GCSE

Chemistry A

Twenty First Century Science Suite

OCR GCSE in Chemistry A J634

Foreword to the Second Edition

This Second Edition of the OCR GCSE Chemistry 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.

QAN 100/5566/6

Contents

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 our 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 Chemistry Specification

This booklet contains OCR's GCSE specification in Chemistry for teaching from September 2006 and first certification in June 2008.

This specification aims to provide candidates with the scientific understanding needed to progress to further studies of chemistry, should they choose to undertake them. Candidates should gain an insight into:

- what is involved in being a practitioner of science;
- how scientists develop scientific understanding of ourselves and the world we inhabit;
- how these understandings can be applied to the benefit of humanity.

Candidates must have a broad understanding of the scientific ideas that provide a conceptual foundation for further studies of science. 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 on the issues that arise when scientific knowledge is put to practical use. These are referred to as 'Ideas about Science' (IaS). This specification provides a combination of these two essential elements.

This specification comprises seven teaching modules which are assessed through four units. Candidates take Units 1, 2 and 3 **and** either Unit 4 **or** 5.

Unit	Unit Code	Title	Duration	Weighting	Total Mark
1	A321	Chemistry A Unit 1 – modules C1, C2, C3	40 mins	16.7%	42
2	A322	Chemistry A Unit 2 – modules C4, C5, C6	40 mins	16.7%	42
3	A323	Chemistry A Unit 3 – Ideas in Context plus C7	60 mins	33.3%	55
4	A329	Chemistry A Unit 4 – Practical Data Analysis and Case Study	-	33.3%	40
5	A330	Chemistry A Unit 5 – Practical Investigation	-	33.3%	40

1.3 Qualification Titles and Levels

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

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 in a range of domestic, industrial and environmental contexts;
- acquire an understanding of scientific ideas, how they develop, the factors which may affect their development and their power and limitations;
- plan and carry out investigative tasks, considering and evaluating critically their own data and that obtained from other sources, and using ICT where appropriate;
- use electronic (internet, CD ROMs, databases, simulations etc.) and/or more traditional sources or information (books, magazines, leaflets etc.) to research and plan an investigation;
- select, organise and present information clearly and logically, using appropriate scientific terms and conventions, and using ICT where appropriate;
- interpret and evaluate scientific data from a variety of sources.

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

Modules C1–6 are designed to be taught in approximately half a term, in 10% of the candidates' curriculum time. Module C7 is designed to be taught in approximately one and a half terms at 10% curriculum time.

A module defines the required teaching and learning outcomes.

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

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 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 is does its job? How should we manage the wastes that arise from our use of materials?

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 C4: Chemical Patterns

- What are the patterns in the properties of elements?
- How do chemists explain the patterns in the properties of the elements?
- How do chemists explain the properties of compounds of Group 1 and Group 7 elements?

Module C5: Chemicals of the Natural Environment

- What types of chemicals make up the atmosphere and hydrosphere?
- What types of chemicals make up the Earth's lithosphere?
- Which chemicals make up the biosphere?
- How can we extract useful metals from minerals?

Module C6: Chemical Synthesis

- Chemicals and why we need them
- Planning, carrying out and controlling chemical synthesis

Module C7: Further Chemistry

- Alcohols, carboxylic acids and esters
- Energy changes in chemistry
- Reversible reactions and equilibria
- Analysis
- Green chemistry

3 Content

Layout of Module Content

The specification content of modules C1, C2 and C3 is based on a set of Science Explanations and the Ideas about Science (see Appendices F and G). The presentation of the content of these modules recognises these ideas about science in the presentation of the synopsis page, which has a layout shown here.

Issues for citizens	Questions that science may help to answer
e.g. How do I make sense of data about air pollution?	e.g. What chemicals make up air, and which ones are pollutants?
Science Explanations	**Ideas about Science**
e.g. SE1 Chemicals	e.g. IaS 1 Data and its limitations

The overview identifies:

- issues for citizens 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 can help 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.

Modules C4, C5, C6 and C7 also begin with a synopsis page, which outlines the content of 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 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.

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
SE1 Chemicals	IaS 1 Data and its limitations
SE2 Chemical change	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 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 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.

MODULE C2: MATERIAL CHOICES

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

1. understand 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 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 5 b,c The chemical cycles of life	IaS 5.1–5.5 Risk
SE 7 a,d Maintenance of life	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 my 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 C4: CHEMICAL PATTERNS – OVERVIEW

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

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

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

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

ICT Opportunities

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

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

Use of ICT in teaching and learning can include:

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

MODULE C4: CHEMICAL PATTERNS

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

1. recall that atoms of each element have different proton numbers;
2. understand that arranging the elements in order of their proton numbers gives repeating patterns in the properties of elements;
3. be able to use the Periodic Table to obtain the names, symbols, relative atomic masses and proton numbers of elements;
4. recall that a group of elements is a vertical column in the Periodic Table and that the elements have similar properties;
5. recall that a period is a row of elements in the Periodic Table;
6. be able to use the Periodic Table to classify an element as a metal or non-metal;
7. be able to use patterns in the Periodic Table to interpret data and predict properties of elements.

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

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

MODULE C4: CHEMICAL PATTERNS

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

22. be able to use qualitative and quantitative data to identify patterns and make predictions about the properties of the group 7 elements (for example melting point, boiling point, formulae of compounds and relative reactivity);
23. recall and be able to give examples to show that the halogens become less reactive as the group is descended;
24. explain the safety precautions necessary when working with the halogens;
25. recall the formulae of:
    - hydrogen, water and halogen molecules;
    - the halides and hydroxides of group 1 metals;
26. **be able to balance unbalanced symbol equations;**
27. **be able to write balanced equations to describe the chemical reactions of group 1 metals with water and halogens;**
28. recall and use state symbols: (s), (l), (g) and (aq) in equations.

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

1. describe the structure of an atom in terms of protons and neutrons in a very small central nucleus with electrons arranged in shells around the nucleus;
2. recall the relative masses and charges of protons, neutrons and electrons;
3. recall that in any atom the number of electrons equals the number of protons;
4. recall that all the atoms of the same element have the same number of protons;
5. recall that the elements in the modern Periodic Table are arranged in order of proton number;
6. recall that some elements emit distinctive flame colours when heated (for example lithium, sodium and potassium);
7. understand that the light emitted from an element gives a characteristic line spectrum;
8. understand that the study of spectra has helped chemists to discover new elements;
9. understand that the discovery of some elements depended on the development of new practical techniques (for example spectroscopy);
10. be able to use simple conventions (for example 2.8.1 or dots in circles) to represent the electron arrangements in the atoms of the first 20 elements in the Periodic Table;
11. recall that a shell (or energy level) fills across a period;
12. **understand that the chemical properties of an element are determined by its electron arrangement, illustrated by the electron configurations of the atoms of elements in groups 1 and 7.**

MODULE C4: CHEMICAL PATTERNS

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

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

MODULE C5: CHEMICALS OF THE NATURAL ENVIRONMENT – OVERVIEW

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

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

The second topic uses chemicals in the Earth's crust, such as silicon dioxide, to demonstrate and describe the properties of giant structures with strong covalent bonding. The third topic shows that the natural environment is not static but that elements move between the spheres. The study of natural cycles features the nature of some chemicals in the biosphere such as proteins. The final topic covers the distribution, structure and properties of metals through a study of their extraction from ores. This includes the use of relative atomic masses to give a quantitative interpretation of chemical formulae.

Topics
C5.1 What types of chemicals make up the atmosphere and hydrosphere?
The structure and properties of chemicals found in the atmosphere and hydrosphere.
C5.2 What types of chemicals make up the Earth's lithosphere?
Relating the properties of chemicals to their giant structure using examples found in the Earth's lithosphere.
C5.3 Which chemicals make up the biosphere?
Composition of chemicals found in the biosphere and the natural cycles of elements between the spheres.
C5.4 How can we extract useful metals from minerals?
Relating the structure and properties of metals to suitable methods of extraction. Using ionic theory to explain electrolysis. Discussing issues relating to metal extraction and recycling.

ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, modelling molecules and giant structures to explain properties.

Use of ICT in teaching and learning can include:

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

MODULE C5: CHEMICALS OF THE NATURAL ENVIRONMENT

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

1. recall that dry air consists of gases, some of which are elements (for example oxygen, nitrogen and argon) and some compounds (for example carbon dioxide);
2. recall the symbols for the atoms and molecules of these gases in the air;
3. recall that most non-metal elements and most compounds between non-metal elements are molecular;
4. understand that some molecular elements and compounds have low melting and boiling points;
5. interpret qualitative and quantitative data about the properties of molecular elements and compounds, for example melting and boiling points;
6. understand that the elements and compounds in the air are gases because they consist of small molecules with weak forces of attraction between the molecules;
7. understand that pure molecular compounds do not conduct electricity because their molecules are not charged;
8. **understand that bonding within molecules is covalent and arises from the electrostatic attraction between the nuclei of the atoms and the electrons shared between them: covalent bonds are strong;**
9. translate between representations of molecules including molecular formulae, 2-D diagrams in which covalent bonds are represented by lines and 3-D diagrams for:
   - elements that are gases at 20°C;
   - simple molecular compounds;
10. recall that the Earth's hydrosphere (oceans) consists mainly of water with some dissolved compounds;
11. recall that sea water in the hydrosphere is 'salty' because it contains dissolved ionic compounds called salts;
12. understand that solid ionic compounds form crystals because the ions are arranged in a regular way;
13. understand that ions in a crystal are held together by the attraction between opposite charges: this is ionic bonding;
14. understand how the physical properties of solid ionic compounds (melting point, boiling point, electrical conductivity) relate to their giant, three-dimensional structures;
15. describe what happens to the ions when an ionic crystal dissolves in water;
16. explain that ionic compounds conduct electricity when dissolved in water because the ions are charged and they are able to move around independently in the liquid;
17. **be able to work out the formulae for salts in the sea given a table of charges on ions (for example sodium chloride, magnesium chloride, magnesium sulfate, potassium chloride and potassium bromide.).**

MODULE C5: CHEMICALS OF THE NATURAL ENVIRONMENT

C5.2 What types of chemicals make up the Earth’s lithosphere?

1. recall that the Earth’s lithosphere (the rigid outer layer of Earth made up of the crust and the part of the mantle just below it) is made up of a mixture of minerals;
2. recall that silicon, oxygen and aluminium are very abundant elements in the crust;
3. be able to interpret data about the abundances of elements in rocks.
4. recall that much of the silicon and oxygen is present in the Earth’s crust as the compound silicon dioxide;
5. recall the properties of silicon dioxide (for example hardness, melting point, electrical conductivity and solubility in water);
6. explain the properties of silicon dioxide in terms of a giant structure of atoms held together by strong covalent bonding (for example melting point, boiling point, hardness, solubility and electrical conductivity)
7. understand that silicon dioxide is found as quartz in granite, and is the main constituent of sandstone;
8. understand that some minerals are valuable gemstones because of their rarity, hardness and appearance;
9. **interpret data and explain the uses and properties of other elements and compounds with giant covalent structures (no recall expected).**

C5.3 Which chemicals make up the biosphere?

1. understand that living things are mainly made up from compounds containing the elements carbon, hydrogen, oxygen and nitrogen with small amounts of other elements such as phosphorus and sulfur;
2. interpret data about the percentage composition of carbohydrates, proteins, fats and DNA;
3. recall that carbohydrates, proteins and DNA are molecular;
4. given a diagram of a molecule, identify the elements in the compound and write its formula;
5. interpret flow charts describing chemical changes in cycles between the spheres (for example the oxygen, carbon or nitrogen cycles) (no recall expected).

MODULE C5: CHEMICALS OF THE NATURAL ENVIRONMENT

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

1. recall that ores are rocks that contain varying amounts of minerals from which metals can be extracted;
2. recall that for some minerals, large amounts of ore need to be mined to recover small percentages of valuable minerals (for example in copper mining);
3. recall examples of metals that can be extracted by heating the oxide with carbon (for example zinc, iron and copper (technical details not required));
4. recall that when a metal oxide loses oxygen it is reduced while the carbon gains oxygen and is oxidised;
5. understand that some metals are so reactive that their oxides cannot be reduced by carbon;
6. be able to balance unbalanced symbol equations;
7. recall and use state symbols: (s), (l), (g) and (aq) in equations;
8. be able to use the Periodic Table to obtain the relative atomic masses of elements;
9. **be able to calculate the mass of the metal that can be extracted from a mineral given its formula or an equation;**
10. describe electrolysis as the decomposition of an electrolyte with an electric current;
11. understand that electrolytes include molten ionic compounds;
12. describe what happens to the ions when an ionic crystal melts;
13. recall that, during electrolysis, metals form at the negative electrode and non-metals form at the positive electrode;
14. describe the extraction of aluminium from aluminium oxide by electrolysis;
15. **show that during electrolysis of molten aluminium oxide the positively charged aluminium ions gain electrons from the negative electrode to become neutral atoms;**
16. **show that during electrolysis of molten aluminium oxide, negatively charged oxide ions lose electrons to the positive electrode to become neutral atoms which then combine to form oxygen molecules;**
17. **use ionic theory to explain the changes taking place during the electrolysis of a molten salt (limited to using diagrams or symbol equations to account for the conductivity of the molten salt and the changes at the electrodes);**
18. recall the properties of metals related to their uses (limited to strength, malleability, melting point and electrical conductivity);
19. explain the properties of metals in terms of a giant structure of atoms held together by strong metallic bonding;
20. **understand that in a metal crystal there are positively charged ions held closely together by a sea of electrons that are free to move;**
21. evaluate, given appropriate information, the impacts on the environment that can arise from the extraction, use and disposal of metals.

MODULE C6: CHEMICAL SYNTHESIS – OVERVIEW

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

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

A further development of ionic theory shows how chemists use this theory to account for the characteristic behaviours of acids and alkalis.

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

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.

Use of ICT in teaching and learning can include:

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

MODULE C6: CHEMICAL SYNTHESIS

C6.1 Chemicals and why we need them

1. understand the importance of chemical synthesis to provide food additives, fertilisers, dyestuffs, paints, pigments and pharmaceuticals;
2. interpret information about the sectors, scale and importance of chemical synthesis in industry and in laboratories;
3. recall the formulae of the following chemicals: chlorine gas, hydrogen gas, nitrogen gas, oxygen gas, hydrochloric acid, nitric acid, sulfuric acid, sodium hydroxide, sodium chloride, sodium carbonate, potassium chloride, magnesium oxide, magnesium hydroxide, magnesium carbonate, magnesium sulfate, calcium carbonate, calcium chloride;
4. **work out the formulae of ionic compounds given the charges on the ions (from C4);**
5. **work out the charge on one ion given the formula of a salt and the charge on the other ion (from C4);**
6. recall the main hazard symbols and understand the safety precautions to use when handling hazardous chemicals;
7. recall examples of pure acidic compounds which are solids (citric and tartaric acids), liquids (sulfuric, nitric and ethanoic acids) or gases (hydrogen chloride);
8. recall that common alkalis include the hydroxides of sodium, potassium and calcium;
9. recall the pH scale;
10. recall the use of indicators and pH meters to measure pH;
11. recall the characteristic reactions of acids that produce salts to include the reactions with metals, oxides, hydroxides and carbonates;
12. write balanced equations with state symbols to describe the characteristic reactions of acids;
13. recall that the reaction of acid with an alkali to form a salt is a neutralisation reaction;
14. **balance unbalanced symbol equations;**
15. explain that acidic compounds produce aqueous hydrogen ions, $H^+(aq)$, in water;
16. explain that alkaline compounds produce aqueous hydroxide ions, OH^- (aq), when they dissolve in water;
17. write down the formula of the salt produced given the formulae of the acid and the alkali;
18. explain that during a neutralisation reaction, the hydrogen ions from the acid react with hydroxide ions from the alkali to make water:
    $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$.

MODULE C6: CHEMICAL SYNTHESIS

C6.2 Planning, carrying out and controlling chemical synthesis

1. identify the stages in a given chemical synthesis of an inorganic compound including:
   - choosing the reaction or series of reactions to make the required product;
   - carrying out a risk assessment;
   - **working out the quantities of reactants to use;**
   - carrying out the reaction in suitable apparatus in the right conditions (such as temperature, concentration or the presence of a catalyst);
   - separating the product from the reaction mixture;
   - purifying the product;
   - measuring the yield and checking the purity of the product;
2. understand the purpose of these techniques: dissolving, crystallisation, filtration, evaporation, drying in an oven or dessicator;
3. understand the importance of purifying chemicals and checking their purity;
4. understand that a balanced equation for a chemical reaction shows the relative numbers of atoms and molecules of reactants and products taking part in the reaction;
5. understand that the relative atomic mass of an element shows the mass of its atom relative to the mass of other atoms;
6. be able to use the Periodic Table to obtain the relative atomic masses of elements;
7. calculate the relative formula mass of a compound using the formula and the relative atomic masses of the atoms it contains;
8. **calculate the masses of reactants and products from balanced equations;**
9. calculate percentage yields given the actual and the theoretical yield;
10. describe how to carry out an acid-alkali titration accurately (solid sample weighed out into a titration flask, dissolved in water and then titrated with acid or alkali from a burette);

ⓘ Making up of standard solutions is not required.

11. substitute results in a given formula to interpret titration results quantitatively.

MODULE C6: CHEMICAL SYNTHESIS

C6.2 Planning, carrying out and controlling chemical synthesis

12. understand why it is important to control the rate of a chemical synthesis (to include safety and economic factors);
13. explain the term: ‘rate of chemical reaction’;
14. describe methods for following the rate of a reaction (for example by collecting a gas, weighing the reaction mixture or observing the formation of a colour or precipitate);
15. interpret results from experiments that investigate rates of reactions;
16. recall that reaction rates vary with the particle size of insoluble chemicals, the concentration of solutions of soluble chemicals and the temperature of the reaction mixture;
17. understand that catalysts speed up chemical reactions while not being used up in the chemical changes;
18. interpret information about the control of rates of reaction in chemical synthesis;
19. **use simple collision theory to explain how rates of reaction depend on the concentration of solutions of soluble chemicals.**

MODULE C7: FURTHER CHEMISTRY – OVERVIEW

The five topics in this longer module introduce new chemical ideas while illustrating important features of the applications of chemistry and exploring Ideas about Science from IaS1 Data and its limitations, IaS3 Developing explanations, IaS5 Risk, and IaS6 Making decisions about science and technology.

The first topic covers introductory organic chemistry taking alcohols and carboxylic acids as the main examples. This builds on the coverage of hydrocarbon molecules in modules C1 Air pollution and C2 Material choices. The second and third topics lay the foundations for more advanced study of physical chemistry by exploring chemical concepts on a molecular scale include the connection between energy changes and bond breaking as well as the notion of dynamic equilibrium.

The fourth topic introduces concepts of valid analytical measurements in contexts where the results of analysis matter. The two main analytical methods featured are chromatography and volumetric analysis. The final topic covers green chemistry and describes how the chemical industry is reinventing processes so that the manufacture of bulk and fine chemicals is more sustainable.

Topics
C7.1 Alcohols, carboxylic acids and esters
Organic molecules and functional groups; alcohols; carboxylic acids; esters.
C7.2 Energy changes in Chemistry
Why are there energy changes during chemical reactions?
C7.3 Reversible reactions and equilibria
Introducing dynamic equilibrium
C7.4 Analysis
Analytical procedures; chromatography; quantative analysis
C7.5 Green Chemistry
The chemical industry; the characteristics of green Chemistry; making ethanol.

ICT Opportunities

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

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

Use of ICT in teaching and learning can include:

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

MODULE C7: FURTHER CHEMISTRY

C7.1 Alcohols, carboxylic acids and esters

Organic molecules and functional groups

1. recall that there is a family of hydrocarbons called alkanes;
2. recall the names and molecular formulae of the alkanes methane, ethane, propane and butane;
3. translate between molecular, structural and ball-and-stick representations of simple organic molecules;
4. recall that alkanes burn in plenty of air to give carbon dioxide and water;
5. understand that alkanes are unreactive towards aqueous reagents because C—C and C—H bonds are unreactive.
6. **represent chemical reactions by balanced equations, including state symbols.**

Alcohols

7. recall the names and molecular formulae of methanol and ethanol;
8. recall two uses of methanol and two of ethanol;
9. recognise the formulae of alcohols;
10. understand that the characteristic properties of alcohols are due to the presence of the –OH functional group;
11. recall how ethanol compares in its physical properties with water and with alkanes;
12. understand that alcohols burn in air because of the presence of a hydrocarbon chain;
13. **recall the reaction of alcohols with sodium and how this compares with the reactions of water and alkanes with this metal.**

Carboxylic acids

14. understand that the characteristic properties of carboxylic acids are due to the presence of the –COOH functional group;
15. recall the names and formulae of methanoic and ethanoic acids;
16. recognise the formulae of carboxylic acids;
17. recall that many carboxylic acids have unpleasant smells and tastes and are responsible for the smell of sweaty socks and the taste of rancid butter;
18. understand that carboxylic acids show the characteristic reactions of acids with metals, alkalis and carbonates;
19. recall that vinegar is a dilute solution of ethanoic acid.

MODULE C7: FURTHER CHEMISTRY

C7.1 Alcohols, carboxylic acids and esters

Esters

20. understand that carboxylic acids react with alcohols, in the presence of a strong acid catalyst, to produce esters;
21. write a word equation for the formation of an ester;
22. recall that esters have distinctive smells;
23. recall that esters are responsible for the smells and flavours of fruits;
24. recall the use of esters in products such as food, perfumes, solvents and plasticisers;
25. **understand the procedure for making an ester (such as ethyl ethanoate) from a carboxylic acid and an alcohol;**
26. **understand techniques used to make a liquid ester including heating under reflux, distillation, purification by treatment with reagents in a tap funnel and drying;**
27. understand that fats are esters of glycerol and fatty acids;
28. recall that living organisms make fats and oils as an energy store;
29. recall that animal fats are mostly saturated molecules and that vegetable oils are mostly unsaturated molecules;
30. understand that in saturated compounds all the C—C bonds are single but that in unsaturated compounds there are C=C double bonds.

C7.2 Energy changes in chemistry

Why are there energy changes during chemical reactions?

1. understand the terms exothermic and endothermic;
2. use simple energy level diagrams to represent exothermic and endothermic changes;
3. understand that energy is needed to break chemical bonds and that energy is given out when chemical bonds form;
4. **use data on the energy needed to break given covalent bonds to estimate the overall energy change in simple examples (for example the formation of steam or hydrogen halides from their elements) IaS 3.1, 3.3, 3.4;**
5. understand the term activation energy in terms of the energy needed to break bonds to start a reaction.

MODULE C7: FURTHER CHEMISTRY

C7.3 Reversible reactions and equilibria

Introducing dynamic equilibrium

1. understand that some chemical reactions are reversible;
2. understand that reversible reactions reach a state of equilibrium;
3. understand the dynamic equilibrium explanation for chemical equilibrium (IaS 3.1, 3.3, 3.4);
4. understand the difference between strong and weak acids in terms of dynamic equilibrium;
5. recall that hydrochloric acid is a strong acid but that carboxylic acids are weak acids.

C7.4 Analysis

Analytical procedures

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

Chromatography

5. recall that in chromatography, substances are separated by movement of a mobile phase through a stationary phase;
6. know the meaning of the terms aqueous and non-aqueous as applied to solvents;
7. understand that for each component in a sample there is a dynamic equilibrium between the stationary and mobile phases;
8. understand that a separation by chromatography depends on the distribution of the compounds in the sample between the mobile and stationary phases;
9. understand the use of standard reference materials in chromatography;
10. describe and compare paper and thin-layer chromatography;
11. use the formula:
    $R_f = \frac{\text{distance travelled by solute}}{\text{distance travelled by solvent}}$
12. understand the use of locating agents in paper or thin-layer chromatography;
13. recall in outline the procedure for separating a mixture by gas chromatography (gc);
14. understand the term retention time as applied to gc;
15. interpret print-outs from gc analyses.

MODULE C7: FURTHER CHEMISTRY

C7.4 Analysis

Quantitative analysis by titration

16. understand the main stages of a quantitative analysis;
    - measuring out accurately a specific mass or volume of the sample,
    - working with replicate samples;
    - dissolving the samples quantitatively;
    - measuring a property of the solution quantitatively;
    - calculating a value from the measurements (IaS 1.2–1.4);
    - estimating the degree of uncertainty in the results (IaS 1.5–1.6);
17. recall that concentrations of solutions are measured in g/dm^3;
18. recall the procedure for making up a standard solution;
19. **calculate the concentration of a given volume of solution given the mass of solvent;**
20. **calculate the mass of solute in a given volume of solution with a specified concentration;**
21. recall the procedure for carrying out an acid-base titration using a pipette and burette;
22. substitute results in a given formula to interpret titration results quantitatively;
23. **use the balanced equation and relative formula-masses to interpret the results of a titration;**
24. use values from a series of titrations to assess the degree of uncertainty in a calculated value.

MODULE C7: FURTHER CHEMISTRY

C7.5 Green Chemistry

The chemical industry

1. recall and use the terms 'bulk' (made on a large scale) and 'fine' (made on a small scale) in terms of the chemical industry;
2. recall examples of chemicals made on a large scale (ammonia, sulfuric acid, sodium hydroxide, phosphoric acid) and examples of chemicals made on a small scale (drugs, food additives, fragrances);
3. interpret information about the work done by people who make chemicals (no recall expected);
4. understand that new chemical products or processes are the result of an extensive programme of research and development (for example catalysts for new processes);
5. understand that governments have strict regulations to control chemical processes as well as the storage and transport of chemicals to protect people and the environment.

What are the characteristics of green chemistry?

6. understand that the production of useful chemicals involves several stages (to include the preparation of feedstocks, synthesis, separation of products, handling of by-products and wastes, and the monitoring of purity);
7. understand that sustainability of any chemical process (IaS 6.2) depends on:
   - whether or not the feedstock is renewable;
   - the atom economy;
   - the nature and amount of by-products or wastes and what happens to them;
   - the energy inputs or outputs;
   - the environmental impact;
   - the health and safety risks (IaS 5.3 & 5.4);
   - the social and economic benefits.
8. understand that a catalyst provides an alternative route for a reaction with a lower activation energy;
9. **represent chemical reactions by balanced equations, including state symbols;**
10. **calculate the masses of reactants and products from balanced equations including state symbols;**
11. **calculate the masses of reactants and products from balanced equations.**

MODULE C7: FURTHER CHEMISTRY

C7.5 Green Chemistry

Making ethanol by three methods

12. understand how ethanol is made on an industrial scale as a fuel, a solvent and as a feedstock for other processes;
13. understand that there is a limit to the concentration of ethanol solution that can be made by fermentation;
14. understand how ethanol solution can be concentrated by distillation to make products such as whisky and brandy;
15. understand the optimum conditions for making ethanol by fermentation of sugar with yeast, taking into consideration temperature and pH;
16. understand how genetically modified E coli bacteria can be used to convert waste biomass from a range of sources into ethanol and recall the optimum conditions for the process;
17. recall in outline the synthetic route for converting ethane (from oil refining) into ethanol;
18. interpret data about these processes and evaluate their sustainability (IaS 6.5).

4 Scheme of Assessment

4.1 Units of Assessment

GCSE Chemistry A (J634)	
Unit 1: Chemistry A Unit 1 – modules C1, C2, C3 (A321)	
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 C1, C2 and C3; • 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.
Unit 2: Chemistry A Unit 2 – C4, C5, C6 (A322)	
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 C4, C5 and C6; • 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.
Unit 3: Chemistry A Unit 3 – Ideas in Context plus C7 (A323)	
33.3% of the total GCSE marks 1 hr written paper 55 marks	This question paper: • is offered in Foundation and Higher Tiers; • assesses knowledge and understanding of the specification content and application of that knowledge and understanding; • incorporates pre-release material; • the subject focus of the pre-release material will normally be one or two of modules C1 to C6, the precise focus will be clear from the stimulus material; • the remaining questions will be focused on the content of C7 Further Chemistry; • uses structured questions throughout (there is no choice of questions); • includes some marks for communication skills.

GCSE Chemistry A (J634)	
Unit 4: Chemistry A Unit 4 – Practical Data Analysis and Case Study (A329)	
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.
Unit 5: Chemistry A Unit 5 – Practical Investigation (A330)	
33.3% of the total GCSE marks skills assessment 40 marks	• This unit comprises five strands, which together are used to assess a complete investigative task. • This unit is assessed by teachers, internally standardised and then externally moderated by OCR.

4.2 Unit Options

Candidates take Units 1, 2 and 3 **and** either Unit 4 **or** Unit 5.

4.3 Tiers

Units 1, 2 and 3 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.

Units 4 and 5 (skills assessment) are not tiered. Candidates enter either A329, Practical Data Analysis task plus a Case Study, or A330, Practical Investigation.

Candidates may enter Units 1, 2, and 3 at different tiers, so for example, a candidate may take A321F, A322F and A323H.

4.4 Assessment Availability

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

	Unit 1 (A321)	Unit 2 (A322)	Unit 3 (A323)	Unit 4 (A329)	Unit 5 (A330)
January 2007	–	–	–	–	–
June 2007	✓	–	–	–	–
January 2008	✓	✓	–	–	–
June 2008	✓	✓	✓	✓	✓

After June 2008, A321 and A322 will be available in the January and June sessions. The Chemistry Ideas in Context paper, A323 and skills assessment (Units A329 and A330) 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

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

Assessment Objectives	Weighting
AO1: Knowledge and understanding	30%
AO2: Application of knowledge and understanding, analysis and evaluation	40.6%
AO3: Enquiry	29.3%

The relationship between the components and the assessment objectives of the scheme of assessment is shown in the following grid.

	Weighting of Assessment Objectives by Unit			
	AO1	AO2	AO3	Total
Unit 1 (A321 Unit 2 (A322)	15%	16.3%	2.0%	33.3%
Unit 3 (A323)	13%	18.3%	2.0%	33.3%
Unit 4 (A329) Unit 5 (A330)	2%	6%	25.3%	33.3%
Overall	30%	40.6%	29.3%	100%

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 will be assessed in the Ideas in Context paper (A323) and in the Case Study (A329) or Practical Investigation (A330).

5 Skills Assessment

5.1 Nature of Skills Assessment

Rationale

The skills assessment accounts for 33.3% of the marks for this specification. There is some choice of the material that is presented for assessment. However it is hoped that candidates have opportunities to develop their skills in all aspects of the tasks described here and then present the highest scoring piece of work.

Skills assessment should arise naturally out of teaching, so that it can be assessed by teachers, internally standardised and then externally moderated by OCR. Candidates are required to submit work for either Unit 4 (A329) or Unit 5 (A330).

Practical Data analysis and Case study (Unit 4, A329)

The Unit 4 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 the research. Centres should note that marks for both elements of Unit 4 (A329) 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.

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.

Practical Investigation (Unit 5, A330)

The use of practical investigations to assess skills in science was based on research in a number of centres, particularly the University of Durham. For more than 10 years, it has formed the basis of coursework assessment for National Curriculum science.

Investigations require the drawing together of skills in planning, collecting data, interpreting data and evaluation. They provide an effective and valid assessment instrument for a course which is seen as a basis for further studies and possible future careers in science. However, the regulations used at Key Stage 4 over the past 5-year cycle have been constructed in a way which has restricted the variety of work attempted and has led to rather mechanical 'criterion matching', rather than genuine open-ended work.

For this specification, the basic structure of investigations is retained, but the emphasis on prediction is removed, allowing a much wider range of activities and approaches. A different marking style has been developed, drawing more on the professional judgment of teachers.

The task aims to motivate candidates and help them to appreciate the importance of having a clear and manageable question, to learn how to choose equipment and use it appropriately, and to design suitable apparatus for making observations and measurements. First-hand experience of the problems of collecting valid and reliable data can give candidates a better sense of what the difficulties really are, and a 'feel' for how great they are in specific cases, and provide a context for beginning to understand how to tackle and perhaps overcome these.

Candidates are required to complete one single practical investigation. The Investigation, accounts for 33% of the marks for this specification. It is assessed by teachers, internally standardised, and then externally moderated.

Within this science suite, investigative work is designed to have a broad definition. In addition to confirming the predicted effect of a variable on a system over a range, the definition also includes more speculative investigation of systems where no clear prediction can be made in advance, e.g. where there is little relevant explanatory theory available in the course, or where the experimental material is likely to be variable, for example in surveys of distribution of species. It also includes tasks which involve determining the consistency of measurements e.g. comparing the characteristics of different artefacts, obtaining evidence for the 'normal' variation in respiratory peak flow-rates of an individual, etc.

The initial stimulus for an investigation should arise from class teaching or discussion which ensures that candidates are aware of suitable practical techniques and have some relevant background theoretical knowledge.

This element of the assessment is based on complete, first hand practical investigations. Candidates may complete as many investigations as they wish during the course. The final mark will be the total for the highest-scoring single piece of work assessed. It is not permitted to aggregate together marks taken from different investigations. Where appropriate, first hand data collected by the candidate may be supplemented by secondary data from other sources. In such cases, credit for collecting data should be based on the overall quality of all the data obtained or selected.

Marks are awarded for 5 strands of the investigation, with each strand marked on a scale of 0–8.

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.

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 have 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 for moderation. The final mark should be submitted to OCR on form MS1 by **15th May** in the year of entry. These forms are produced and dispatched 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 4 (A329), Element 1: Practical Data Analysis (13.3%)

Marking Criteria – Practical Data Analysis

There are two strands in this element; Interpreting Data and Evaluation. The descriptors for each strand are identical to those found in Unit 5 Practical Investigation (A330).

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.

[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, showing what they have learned from doing it and explaining 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 4 (A329), Element 2: Case Study

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 element 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 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 different topics.

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 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 two years of 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 areas of performance to be awarded credit are:

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

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.

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).

Each row of mark descriptions represents a different aspect of the use of resources. For each row, the level of achievement displayed should be indicated, then a single overall mark on a scale of 0–8 for the quality should be awarded, using professional judgement to decide the best overall match to the achievement shown.

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 for an identified public audience, PowerPoint presentations, posters for a campaign, 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.

Unit 5 (A330), Practical Investigation

This unit is designed to test the ability of the candidate to plan and undertake a whole investigation or problem-solving task. Scoring individual marks in different tasks, or parts of tasks, removes this holistic element, and can result in performances of very different quality leading to the same final assessment total. For this reason, the final unit mark for each candidate will be the highest total mark achieved on any one task. This total mark is obtained by adding together the marks achieved on each strand of the work on that task.

The requirement is for the highest mark from a single piece of work. It is not essential for this to be complete, in the sense of providing evidence across all strands. It may happen that some candidates achieve their highest total for a piece of work in which evidence for one or more strands is missing; in such cases this total should be chosen as the final assessment total.

Centres may assess the performance of candidates on any occasion when investigative work is taking place throughout the course.

Marking Criteria – Practical Investigation

Strand S: Strategy

Practical investigations are likely to arise out of work on most or all of the course modules. Suitable tasks might be suggested to candidates, but they should also have opportunities to modify or extend these, or to suggest questions or tasks to investigate in topic areas they are studying. Candidates can (and should) obtain more credit for tackling somewhat more demanding tasks, and for being involved in devising the question/task, rather than 'playing safe' with a given, or routine task, or one involving little skill in the use of equipment.

Whilst candidates should be encouraged to plan an investigation before starting, there is limited value in requiring them to produce a detailed written plan – as their actions should be open to modification as they proceed. Indeed, it is good practice to try taking a few measurements or making a few observations to get a 'feel' for the equipment and the system being investigated, before planning a detailed data collection strategy. For that reason, the candidate's understanding of issues concerning data is better assessed from the final data set they present (see Strand C below), rather than from an initial plan.

Assessment of the quality of strand S focuses on:

- the complexity and demand of the task and approach chosen;
- the choice of equipment, materials and techniques;
- the degree of independence shown in formulating the task and the approach to it.

Aspect of Performance	Strand S Mark			
	2	4	6	8
a evaluation of procedures	Simple measurement or comparison task, based on straight-forward use of simple equipment	Routine task requiring only limited precision or range of data to be collected.	Straightforward task of limited complexity, but requiring good precision or a wide range of data.	Complex task requiring high levels of precision/reliability in the data collected.
b reliability of evidence	Follow a given technique, but with very limited precision or reliability.	Select and use basic equipment to collect a limited amount of data.	Select and use techniques and equipment which are appropriate for the range of data required.	Justify the choice of equipment and technique to achieve data which is precise and reliable.
c reliability of conclusion	The task has been set by the teacher and/or is based on specific, task-related structured worksheets.	The task is closely defined by the teacher, but is carried out with little further guidance.	The task is defined by the candidate from a more general brief, then carried out independently.	The topic is reviewed by the candidate to justify a choice of task. The work is completed independently.

Strand C: Collecting Data

Candidates are expected to be able to collect a set of data in a manner which shows understanding of how to ensure (and assess) quality.

The quality of a data set depends on:

- the quality of individual data points, which in turn depends on:
  - how carefully the measurements have been taken, and how accurate the available instruments are (IaS 1.1-2);
  - how much variation or scatter there is in repeated measurements and the steps that have been taken to assess and deal with this (IaS 1.1–4);
  - whether the instruments used, or the way they are used, results in measurements that differ from the ‘true’ value of the quantity (IaS 1.1–2);
- the extent and design of the set of data points collected, that is:
  - whether enough data points have been collected (IaS 2.1, 2.3, 2.7);
  - whether these cover an adequate range (of cases, or situations, or values of an independent variable) (IaS 2.3);
  - (if a relationship is being explored) whether the design of the data set enables the effect of other variables to be excluded (for example (IaS 2.2–3, 2.6–7).

Candidates should use preliminary experiments or other information to confirm that their choices of techniques and range of values to be tested will lead to results of good quality.

The statements are written to refer to primary data that the candidate has collected. Where this is supported by data from secondary sources, the statements should be read as referring to the data ‘selected’ (as opposed to ‘collected’). The mark awarded should be based on all of the data considered as a whole.

	Aspect of Performance	Strand C Mark			
		2	4	6	8
a	identification and control of interfering factors	Little or no care has been taken to identify or control outside influences.	Identifies some factors which may affect the outcomes and need to be controlled or accounted for.	Identifies the majority of factors which may affect the outcomes and need to be controlled or accounted for.	Reviews factors which might affect the outcomes and describes how they have been controlled or account for.
b	extent and design of data set	The data is very limited in amount (e.g. isolated individual data points, with no clear pattern), covering only part of the range of relevant cases/ situations, with no checking for reliability.	An adequate amount or range of data is collected, but with little or no checking for reliability.	Data is collected to cover the range of relevant cases/ situations, with regular repeats or checks for reliability.	Values tested are well-chosen across the range, with regular repeats and appropriate handling of any anomalous results. Preliminary tests are used to establish the range.
c	quality/ precision of manipulation	Little care evident in use of apparatus. Data generally of low quality.	Use of techniques and apparatus generally satisfactory. Data of variable quality, with some operator error apparent.	Sound techniques in use of apparatus/ equipment. Data of generally good quality.	Consistent precision and skill shown in use of apparatus/ equipment. Where appropriate, checks or preliminary work are included to confirm or adapt the apparatus or techniques to ensure data of high quality.

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'[2] 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, 3.4, 3.5).

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.

[2] '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 investigation they have carried out, showing what they have learned from doing it and explaining 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 1.1–2);
- 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, 2.7–8).

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.

Strand P: Presentation

The ability to report clearly and effectively on one's work is essential in order to demonstrate understanding of the Ideas about Science that relate to practical investigations.

Credit is awarded for three aspects of reporting and communicating a practical investigation:

- completeness of the report, with all practical procedures clearly described, all parameters and evidence reported, a full analysis of the evidence, and an evaluation of both procedures and evidence;
- presentation of the report, including layout and effective sequencing, use of illustrations as appropriate and use of graphs and charts to present information;
- correct use of English, including accurate grammar, punctuation and appropriate use of scientific terms.

Aspect of Performance	Strand P Mark			
	2	4	6	8
a Description of work planned and carried out	The purpose/ context of the investigation is not made clear. Key features of experi-mental procedures are omitted or unclear.	The purpose of the work is stated. Main features of the work are described, but there is a lack of detail.	There is a clear statement of the question/task and its scope. Practical procedures are clearly described.	All aspects of the task are reviewed. Practical procedures are discussed critically and in detail.
b Recording of data	Major experimental parameters are not recorded. Some data may be missing.	Most relevant data is recorded, but where repeats have been used, average values rather than raw data may be recorded.	All raw data, including repeat values, are recorded.	All relevant parameters and raw data including repeat values are recorded to an appropriate degree of accuracy.
	Labelling of tables is inadequate. Most units are absent or incorrect.	Labelling is unclear or incomplete. Some units may be absent or incorrect.	All quantities are identified, but some units may be omitted.	A substantial body of information is correctly recorded to an appropriate level of accuracy in well-organised ways.
	Observations are incomplete or sketchily recorded.	Recording of observations is adequate but lacks detail.	Observations are adequate and clearly recorded.	Observations are thorough and recorded in full detail.
c General quality of communication	Spelling, punctuation and grammar are of generally poor quality. Little or no relevant technical or scientific vocabulary is used.	Use of appropriate vocabulary is limited. Spelling, punctuation and grammar are of very variable quality.	Appropriate scientific vocabulary is used. Spelling, punctuation and grammar are generally sound.	There is 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.

Coursework 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.

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 includes 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 coursework.

However, the main purpose of annotating candidates' coursework 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, Ea8) 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 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 A321, A322 and A323 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.

Entry code	Option code	Component to be taken	
A321	F	01	Chemistry A Unit 1 – modules C1, C2, C3 Foundation
	H	02	Chemistry A Unit 1 – modules C1, C2, C3 Higher
A322	F	01	Chemistry A Unit 2 – modules C4, C5, C6 Foundation
	H	02	Chemistry A Unit 2 – modules C4, C5, C6 Higher
A323	F	01	Chemistry A Unit 3 – Ideas in Context plus C7 Foundation
	H	02	Chemistry A Unit 3 – Ideas in Context plus C7 Higher
A329	–	01	Chemistry A Unit 4 – Practical Data Analysis and Case Study
A330	–	01	Chemistry A Unit 5 – Practical Investigation

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 **J634** 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 (within a specified period after publication of results) or at a later session.

First certification will be available in June 2008 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. 41/50.

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 and 2	50-45	44-40	39-35	34-30	29-25	24-20	19-15	14-10	10-0
Units 3, 4 and 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

Prior to certification, candidates may re-sit any unit once only. *Centres should note that at the time of publication this rule is under review.*

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

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

6.7 Guided Learning Hours

GCSE Chemistry 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 Chemistry 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 1110.

7 Other Specification Issues

7.1 Overlap with other Qualifications

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

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 chemistry at Advanced Level (Level 3 in the National Qualifications Framework) should have completed either a course in GCSE Chemistry A or both GCSE Science and GCSE Additional Science.

7.3 ICT

In order to move on to more advanced study of science, candidates need to be confident and effective users of ICT. This specification provides candidates with a wide range of appropriate opportunities to use ICT in order to further their study of science.

Opportunities for ICT include:

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

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

7.4 Citizenship

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

Core 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	
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. C5: The role of manufacturing industry in adding value by extracting metals from their ores. C6 and C7: The scale and importance of the chemical industry
The work of parliament, the government and the courts in making and shaping the law	C1: Role of regulation in limiting air pollution.
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 rights and responsibilities of consumers, employers and employees	C6 and C7: The responsibility of the chemical industry to minimise damage to people and the environment while producing products that are effective and safe.
The issues and challenges of global interdependence and responsibility, including sustainable development and Local Agenda 21	C5 and C7: Insight into the chemical nature of the natural environment needed for an understanding of issues of sustainability including the use of manufactured fertilisers.
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	Coursework: 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.
Contributing to group and class discussions	There will be opportunities for discussion in every module, e.g. C2: Discussion of use of alternative materials for manufacture of a product following life-cycle analysis.

Citizenship Programme of Study	Opportunities for Teaching the Issues during the Course
Section 3: Developing skills of participation and responsible action	
Consider and evaluate views that are not their own	Coursework: Case Study of a topical science-related issue.

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

A number of the scientific ideas which feature in this specification have a significant cultural influence on how people think about themselves and their environment. Also in this specification, candidates gain more insight into the reliability and significance of scientific data.

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.	Practical investigation: reviewing the strategy and procedures.
The range of factors which have to be considered when weighing the costs and benefits of scientific activity.	C2: The technical, economic and social issues that have to be taken into account when designing a material object. C6: Evaluating the costs and benefits associated with chemical manufacturing.
The ethical implications of selected scientific issues.	C7: Green chemistry
Scientific explanations which give insight into the local and global environment	C1: The origins of pollutants and what happens to them in the atmosphere. C5: Insight into the chemical nature of natural changes in the lithosphere, hydrosphere, atmosphere and biosphere.

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	
Managing wastes from manufacturing industry	C7: The by-products and waste products of chemical manufacturing and what can be done to mitigate potential harmful effects.
Food and agriculture	C5: The scale of the impact of the use of manufactured fertilisers on the nitrogen cycle.
Use and disposal of materials	C5: Recycling metals and other ways of reducing the quantity of waste products from mineral processing and the extraction of metals from their ores.
Health and Safety issues	
Safe practice in the laboratory	Practical investigation: designing a strategy

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	C6 and C7: The economic importance of the chemical industry in the UK and other countries.
Environmental issues which extend over a larger area than the UK	C3: Impact of European agriculture policy on the scale and methods of different forms of agriculture. C7: The European wide approach to green chemistry and the quest to develop more efficient and less polluting processes.

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)
gravitational field strength	N/kg
potential difference	volt (V)
resistance	ohm (Ω)

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 are planning 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 Ideas-about-Science are expressed in terms of what the candidates know, understand or can do, and are prefixed by 'Candidates should …..' 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 a 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 laws.
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.

This section lists the Science Explanation relevant to this specification. Other ideas about Science are listed in GCSE Biology A and GCSE Physics A specifications. The full set of Science Explanations are included in the GCSE Science A specification.

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 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.

Appendix H: Periodic Table

Key

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

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

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

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