quality and fitness for purpose should be rewarded in the assessment, rather than the sheer quantity of the work.

Where written reports are given, candidates should be encouraged to structure the report clearly. An attractive cover helps to improve motivation and make the work "special"; thinking about a good structure for the contents can help candidates to organise their ideas. Use of tables of contents, and sub-headings between sections of text are valuable in this context.

Illustrations should be used where they lead to clearer communication of ideas. These may be taken from resource leaflets or 'clip-art' sources, or drawn by candidates: they may be pictorial or graphical. Tables, charts and graphs should be used to present and summarise data. Reports may be hand-written or word-processed.

Candidates should be encouraged to think carefully of their target audience and how to communicate their ideas clearly.

Aspect of Performance	Strand D Mark			
	1	2	3	4
a structure and organisation of the report	The report has little or no structure or coherence, or follows a pattern provided by worksheets.	The report has an appropriate sequence or structure.	Information is organised for effective communication of ideas, with contents listing, page numbering etc. as appropriate to aid location of key elements.	Considerable care has been taken to match presentation and format to present issues and conclusions clearly and effectively to a chosen audience.
b use of visual means of communication	There is little or no visual material (charts, graphs, pictures etc.) to support the text.	Visual material is merely decorative, rather than informative.	Visual material is used to convey information or illustrate concepts.	Pictures, diagrams, charts and or tables are used appropriately and effectively to convey information or illustrate concepts.
c spelling, punctuation and grammar	Spelling, punctuation and grammar are of generally poor quality, with little or no use of appropriate technical or scientific vocabulary.	Spelling, punctuation and grammar are of variable quality, with limited use of appropriate technical or scientific vocabulary.	Spelling, punctuation and grammar are generally sound, with adequate use of appropriate technical or scientific vocabulary.	The report is concise, with full and effective use of relevant scientific terminology. Spelling, punctuation and grammar are almost faultless.

5.3 Regulations for Internally Assessed Work

Supervision and authentication of work

OCR expects teachers to supervise and guide candidates who are undertaking work that is internally assessed. The degree of teacher guidance will vary according to the kind of work being undertaken. It should be remembered, however, that candidates are required to reach their own judgements and conclusions.

When supervising internally assessed tasks, teachers are expected to:

- offer candidates advice about how best to approach such tasks;
- exercise supervision of work in order to monitor progress and to prevent plagiarism;
- ensure that the work is completed in accordance with the specification requirements and can be assessed in accordance with the specified mark descriptions and procedures.

Skills assessment should, wherever possible, be carried out under supervision. However, it is accepted that some tasks may require candidates to undertake work outside the Centre. Where this is the case, the Centre must ensure that sufficient supervised work takes place to allow the teachers concerned to authenticate each candidate's work with confidence.

Candidates will require guidance in their choice of Case Study and some of the work is likely to be carried out individually and independently without direct supervision. Teachers will need to take steps to ensure that the work presented for assessment accurately reflects each candidate’s individual attainment. It is strongly recommended that a substantial proportion of the production of the final report is written under supervision.

Production and presentation of internally assessed work

Candidates must observe certain procedures in the production of internally assessed work.

- Any copied material must be suitably acknowledged.
- Where work is based on the use of additional secondary data, the original sources must be clearly identified.
- Each candidate's assessed work submitted for moderation should be stapled together at the top left hand corner and have a completed cover sheet as the first page.

Annotation of candidates' work

Each piece of assessed work should be annotated to show how the marks have been awarded in relation to the mark descriptions.

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

However, the main purpose of annotating candidates' work is to provide a means of communication between teacher and moderator, showing where marks have been awarded and why they have been awarded.

Annotations should be made at appropriate points in the margins of the script of all work submitted for moderation. The annotations should indicate where achievement for a particular skill has been recognised.

It is suggested that the minimum which is necessary is that the 'shorthand' mark descriptions (for example, Ba6) should be written at the point on the script where it is judged that the work has met the mark description.

Moderation

All internally assessed work is marked by the teacher and internally standardised by the Centre. Marks are then submitted to OCR by a specified date, after which moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard of the award of marks is the same for each Centre and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

It is the responsibility of the Centre to carry out effective internal standardisation to ensure that similar standards are applied by each teacher involved in the assessment. The Moderator will require a written statement describing how internal standardisation has been carried out within the Centre.

External moderation will be by postal sample selected by the Moderator.

The sample will represent performance across the whole ability range from the Centre. The sample of work which is presented to the Moderator for moderation must show how the marks have been awarded in relation to the mark descriptions.

Separate cover sheets are required for each element of the candidate’s work in the sample submitted for moderation.

Minimum requirements for internally assessed work

If a candidate submits no work for this internally assessed unit, then the candidate should be indicated as being absent from that unit on the mark sheets submitted to OCR. If a candidate completes any work at all for an internally assessed unit, then the work should be assessed according to the criteria and mark descriptions and the appropriate mark awarded, which may be zero.

6 Technical Information

6.1 Making Unit Entries

Please note that centres must be registered with OCR in order to make any entries, including estimated entries. It is recommended that centres apply to OCR to become a registered centre well in advance of making their first entries. Centres should be aware that a minimum of ten candidates for summer examinations is normally required.

Unit Entry Options

Within Units A211, A212, A213 and A214 candidates must be entered for either the Foundation Tier or the Higher Tier option. It is not necessary for candidates to enter at the same tier in every unit. Candidates may, if they wish, attempt papers at both tiers, but not in the same examination session, since the papers will be timetabled simultaneously.

Centres should note that marks for both elements of Unit A219 must be submitted in the same examination session.

Entry code	Option code	Component to be taken	
A211	F	01	Science A Unit 1 – modules B1, C1, P1 Foundation
	H	02	Science A Unit 1 – modules B1, C1, P1 Higher
A212	F	01	Science A Unit 2 – modules B2, C2, P2 Foundation
	H	02	Science A Unit 2 – modules B2, C2, P2 Higher
A213	F	01	Science A Unit 3 – modules B3, C3, P3 Foundation
	H	02	Science A Unit 3 – modules B3, C3, P3 Higher
A214	F	01	Science A Unit 4 – Ideas in Context Foundation
	H	02	Science A Unit 4 – Ideas in Context Higher
A219	–	01	Science A Unit 5 – Practical Data Analysis and Case Study

Candidate entries must be made by 21 October for the January session and by 21 February for the June session.

6.2 Making Qualification Entries

Candidates **must** be entered for certification code **J630** to claim their overall GCSE grade.

If a certification entry is not made, no overall grade can be awarded.

A candidate who has completed all the units required for the qualification may enter for certification either in the same examination session (at the usual time or within a specified period after publication of results) or at a later session.

First certification will be available in June 2007 and every January and June thereafter.

Certification cannot be declined.

6.3 Grading

GCSE results are awarded on the scale A*-G. Units are awarded a* to g. Grades are awarded on certificates. Results for candidates who fail to achieve the minimum grade (G or g) will be recorded as unclassified (U or u).

In modular schemes candidates can take units across several different sessions. They can also re-sit units or choose from optional units available. When working out candidates' overall grades OCR needs to be able to compare performance on the same unit in different sessions when different grade boundaries have been set, and between different units. OCR uses uniform marks to enable this to be done.

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

When unit results are issued, the candidate's unit grade and uniform mark are given. The uniform mark is shown out of the maximum uniform mark for the unit e.g. 43/50.

Results for each unit will be published in the form of uniform marks according to the following scales.

	Unit Grade								
	a*	a	b	c	d	e	f	g	u
Units 1, 2, 3 and 4	50-45	44-40	39-35	34-30	29-25	24-20	19-15	14-10	10-0
Unit 5	100-90	89-80	79-70	69-60	59-50	49-50	39-30	29-20	19-0

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

Candidates' uniform marks for each module are aggregated and grades for the specification are generated on the following scale.

Qualification Grade								
A*	A	B	C	D	E	F	G	U
300-270	269-240	239-210	209-180	179-150	149-120	119-90	89-60	59-0

The candidate's grade will be determined by this total mark. Thus, the grade awarded will depend in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of the assessment may be balanced by better performance in others. Candidates achieving less than the minimum mark for grade G will be unclassified.

6.4 Result Enquiries and Appeals

Under certain circumstances, a centre may wish to query the grade available to one or more candidates or to submit an appeal against an outcome of such an enquiry. Enquiries about unit results must be made immediately following the series in which the relevant unit was taken.

For procedures relating to enquires on results and appeals, centres should consult the OCR *Handbook for Centres* and the document *Enquiries about Results and Appeals – Information and Guidance for Centres* produced by the Joint Council. Copies of the most recent editions of these papers can be obtained from OCR.

6.5 Shelf-Life of Units

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

6.6 Unit and Qualification Re-Sits

Candidates may re-sit any unit an **unlimited** number of times.

For each unit the best score will be used towards the final overall grade.

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

6.7 Guided Learning Hours

GCSE Science A requires 120 guided learning hours in total.

6.8 Code of Practice/Subject Criteria/Common Criteria Requirements

These specifications comply in all respects with the revised *GCSE, GCE, VCE, GNVQ and AEA Code of Practice 2005/6*, the subject criteria for GCSE Science A and *The Statutory Regulation of External Qualifications 2004*.

6.9 Arrangements for Candidates with Particular Requirements

For candidates who are unable to complete the full assessment or whose performance may be adversely affected through no fault of their own, teachers should consult the *Access Arrangements and Special Consideration Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examinations*. In such cases advice should be sought from OCR as early as possible during the course.

6.10 Prohibited Qualifications and Classification Code

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

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

The classification code for this specification is 1310.

7 Other Specification Issues

7.1 Overlap with other Qualifications

This specification has been developed alongside GCSE Additional Science A and GCSE Additional Applied Science A, GCSE Biology A, GCSE Chemistry A, GCSE Physics A. Aspects of the skills assessment are common across some of these qualifications.

7.2 Progression from these Qualifications

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

Many candidates who enter employment with one or more GCSEs would undertake training or further part-time study with the support of their employers.

Progression to further study from GCSE will depend upon the number and nature of the grades achieved. Broadly, candidates who are awarded mainly grades G to D at GCSE could either strengthen their base through further study of qualifications at Level 1 within the National Qualifications Framework or could proceed to Level 2. Candidates who are awarded mainly grades C to A* at GCSE would be well prepared to broaden their base through further study of qualifications at Level 2 or to proceed to appropriate qualifications at Level 3 within the National Qualifications Framework. Candidates intending to proceed to qualifications in the sciences at Advanced Level (Level 3 in the National Qualifications Framework) should have completed courses in both GCSE Science and GCSE Additional Science or GCSE Additional Applied Science or one or more of the separate sciences.

7.3 ICT

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

Opportunities for using ICT include:

- gathering information from the internet and CD ROMs;
- use of video clips to show the impact of science on people's lives;
- gathering data using sensors linked to data-loggers or directly to computers;
- using spreadsheets and other software to process data;
- using animations and simulations to visualise scientific ideas;
- using software to present ideas and information on paper and on screen.

Particular opportunities for the use of ICT are suggested in the introduction to each module.

7.4 Citizenship

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

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

Citizenship Programme of Study	Opportunities for Teaching the Issues during the Course
Section 1: Knowledge and understanding about becoming informed citizens	
The work of parliament, the government and the courts in making and shaping the law	C1: Role of regulation in limiting air pollution. B2: The role of government in determining vaccination policy and making decisions about public safety. The legal aspects of controlling animal experimentation.
How the economy functions, including the role of business and financial services	C2: The role of the chemical industry to add value to raw materials (oil) by converting them to polymers. P3: Need for large scale power generation and the factors underlying the choice of fuels.
The opportunities for individuals and voluntary groups to bring about social change locally, nationally, in Europe and internationally	C1: Actions which individuals, communities and governments can take to reduce air pollution. C2: Opportunities to change policies for dealing with domestic waste.
The media's role in society, including the internet, in providing information and affecting opinion	B2: The media's role in reporting health issues such as vaccination and heart disease. P2: The role of the media in reporting issues such as the possible health risks associated with mobile phones.
The rights and responsibilities of consumers, employers and employees	P2: The precautionary principle and its implications. P3: The rights and responsibilities of workers and patients exposed to ionising radiation.
The issues and challenges of global interdependence and responsibility, including sustainable development and Local Agenda 21	P2: The enhanced greenhouse effect, global warming and climate change. B3: Maintaining biodiversity as an important part of sustainable development. C3: Exploration of issues related to agriculture and food production, including methods of food preservation, the use of chemicals in agriculture and the possibilities of genetic modification.
Section 2: Enquiry and communication	
Researching a topical scientific issue by analysing information from different sources, including ICT-based sources, showing an awareness of the use and abuse of statistics	Case Study of a topical science-related issue. C2: Investigating the issues that arise at each stage in the life cycle of a material object. C3: Exploring topical issues related to food and agriculture.

Citizenship Programme of Study	Opportunities for Teaching the Issues during the Course
Expressing, justifying and defending orally and in writing a personal opinion about a topical scientific issue	Case Study of a topical science-related issue. C2 Coming to a view as a result of carrying out a life cycle analysis. C3: Exploring topical issues related to food and agriculture.
Contributing to group and class discussions	There will be opportunities for discussion in every module e.g.: B1: Discussion of ethical issues arising from genetic testing, or the potential applications of stem cell technology. P1: Discussion of alternative explanations to account for the distribution of the continents on Earth. C2: Discussion of use of alternative materials for manufacture of a product following life-cycle analysis.

7.5 Key Skills

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

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

Level	Communication	Application of Number	IT	Working with Others	Improving Own Learning and Performance	Problem Solving
1	✓	✓	✓	✓	✓	✓
2	✓	✓	✓	✓	✓	✓

7.6 Spiritual, Moral, Ethical, Social, Legislative, Economic and Cultural Issues

The ideas-about-science are a major feature of this specification and they cover the values that underpin scientific activity as well as the values that influence people's thinking when faced with scientific issues. The science explanations chosen for study in this course are particularly those which have a profound influence on how people think about themselves, their immediate environment, the Earth as a whole and the Universe.

Issue	Opportunities for Teaching the Issues during the Course
The commitment of scientists to publish their findings and subject their ideas to testing by others.	P1: Study of scientists and their reactions to competing explanations to account for the distribution of the continents on Earth. P2: Exploring the variety of opinions of scientists about the likely extent of global warming. B3: Study of scientists reactions to competing explanations to account for evidence relating to evolution of life on Earth.
Risk and the factors which decide the level of risk people are willing to accept in different circumstances.	B2: Assessing the risks associated with vaccination and the reaction of different people to these risks. P2: People's response to the risks associated with electromagnetic radiation. P3: Risks associated with contamination or irradiation by radioactive materials.
The range of factors which have to be considered when weighing the costs and benefits of scientific activity.	Case Study of a topical science-related issue. C2: The technical, economic and social issues that have to be taken into account when designing a material object. P3: Long and short term economic and environmental costs and benefits related to the use of various energy sources.
The ethical implications of selected scientific issues.	B1: Ethical issues arising from implications of modern genetic technologies. B2: Ethical issues arising from vaccination policy. C2: Comparison of technical feasibility and values in the context of life cycle analysis for a particular product.
Scientific explanations which give insight into human nature.	B1: Genes and inheritance. B3: The human nervous system.
Scientific explanations which give insight into the local and global environment.	C1: The origins of pollutants and what happens to them in the atmosphere. B2: Vaccination policy, for different diseases, and in different countries. P2: The cycling of carbon and climate change.
Scientific explanations which give insight into our planet and its place in the Universe.	P1: Study of the life history of stars, the possible futures for the Universe, and the possibility of life in other parts of the Universe.

7.7 Sustainable Development, Health and Safety Considerations and European Developments

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

Issue	Opportunities for Teaching the Issues during the Course
Environmental issues	
Air pollution	C1: The origins of air pollution from burning fuels and the steps that can be taken to improve air quality. P2: The enhanced greenhouse effect and global warming.
Natural disasters and how to predict them	P1: Volcanic eruptions and earthquakes.
Food and agriculture	C3: Regulation of food additives.
Origins and management of waste materials	C2: Life cycle analysis as a basis for decisions related to the use and disposal of materials.
Energy resources	P3: The environmental advantages and disadvantages of different energy sources for generating electricity.
Health and Safety issues	
Safe practice in the laboratory	Data Analysis of primary data collected by candidates, including evaluation of the procedures used.
Health and disease	B1: The study of inherited diseases. B2: A range of issues related to keeping healthy in a complex world including epidemiological studies for investigating the causes of disease. P3: The risk of cancer associated with exposure to radioactive decay.
Food and nutrition	C3: Food safety and the risks and benefits associated with novel agricultural technologies.
Living with radiation	P2: ALARA principle and how it applies to electromagnetic radiation. P3: ALARA principle and how it applies to radioactive decay.

OCR has taken account of the 1988 Resolution of the Council of the European Community in preparing this specification and associated specimen assessments. European examples should be used where appropriate in the delivery of the subject content.

Although this specification does not make specific reference to the European Dimension it may be drawn into the course of study in a number of ways. The table below provides some appropriate opportunities.

Issue	Opportunities for Teaching the Issues during the Course
The importance of the science-based industry to European economies	C2: The scale and distribution of the petrochemical industry in Europe. P3: Contrasting solutions to the provision of electricity supplies on a large scale.
Environmental issues which extend over a larger area than the UK	P1: Study of volcanic eruptions and earthquakes including European examples. P2: Study of global warming and climate change.
Differences in attitudes to key issues in different parts of Europe	B2: Contrasting attitudes across Europe to health issues. C2: European policies for the use and disposal of materials.

7.8 Avoidance of Bias

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

7.9 Language

These specifications and associated assessment materials are in English only.

7.10 Support and Resources

The University of York Science Education Group (UYSEG) and the Nuffield Curriculum Centre have produced resources specifically to support this specification. The resources will comprise:

- candidates' texts;
- candidates' work books;
- teacher guide with suggested schemes of work and candidate activity sheets (in customizable format);
- technician guide;
- ICT resources (for example, animations, video clips, models and simulations);
- assessment materials;
- a website for teachers and candidates.

The resources are published by Oxford University Press. Further information is available from:

Customer Services: Telephone: 01536 741068
Fax: 01536 454579
email: schools.orders@oup.com

Support is also available from the OCR GCSE science website **www.gcse-science.com** where centres should register their intention to offer this qualification. Registering on this site provides access to a teachers' forum and local support networks.

Appendix A: Grade Descriptions

Grade F

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

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

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

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

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

Grade C

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

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

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

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

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

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

Grade A

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

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

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

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

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

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

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Appendix B: Requirements Relating to Mathematics

During the course of study for this specification, many opportunities will arise for quantitative work, including appropriate calculations. The mathematical requirements which form part of the specification are listed below. Items in the first table may be examined in written papers covering both Tiers. Items in the second table may be examined only in written papers covering the Higher Tier.

Both Tiers
add, subtract and divide whole numbers
recognise and use expressions in decimal form
make approximations and estimates to obtain reasonable answers
use simple formulae expressed in words
understand and use averages
read, interpret, and draw simple inferences from tables and statistical diagrams
find fractions or percentages of quantities
construct and interpret pie-charts
calculate with fractions, decimals, percentage or ratio
solve simple equations
substitute numbers in simple equations
interpret and use graphs
plot graphs from data provided, given the axes and scales
choose by simple inspection and then draw the best smooth curve through a set of points on a graph

Higher Tier only
recognise and use expressions in standard form
manipulate equations
select appropriate axes and scales for graph plotting
determine the intercept of a linear graph
understand and use inverse proportion
calculate the gradient of a graph

Appendix C: Physical Quantities and Units

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

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

Derived Quantities and Units	
Physical quantity	Unit(s)
area	cm^2; m^2
volume	cm^3; dm^3; m^3; litre (l); millilitre (ml)
density	kg/m^3; g/cm^3
force	Newton (N)
speed,	m/s; km/h
energy	joule (J) ; kilojoule (kJ); megajoule (MJ)
power	watt (W); kilowatt (kW); megawatt (MW)
frequency	hertz (Hz); kilohertz (kHz)
radioactivity	becquerel (Bq)
radiation dose	sievert (Sv)

Appendix D: Health and Safety

In UK law, health and safety is the responsibility of the employer. For most centres entering candidates for GCSE examinations this is likely to be the Local Education Authority or the Governing Body. Teachers have a duty to co-operate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment.

A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of Safety in Science Education. For members, the CLEAPSS guide, Managing Risk Assessment in Science offers detailed advice.

Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X
- Topics in Safety 3rd edition, 2001, ASE ISBN 0 86357 316 9
- Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2
- Hazcards, 1995 with 2004 updates, CLEAPSS School Science Service*
- CLEAPSS Laboratory Handbook, 1997 with 2004 update, CLEAPSS School Science Service*
- CLEAPSS Shorter Handbook (CLEAPSS 2000) CLEAPSS School Science Service*
- Hazardous Chemicals, A manual for Science Education, (SSERC, 1997) ISBN 0 9531776 0 2

*Note that CLEAPSS publications are only available to members or associates.

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual Centre then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely.

The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc.

There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

When candidates plan and carry out their own investigative work the teacher has a duty to check the plans before the practical work starts and to monitor the activity as it proceeds.

Appendix E: Explanation of Terms Used in Module Content

All the module content statements are expressed in terms of what the candidates know, understand or can do, and are prefixed by ‘Candidates should be able to … ..’ which is followed by statement containing one or more ‘command’ words.

This appendix, which is not intended to be exhaustive or prescriptive, provides some guidance about the meanings of these command words.

It must be stressed that the meaning of a term depends on the context in which it is set, and consequently it is not possible to provide precise definitions of these words which can be rigidly applied in all circumstances. Nevertheless, it is hoped that this general guidance will be of use in helping to interpret both the specification content and the assessment of this content in written papers.

Command words associated with scientific knowledge and understanding (AO1).

Candidates are expected to remember the facts, concepts, laws and principles which they have been taught. Command words in this category include Learning Outcomes beginning:

recall ...state…; ...recognise…; …name...; ...draw...; ...test for…; …appreciate… ; describe…

The words used on examination papers in connection with the assessment of these Learning Outcomes may include:

Describe...; List...; Give...; Name...; Draw...; Write...; What?...; How?...; What is meant by..?

e.g. `What is meant by the term `catalyst’ ?’

`Name parts A, B and C on the diagram.’

Command words associated with interpretation, evaluation, calculation and communication (AO2)

The command words include:

...relate...; ...interpret…; ...carry out ...; …deduce...; ..explain...; ...evaluate...;

...predict..;. ...use…; ...discuss..; ...construct...; ...suggest...; ...calculate.;

...demonstrate..;.

The use of these words involves the ability to recall the appropriate material from the specification content and to apply this knowledge and understanding.

Questions in this category may include the command words listed above together with
Why…? Complete... Work out... How would you know that...? Suggest...

e.g. `Use the graph to calculate the concentration of the acid.’

`Explain why it is important for these materials to be recycled.’

`Suggest two reasons why some people are concerned about the use of these artificial flavours in foods.

Appendix F: Ideas About Science

In order to deal sensibly with science as we encounter it in everyday life, it is important not only to understand some of the fundamental scientific explanations of the behaviour of the natural world, but also to know something about science itself, how scientific knowledge has been obtained, how reliable it therefore is, what its limitations are, and how far we can therefore rely on it – and also about the interface between scientific knowledge and the wider society.

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

The aim of science is to find explanations for the behaviour of the natural world. A good explanation may allow us to predict what will happen in other situations, and perhaps to control and influence events.

There is no single 'method of science' that leads automatically to scientific knowledge. Scientists do, however, have characteristic ways of working. In particular, data, from observations and measurements, are of central importance.

One kind of explanation is to identify a correlation between a factor and an outcome. This factor may then be the cause, or one of the causes, of the outcome. In complex situations, a factor may not always lead to the outcome, but increases the chance (or the risk) of it happening. Other explanations involve putting forward a theory to account for the data. Scientific theories often propose an underlying model, which may involve objects (and their behaviour) that cannot be observed directly.

Devising and testing a scientific explanation is not a simple or straightforward process. First, we can never be completely sure of the data. An observation may be incorrect. A measurement can never be completely relied upon, because of the limitations of the measuring equipment or the person using it.

Second, explanations do not automatically 'emerge' from the data. Thinking up an explanation is a creative step. So, it is quite possible for different people to arrive at different explanations for the same data. And personal characteristics, preferences and loyalties can influence the decisions involved.

The scientific community has established procedures for testing and checking the findings and conclusions of individual scientists, and arriving at an agreed view. Scientists report their findings to other scientists at conferences and in special journals. Claims are not accepted until they have survived the critical scrutiny of the scientific community. In some areas of enquiry, it has proved possible to eliminate all the explanations we can think of but one – which then becomes the accepted explanation (for the time being).

Where possible scientists choose to study simple situations in order to gain understanding. But it can then be difficult to apply this understanding to complex, real-world situations. So there can be legitimate disagreements about how to explain such situations, even where there is no dispute about the basic science involved.

The application of scientific knowledge, in new technologies, materials and devices, greatly enhances our lives, but can also have unintended and undesirable side-effects. An application of science may have social, economic and political implications, and perhaps also ethical ones. Personal and social decisions require an understanding of the science involved, but also involve knowledge and values beyond science.

This is, of course, a simplified account of the nature of science, which omits many of the ideas and subtleties that a contemporary philosopher or sociologist of science might think important. It is intended as an overview of science in terms which might be accessible to 14-16 year old candidates, to provide a basic understanding upon which those who wish may later build more sophisticated understandings. It is important to note that the language in which it is expressed may well not be that which one would use in talking to candidates of this age.

The following pages set out in more detail the key ideas that such an understanding of science might involve, and what candidates should be able to do to demonstrate their understanding.

1 Data and their limitations

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

	Ideas about science	A candidate who understands this…
1.1	Data are crucial to science. Explanations are sought to account for known data, and data are collected to test proposed explanations.	uses data rather than opinion in justifying an explanation
1.2	We can never be sure that a measurement tells us the true value of the quantity being measured.	can suggest reasons why a measurement may be inaccurate
1.3	If we make several measurements of the same quantity, the results are likely to vary. This may be because we have to measure several individual examples (e.g. the height of cress seedlings after 1 week), or because the quantity we are measuring is varying (e.g. amount of ozone in city air, time for a vehicle to roll down a ramp), and/or because of the limitations of the measuring equipment or of our skill in using it (e.g. repeat measurements when timing an event).	can suggest reasons why several measurements of the same quantity may give different results when asked to evaluate data, makes reference to its reliability (i.e. is it repeatable?)
1.4	Usually the best estimate of the value of a quantity is the average (or mean) of several repeat measurements.	can calculate the mean of a set of repeated measurements from a set of repeated measurements of a quantity, uses the mean as the best estimate of the true value can explain why repeating measurements leads to a better estimate of the quantity
1.5	The spread of values in a set of repeated measurements give a rough estimate of the range within which the true value probably lies.	can make a sensible suggestion about the range within which the true value of a measured quantity probably lies **can justify the claim that there is/is not a 'real difference' between two measurements of the same quantity**
1.6	If a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect.	can identify any outliers in a set of data, and give reasons for including or discarding them

2 Correlation and cause

Scientists look for patterns in data, as a means of identifying possible cause-effect links, and working towards explanations.

	Ideas about science	A candidate who understands this…
2.1	It is often useful to think about processes in terms of factors which may affect an outcome (or input variable(s) which may affect an outcome variable).	in a given context, can identify the outcome and the factors that may affect it in a given context, can suggest how an outcome might be affected when a factor is changed
2.2	To investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').	can identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive feature, or the fact that they are not as a design flaw **can explain why it is necessary to control all factors thought likely to affect the outcome other than the one being investigated**
2.3	If an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.	can give an example from everyday life of a correlation between a factor and an outcome
2.4	A correlation between a factor and an outcome does not necessarily mean that one causes the other; both might, for example, be caused by some other factor.	uses the ideas of correlation and cause appropriately when discussing historical events or topical issues in science **can explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this**
2.5	In some situations, a factor increases the chance (or probability) of an outcome, but does not invariably lead to it, e.g. a diet containing high levels of saturated fat increases an individual's risk of heart disease, but may not lead to it. We also call this a correlation.	can suggest factors that might increase the chance of an outcome, but not invariably lead to it can explain that individual cases do not provide convincing evidence for or against a correlation
2.6	To investigate a claim that a factor increases the chance (or probability) of an outcome, we compare samples (e.g. groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples the more confident we can be about any conclusions drawn.	can evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched **can use data to develop an argument that a factor does/does not increase the chance of an outcome**
2.7	Even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.	**can identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link**

3 Developing explanations

Scientific explanations are of different types. Some are based on a proposed cause-effect link. Others show how a given event is in line with a general law, or with a general theory. Some theories involve a model, which may include objects or quantities that cannot be directly observed, which accounts for the things we can observe.

	Ideas about science	A candidate who understands this…
3.1	A scientific explanation is a conjecture (a hypothesis) about how data might be accounted for. It is not simply a summary of the data, but is distinct from it.	can identify statements which are data and statements which are (all or part of) an explanation can recognise data or observations that are accounted for by, or conflict with, an explanation
3.2	An explanation cannot simply be deduced from data, but has to be thought up imaginatively to account for the data.	can identify imagination and creativity in the development of an explanation
3.3	A scientific explanation should account for most (ideally all) of the data already known. It may explain a wide range of observations. It should also enable predictions to be made about new situations or examples.	can justify accepting or rejecting a proposed explanation on the grounds that it: • accounts for observations • **and/or provides an explanation that links things previously thought to be unrelated** • **and/or leads to predictions that are subsequently confirmed**
3.4	Scientific explanations are tested by comparing predictions made from them with data from observations or experiments.	can draw valid conclusions about the implications of given data for a given explanation, in particular: • recognises that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct** • recognises that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong, **and that this may decrease our confidence in the explanation**
3.5	For some questions that scientists are interested in, there is not yet an answer.	can identify a scientific question for which there is not yet an answer, **and suggest a reason why**

4 The scientific community

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

	Ideas about science	A candidate who understands this…
4.1	Scientists report their findings to other scientists through conferences and journals. Scientific findings are only accepted once they have been evaluated critically by other scientists.	can describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists can recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well-established ones
4.2	Scientists are usually sceptical about findings that cannot be repeated by anyone else, and about unexpected findings until they have been replicated.	can identify absence of replication as a reason for questioning a scientific claim **can explain why scientists regard it as important that a scientific claim can be replicated by other scientists**
4.3	Explanations cannot simply be deduced from the available data, so two (or more) scientists may legitimately draw different conclusions about the same data. A scientist's personal background, experience or interests may influence his/her judgments. (e.g. data open to several interpretations; influence of personal background and experience; interests of employers or sponsors).	can suggest plausible reasons why scientists involved in a scientific event or issue disagree(d)
4.4	A scientific explanation is rarely abandoned just because some data are not in line with it. An explanation usually survives until a better one is proposed. (e.g. anomalous data may be incorrect; new explanation may soon run into problems; safer to stick with ideas that have served well in the past).	**can suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it**

5 Risk

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

	Ideas about science	A candidate who understands this…
5.1	Everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.	can explain why it is impossible for anything to be completely safe can identify examples of risks which arise from a new scientific or technological advances can suggest ways of reducing specific risks
5.2	We can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.	can interpret and discuss information on the size of risks, presented in different ways.
5.3	To make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.	**can discuss a given risk, taking account of both the chance of it occurring and the consequences if it did**
5.4	People are often willing to accept the risk associated with an activity if they enjoy or benefit from it. We are also more willing to accept the risk associated with things we choose to do than things that are imposed, or that have short-lived effects rather than long-lasting ones.	can suggest benefits of activities that have a known risk can offer reasons for people's willingness (or reluctance) to accept the risk of a given activity can discuss personal and social choices in terms of a balance of risk and benefit
5.5	If you are not sure about the possible results of doing something, and if serious and irreversible harm could result from it, then it makes sense to avoid it (the 'precautionary principle').	**can identify, or propose, an argument based on the 'precautionary principle'**
5.6	Our perception of the size of a risk is often very different from the actual measured risk. We tend to over-estimate the risk of unfamiliar things (like flying as compared with cycling), and things whose effect is invisible (like ionizing radiation).	**can distinguish between actual and perceived risk, when discussing personal and social choices** **can suggest reasons for given examples of differences between actual and perceived risk**
5.7	Reducing the risk of a given hazard costs more and more, the lower we want to make the risk. As risk cannot be reduced to zero, individuals and/or governments have to decide what level of risk is acceptable.	**can explain what the ALARA (as low as reasonably achievable) principle means and how it applies in a given context**

6 Making decisions about science and technology

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

	Ideas about science	A candidate who understands this…
6.1	Science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.	In a particular context, can identify the groups affected and the main benefits and costs of a course of action for each group
6.2	Scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.	can explain the idea of sustainable development, and apply it to specific situations
6.3	In many areas of scientific work, the development and application of scientific knowledge are subject to official regulations and laws (e.g. on the use of animals in research, levels of emissions into the environment, research on human fertility and embryology).	shows awareness that scientific research and applications are subject to official regulations and law
6.4	Some questions, such as those involving values, cannot be addressed by scientists.	can distinguish questions which could be addressed using a scientific approach, from questions which could not
6.5	Some applications of science have ethical implications. As a result, people may disagree about what should be done (or permitted).	where an ethical issue is involved, can: • say clearly what this issue is • summarise different views that may be held
6.6	In discussions of ethical issues, one common argument is that the right decision is one which leads to the best outcome for the majority of people involved. Another is that certain actions are unnatural or wrong, and should not be done in any circumstances. A third is that is that it is unfair for a person to choose to benefit from something made possible only because others take a risk, whilst avoiding that risk themselves.	in a particular context, can identify, and develop, arguments based on the ideas that: • the right decision is the one which leads to the best outcome for the majority of people involved • certain actions are never justified because they are unnatural or wrong
6.7	In assessing any proposed application of science, we must first decide if it is technically feasible. Different decisions on the same issue may be made in different social and economic contexts.	**in a particular context, can distinguish what can be done (technical feasibility), from what should be done (values)** **can explain why different courses of action may be taken in different social and economic contexts**

Appendix G: Science Explanations

Material in *italics* is from earlier Key Stages. This material will not be the focus of assessment items but clearly there will be instances where an understanding of material from earlier stages will underpin an understanding of Key Stage 4 material. Material in bold is only intended for Higher Tier candidates.

SE 1 Chemicals

a *All materials, living and non-living, are made of chemicals. There are millions of different chemicals in the world around us. They are all made up of about 90 simple chemicals called elements. Elements are made up of very tiny particles called atoms. The atoms of each element are the same as, or very similar to, each other and are different from the atoms of other elements.*

b *The atoms of different elements can join together (combine) to form other substances called compounds. There are many different ways that atoms of elements can join together so there is a very large number of different compounds.*

c In many compounds, atoms of different elements are joined up to make larger building blocks called molecules. No matter how a compound is made, or where it comes from, the types of atom in its molecules, and the number of atoms of each type in each molecule, are always the same. The atoms in each molecule of a compound can be shown in the formula for the compound; water molecules, for example, consist of two atoms of hydrogen joined to one atom of oxygen so the formula for a molecule of water is H_2O.

d The properties of a compound are completely different from the properties of the elements that it is made from.

SE 2 Chemical change

a In chemical reactions, new chemicals are produced. This happens because atoms that were there at the start (in the reactants) have been re-arranged in some way (to form the products):

- atoms that were joined together at the start may have separated;
- atoms that were separate at the start may have joined together;
- atoms that were present at the start may have separated and then joined together in different ways.

For example, when fuels burn, atoms of carbon and/or hydrogen from the fuel combine with atoms of oxygen from the air to produce carbon dioxide and/or water (hydrogen oxide). If the fuel contains any sulfur, sulfur dioxide will also be produced.

b No atoms are destroyed in chemical reactions and no new atoms are created.

SE 3 Materials and their properties

a All the materials that we use are chemicals or mixtures of chemicals. We obtain them, or make them, from materials that we find in the world around us, e.g. in non-living things such as the Earth's crust or in living things such as plants or animals.

b We use materials that have suitable properties for the jobs that we want them to do.

Solid materials can differ with respect to:

- their melting points;
- how strong they are (in tension and in compression);
- how stiff they are;
- how hard they are;
- their density.

c	The properties of solid materials depend on how the particles (e.g. molecules) it is made from are arranged and held together in the solid. For example, the stronger the forces between the molecules, the more energy they need to break out of the solid structure and the hotter the solid must be before it melts (in other words, the higher the melting point).
d	An understanding of why a material has particular properties can help us find ways of improving the properties of a material to make it even more useful.
SE 4	**The interdependence of living things**
a	*All living things need materials and energy from their surroundings to stay alive. They also produce waste materials that they must get rid of into their surroundings. The Sun provides the energy that all living things need. The leaves of green plants use the energy in sunlight to make a sugar called glucose from carbon dioxide (taken from air) and water (taken by roots from the ground). This process is called photosynthesis; oxygen is the waste product. Plants use glucose and chemicals (minerals) from the soil to make all the other chemicals that they need to live and grow. Animals obtain the materials they need to live and grow by eating plants (or by eating other animals that have eaten plants). They obtain the energy they need by reacting glucose (from their food) with oxygen (from the air). This process happens in their cells and is called respiration; carbon dioxide and water are the waste products.*
b	*We can show what eats what else in a particular habitat (or ecosystem) by using a food web.*
c	There is often competition between different species of animals or plants in a particular habitat for the same space or the same food source. A change which affects one species in a food web also affects other species that are part of the same food web. Ecosystems can often adjust to changes but large disruptions may change an ecosystem permanently.
SE 5	**The chemical cycles of life**
a	The materials that living things are made from are used over and over again: they are re-cycled. For example, carbon is a vital element in all the molecules that living things are made from. The continual cycling of compounds containing carbon is called the carbon cycle
b	Decomposers, such as certain microbes, break down the dead bodies of plants and animals. They play a very important part in the re-cycling of materials. Atoms of the element nitrogen are found in the protein molecules that are important in all living cells. **The continual cycling of compounds containing nitrogen is called the nitrogen cycle.** **Other elements that are important in living things, for example potassium and phosphorus, are also continually re-cycled.**
c	Farmers use the same land over and over again to grow plants and animals for food. This means that chemicals containing nitrogen, **potassium and phosphorus** are lost from the soil. Unless these are replaced, the land will gradually produce less and less food.
SE 6	**Cells as the basic units of living things**
a	*All living things (organisms) are made from small units called cells.* Cells are 'chemical factories': the chemical reactions that must happen for living things to stay alive take place inside cells. For example cells make protein molecules and obtain the energy needed to do this by reacting glucose with oxygen (respiration).
b	*Most organisms are made up of many different types of cell. Different types of cell are built in different ways* (they have a different structure) *so that they can do their particular job* (function). *We say that the cells are specialised*.

SE 7 Maintenance of life

a *All living things need to maintain themselves if they are to survive. Animals, including humans, need to take in a balanced mix of proteins, carbohydrates, fats, minerals, vitamins and water in their diet.* Larger molecules are broken down in the human gut by chemicals called enzymes to form smaller molecules. Starch is digested into glucose, and proteins are digested into amino acids. These smaller molecules pass through the wall of the small intestine into the blood which transports them to all the cells of the body.

b In cells glucose reacts with oxygen to provide energy; this process is called respiration. Cells use some of this energy to build up amino acids into the much larger molecules of many different proteins.

c *In humans and in many other animals, the heart pumps blood around the body. The lungs provide the blood with oxygen which is transported from the lungs, via the heart, to all the cells of the body* (including the cells of the heart itself). Regular, but not excessive, exercise reduces the risk of developing heart disease. The risk of heart disease is increased by poor diet, stress, and such activities as cigarette smoking and high levels of alcohol consumption.

d The cells in the body produce waste materials which are toxic and so must be got rid of. *The carbon dioxide that is produced from glucose and oxygen by cells when they respire is transported to the lungs where it is breathed out*. Urea, produced by the breakdown of protein, is excreted from the body by the kidneys in urine. *Undigested food never actually enters our bloodstream but passes through our gut and leaves as faeces.*

e *Organisms are more likely to survive if they can sense, in their surroundings, the things that they need (e.g. water, food or light) and what they need to avoid (e.g. harmful chemicals, extreme temperatures or predators)*. Multicellular organisms have sensor cells that are specialised to detect things in their surroundings and effector cells that are specialised to respond to what is detected. Multicellular animals have nervous systems, comprising nerve cells (neurones) which link sensor cells (in e.g. eyes, ears and skin) to effector cells (e.g. muscles). In humans, and other vertebrates, this linking is coordinated via a central nervous system (spinal cord and brain). Hormones are chemicals which travel in the blood and bring about slower, longer-lasting responses. **Nervous and hormonal communication systems are involved in maintaining a constant internal environment (homeostasis).**

SE 8 The gene theory of inheritance

a *Most animals and plants reproduce by sexual reproduction. In this process a male sex cell joins with a female sex cell to form a fertilised egg. This single cell then grows by cell division and differentiation to form a new individual. Differences between individuals are caused by both genes and environment.*

b Instructions for how an organism develops are found in the nucleus of its cells. The information consists of many pairs of genes which control what the organism is like, for example its shape, its size, its colour and many other characteristics. Each gene affects a specific characteristic. Genes are sections of very long DNA molecules that make up the chromosomes in the nuclei of cells, so each chromosome contains a large number of genes. Chromosomes occur in pairs. One chromosome from each pair came originally from each parents' sex cell. Both chromosomes in a pair carry the same genes in the same place, but genes in a pair are often slightly different versions (called alleles).

c Offspring may be similar to their parents because of this combination of maternal and paternal alleles. Different offspring from the same parents receive different combinations of the alleles of all the genes, so they can differ from each other in many ways.

d Genes are instructions for a cell that describe how to make proteins.

e	Because all organisms use the same genetic code to carry units of information, a gene can be taken from the nucleus of one cell and placed into a different cell. This is called genetic modification. The gene may be from a different organism. This process produces cells with a new combination of genes, and the resulting organism will display new characteristics which may be useful to humans.
f	Bacteria, simple animals and most plants can reproduce without sex (asexually). A new organism just starts to grow from a small part of the older one. Each time a body cell divides, the chromosomes (and hence the genes) are copied so that each body cell contains an identical set of genes. So new individuals produced asexually have exactly the same genes in their cells as the parent (they are called clones). This means that they also have very similar characteristics. Any differences are due only to environment.
g	The cells of multicellular organisms become specialised during the early development of the organism. However, some remain unspecialised and can develop into any type of plant cell. This is why clones of plants can often be grown from small parts (cuttings) of their roots, stems or leaves.
SE 9	The theory of evolution by natural selection
a	The first living things developed from molecules that could copy themselves. These molecules were produced in the conditions on Earth at that time. Most biologists believe that the many different species of living things that now exist, and the many more species which once existed but have died out (become extinct) all evolved from the same, very simple living things that first appeared on Earth about 3 500 million years ago.
b	Evolution happened, and continues to happen, mainly because of a process called natural selection. Individuals of the same species are not identical; their characteristics vary. If the environment changes, or if vital resources become scare, individuals with certain characteristics may have a better chance of surviving long enough to reproduce. This means that there will be more individuals with these characteristics in the next generation and, if the environment stays the same, even more in the generation after that. This process is called <u>natural</u> selection because it produces changes like the ones deliberately produced by farmers or pet-owners when they select the animals or plants with the characteristics that they prefer for breeding the next generation. Natural selection, however, does not involve people making deliberate selections.
c	**The genes that control the way an organism develops can be changed by certain chemicals, by ionising radiation and by copying errors when chromosomes are copied. This is called mutation. Mutations can cause body cells to reproduce in an uncontrolled way (cancer). Mutated genes in sex cells may be passed on to offspring and produce new characteristics. Mutations usually have such a harmful effect that the fertilised eggs do not develop. Some mutations, though, have no effect on an individual or may even improve the chance of surviving and reproducing. When this happens, the mutated gene is passed on and becomes more common.**
d	Over a very long period of time (and many generations) new species have evolved. **The combined effects of mutations, environmental changes and natural selection can produce new species. The 3 500 million years since life on Earth first evolved are believed by most biologists to have been long enough for all the living things that exist (or that have existed) to have evolved in this way.** A large change in the environment may cause a whole species to become extinct.
e	**Evolution has happened in the way that it has because of random mutation, random breeding and natural selection. If the conditions on Earth had, at any stage, been different from what they actually were, evolution by natural selection would have produced different results.**

SE 10	The germ theory of disease
a	*Many diseases are caused by small organisms (microbes) such as bacteria, fungi and viruses. These are present in the environment and can get inside the bodies of humans or other organisms.* The body has natural barriers to reduce the likelihood of harmful microorganisms entering the body from outside. Our skin acts as a barrier and chemicals in tears and sweat and acid in the stomach kill microorganisms.
b	If they get inside a body, the microorganisms can reproduce rapidly. The reproducing microorganisms may cause damage to cells or produce poisons (toxins) they produce to cause the symptoms of the disease. Our bodies have an immune system to defend themselves against the microorganisms that cause infections. Some of our white blood cells can surround microorganisms and destroy them by digesting them. Other white blood cells produce chemicals called antibodies that help destroy microorganisms. A different antibody is needed to recognise each different type of microorganism. Once your body has made the antibody to kill a particular microorganism it can make that antibody again very quickly. This means that your body is then protected against that particular microorganism. We can use this idea to immunise people against diseases: we deliberately infect (vaccinate) them with a form of the microorganism that has been altered so that it is unable to cause disease. The body produces antibodies and, on future exposure to the natural form of the microorganism, protective antibodies will be produced quickly. **Vaccines are not so effective against influenza because there are so many different strains of the virus that causes the disease. As yet, there is no effective vaccination against AIDS, a disease caused by the virus called HIV, because the virus has a high mutation rate within the body.**
c	Sometimes microorganisms against which we have not been immunised get into our bodies. These can cause illness, or even death, before our immune systems can destroy them. In such cases, we can kill bacteria and fungi, but not viruses, using chemicals called antibiotics. Over a period of time, however, bacteria and fungi may become resistant to antibiotics. **Random mutations in the genes of these microorganisms sometimes lead to varieties which are less affected by the antibiotic. These have a better chance of surviving a course of antibiotic treatment, especially if the patient does not complete the course when they feel better.** To prevent this happening we should only use antibiotics when really necessary and always complete the prescribed course.

SE 11	Energy sources and use
a	*We often need a source of energy to change things in some way or make things happen. Fuels (e.g. coal, oil, natural gas and wood) are very valuable because, when oxygen is also available, they are very concentrated sources of energy. There is, however, only a limited amount of fossil fuels (coal, oil and natural gas) in the Earth's crust so they are a non-renewable energy source. Wood, from trees, is a renewable fuel when properly managed.*
b	In some situations, we can use less concentrated renewable energy sources (for example, wind, waves, tides, dammed rainwater or radiation from the Sun) instead of fuels. Radioactive elements such as uranium release energy as they decay. This can heat up rocks in the Earth's crust (geothermal energy). We can also make uranium atoms release a lot of energy by splitting them in nuclear reactors (nuclear fission).
c	*Moving objects have (kinetic) energy; (potential) energy can be stored in objects that are lifted up against the force of gravity and in elastic objects that have been stretched, compressed, bent or twisted; a hot object has more (thermal) energy than the same object when it is cooler.*
d	Energy can be transferred from one object to another in various ways: • mechanically (by one object pushing or pulling another); • thermally (by conduction or convection of energy from a high temperature region to a low temperature region); • electrically (by an electric current); • by radiation.

e Electricity is very convenient because it can readily be transferred from where it is generated to where it is needed, and can then readily be used to produce movement (kinetic) energy, light, sound or heating as required. Electricity is, however, a secondary energy source; another (primary) energy source is needed to generate it. In most power stations this is done by using a fuel (fossil or nuclear) to boil water and then using the steam to turn a turbine, which rotates a generator to generate electricity.

SE 12 Radiation

a Some processes in which one object affects another some distance away fit the following general model:

$$\text{source} \xrightarrow{\text{radiation}} \text{receiver}$$

One object (a source) emits radiation (of some kind). This travels from the source and can affect another object (a receiver) some distance away. When radiation strikes an object, some may pass through it, or be reflected or absorbed. A detector of radiation is simply an absorber which produces some observable response to the radiation it has absorbed. When radiation is absorbed it ceases to exist as radiation; usually it simply heats the absorber.

b Light is one of a family of radiations. The spectrum of visible light (red→violet) can be extended in both directions:

radio microwave infrared red light violet ultraviolet X-ray gamma

The whole family of radiations is called the electromagnetic spectrum.

c Some types of electromagnetic radiation when absorbed do not just cause heating; X-rays, gamma rays and ultraviolet radiation can cause damage to the molecules in living cells. Radiation that can do this is called ionising radiation. **When ionising radiation strikes molecules it can make them more likely to react chemically.** Exposure to large amounts of ionising radiation can kill living cells; smaller amounts may causes changes to cells which can make them grow in an uncontrolled way, causing cancer.

SE 13 Radioactivity

a Some elements emit bursts of radiation all the time. even if they are broken into very small pieces, dissolved or chemically reacted to form new chemicals. Such elements or compounds containing such elements are called radioactive materials.

b There are three types of radiation emitted by radioactive materials:

- alpha (α) radiation — which is easily absorbed, for example by a thin layer of paper or a few centimetres of air;
- beta(β) radiation — which passes fairly easily through many substances but can be absorbed by a thin sheet of any metal;
- gamma(γ) radiation — which passes very easily through most substances (it is penetrating) and needs a thick sheet of a dense metal such as lead, or concrete several metres thick, to absorb most of it.

c Most types of atom never change; they are stable. But radioactive materials contain unstable atoms. The nucleus of an unstable atom can break up (decay) and when this happens it emits radiation. An atom of a different atom is left behind. As time goes by radioactive materials contain fewer and fewer unstable atoms and so become less and less radioactive and emit less and less radiation. The time it takes for a radioactive material to become half as radioactive as it was to begin with (because half of the unstable atoms that were originally there have decayed) is called the half-life. Some radioactive materials have half-lives of billions of years; others have half-lives of a fraction of a second.

d All three types of radiation from radioactive materials are ionising radiations. When such radiation strikes living cells, these may be killed or become cancerous (i.e. grow in an uncontrolled way). Ionising radiation can be used to kill harmful cells and is used in this way to treat cancer and to sterilise surgical instruments. For each millimetre that it travels through a living cell, alpha radiation is most likely to cause damage and gamma radiation is the least likely to cause damage. The risk of cancer from radiation damage increases steadily with the amount of radiation that a person is exposed to.

e Radioactive materials can affect living cells in two different ways:

- the radiation from a radioactive material can reach a person (or other organism). This is irradiation;
- bits of the radioactive material can get into, or on to the person, or their clothes. This is contamination.

We are irradiated and contaminated all the time because of radioactive materials in the air, in building materials, in the soil and in our food. Medical treatments, and occupational or medical exposure to radioactive materials, increase the dose that some individuals receive. The dose received by people who are regularly exposed to radiation is carefully monitored.

f Some unstable atoms, for example atoms of uranium and plutonium, can be made to split into two roughly equal parts. This is called nuclear fission. The amount of energy released is much larger, per atom, than in a chemical reaction. Nuclear fission, at a very carefully limited rate, is used in nuclear power stations. Nuclear fission that is allowed to occur at a rapidly accelerating rate leads to a massive explosion; this is how nuclear weapons work.

SE 14 The Earth

a The Earth is a sphere with a radius of about 6 400 kilometres. It consists of several layers:

- on the outside, where we live, is a relatively thin crust made from solid rocks;
- below the crust, there is a thick layer of rock called the mantle which goes down about halfway to the centre of the Earth.

The rock which makes up the mantle is very hot but under pressure. It melts when the pressure is reduced. The molten rock (magma) formed in this way rises and cause volcanic eruptions.

Some changes in the Earth's surface are very slow and take place over a very long time. The mountains of the Earth's crust are gradually eroded so that the Earth's surface would be worn down to sea level if parts of the Earth's crust were not being uplifted to form new mountains.

Early in the 20th century, Wegener suggested that mountains might be formed as slowly drifting continents collided with each other. He suggested that the jigsaw fit of the east coast of South America and the west coast of Africa, together with the matching patterns of rocks and fossils, were evidence of continental drift. Most geologists at the time rejected this theory.

By the mid-20th century geologists:

- knew that the mantle, even when solid, can flow very slowly;
- knew that the inside of the Earth is kept hot by the energy released when the atoms of radioactive elements inside the Earth decay;
- had discovered [mid-]oceanic ridges **and evidence that these were caused by sea-floor spreading.**

b	The theory of plate tectonics is the unifying theory of Earth Science, explaining many rock cycle processes and changes to the Earth's surface. According to this theory, the outer rigid layer of the Earth consists of a number of separate pieces called tectonic plates. These are constantly, but extremely slowly, moving. Movement of the mantle, caused by heating from radioactive decay, contributes to the movement of the plates. At mid-ocean ridges, where plates are moving apart, molten rock (magma) rises up between the plates. In some places the plates are moving towards each other. This produces tremendous pressures that can deform rocks into mountain chains. The colliding plates may also cause earthquakes and volcanoes. An earthquake occurs when two blocks of rock, that are held together by friction, move suddenly because of the forces acting on them. Earthquakes occur where the edges of plates slide past each other, where plates collide and the more dense oceanic plate sinks beneath a less dense continental plate, and where faulting occurs near the mid-ocean ridges
c	The Earth is surrounded by a thin layer of atmosphere which allows light radiated from the Sun to pass through. This radiation provides the energy for plants to make glucose using carbon dioxide and water by the process of photosynthesis. Radiation from the Sun is absorbed by the Earth's surface, making it warmer. Different infrared radiation is then emitted by the Earth and absorbed by the atmosphere so keeping the Earth warmer than it would otherwise be. This is called the greenhouse effect. The temperature on the Earth's surface is often high enough for water to be liquid. The atmosphere also contains oxygen (a waste product of photosynthesis). This is needed by animals for respiration. **Oxygen is acted on by radiation to produce ozone in the upper atmosphere. This absorbs ultraviolet radiation, and protects living organisms, especially animals, from its harmful effects.**
SE 15	The Solar System
a	*The Earth is a planet that moves round the Sun. It takes one year to make a complete orbit. Other planets also move around the Sun. The Sun, the planets and other smaller bodies such as satellites (moons) of planets, asteroids and comets make up the Solar System.*
b	The Sun is a star. It was formed, **about 5000 million years ago**, in the same way as other stars by clouds of gas, being drawn together by the force of gravity. In stars, hydrogen **nuclei join (fuse)** and energy is released. The Sun will continue to shine for another 5000 million years. It will then become red giant, engulfing or evaporating the Earth, and finally, a very dense black dwarf.
SE 16	The Universe
a	The Sun is just one of billions of stars which are clustered in a group called the Milky Way galaxy. The diameter of the galaxy is 100 000 light years. The Universe is made up of billions of galaxies, many times their own diameter apart, so it is vast.
b	Distant galaxies are moving away from us. This means that the Universe is getting bigger (expanding). The more distant a galaxy is, the faster it is moving away. This suggests that the Universe might have begun in one place with a huge explosion (the 'big bang') about 13700 million years ago.
c	We do not know whether the Universe will keep on expanding for ever or whether the force of gravity between the galaxies will slow them down enough to stop them moving apart so they will then start moving together again. Eventually there would then be a 'big crunch'.
d	There are billions of galaxies, each containing billions of stars. Astronomers have detected planets around some nearby stars. If even a small proportion of stars have planets, many scientists think that it is very likely that life, and perhaps even intelligent life, exists elsewhere in the Universe.

Appendix H: Periodic Table

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

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

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