version 1.1

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Secondary Education

Sciences

Science A and B

Additional Science

Biology

Chemistry

Physics

TEACHERS' GUIDE

AQA General Certificate of Secondary Education 4461, 4462, 4463, 4411, 4421, 4451

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AQA Logistics Centre, Unit 2, Wheel Forge Way, Ashburton Park, Trafford Park, Manchester, M17 1EH.
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Registered address AQA, Devas Street, Manchester, M15 6EX. *Dr Michael Cresswell Director General.*

Contents

Background Information

1 Introduction

1.1 Purpose

This Teachers' Guide has been provided to help teachers in their preparation for the delivery of AQA GCSE Sciences (Science A, Science B, Additional Science, Biology, Chemistry and Physics). These GCSE Sciences have common teaching units and a common model for internal assessment, so one Guide has been produced to support the teaching of all six specifications. Separate Teachers' Guides are available for GCSE Applied Science (Double Award) and GCSE Additional Applied Science.

This Guide should be read in conjunction with the specifications. The specifications are available in hard copy, and may be downloaded from the AQA website (www.aqa.org.uk). Specimen assessment materials are also available for each specification.

1.2 Curriculum Planning

The six specifications, GCSE Science A, Science B, Additional Science, Biology, Chemistry and Physics, offer a variety of possibilities for the KS4 curriculum, which can be extended by Entry Level Certificate Science, GCSE Applied Science (Double Award) and GCSE Additional Applied Science. The following paragraphs attempt to explore some of the possibilities, but teachers are encouraged to view these as a starting point only.

GCSE Science plus GCSE Additional Science

Before the introduction of these specifications the majority of candidates have been following GCSE Science (Double Award) courses. The nearest equivalent for the new specifications is GCSE Science plus GCSE Additional Science. These are two single award GCSEs, each leading to the award of a separate grade. It is anticipated that in many centres, candidates will complete GCSE Science by the end of Y10 and then go on to take GCSE Additional Science by the end of Y11. However, there is no requirement to enter GCSE Science before GCSE Additional Science.

GCSE Science is available from AQA with two different types of assessment (objective tests in Science A, and written papers in Science B). The subject content for these options is exactly the same. Both enable the statutory requirement to teach the KS4 programme of study for science to be met. Centres can choose the type of assessment which suits their candidates, but cannot mix and match the assessment for GCSE Science for a given candidate.

GCSE Science plus GCSE Additional Science are good preparation for progression to AS and A Level Sciences. GCSE Science alone is not. Some concern has been expressed that the new GCSE Sciences contain fewer scientific facts than the previous specifications. This is correct, as teaching time has been made available to tackle 'How Science Works' and this has meant some deletion of topics. However, it should be remembered that GCE Sciences are being revised for first teaching from September 2008/9 in time for the first candidates taking the new GCSE Sciences. The starting point for the GCE specification development will be the new GCSE Sciences; therefore, the GCE Sciences will be a progression of these.

The DfES has for many years stated the expectation that 80% of candidates will undertake two science GCSEs. This expectation continues with the new specifications and will be enforced to the extent that two GCSE Sciences will be an entitlement for candidates; in other words, centres must make it possible for any candidate who wishes to study two science GCSEs. GCSE Science plus GCSE Additional Science is one of a number of ways of achieving this.

GCSE Science plus GCSE Additional Applied Science

One possibility that teachers may want to consider is to offer GCSE Additional Applied Science as an alternative to GCSE Additional Science. Where GCSE Additional Science considers the theoretical and modelling aspects of science, the Applied specification emphasises the vocational aspects relating to the use of science in the workplace. It might be thought that this would be a sensible option for the weakest candidates, but this would be a mistake. This Applied specification has a high percentage of portfolio assessment, which leads to a different teaching and learning regime, requiring a good degree of self-motivation from candidates. That said, the contexts chosen to deliver the content (food science, forensic science and sports science) are motivating for many candidates. GCSE Additional Applied Science might be a good option for candidates of any ability who would prefer to follow the applied route at GCE rather than the separate sciences route.

GCSE Science plus another science

Another option is to offer one or more separate sciences to candidates who have completed GCSE Science, so that for example they follow GCSE Science with GCSE Biology. This enables candidates to study their preferred science(s). Units which are common between specifications (eg in this case Biology 1) have to be retaken to count again towards the second GCSE. Candidates cannot certificate both subjects in the same series. Further information about this is given in Section 3.4 of this Teachers' Guide.

Further possibilities are GCSE Electronics, GCSE Environmental Science, GCSE Human Physiology and Health, and GCSE Psychology, all of which qualify towards the 80% expectation, and all of which are available with AQA.

All the combinations considered so far include GCSE Science, and therefore fulfil the KS4 statutory requirement. A different way of meeting the requirement is to offer GCSE Applied Science (Double Award) from the beginning of the course. This has the same features as GCSE Additional Applied Science, ie contexts which are motivating and a high percentage of portfolio assessment.

Curriculum time

It is expected that all the combinations of two single science GCSEs will require around 20% curriculum time over 2 years. Teaching GCSE Science over 2 years requires about 10% curriculum time.

In some instances, candidates may want to take two separate sciences after GCSE Science. This should be possible in 20% curriculum time over one year. For example, to take GCSE Chemistry and GCSE Physics, candidates would need to cover Chemistry 2, Chemistry 3, Physics 2 and Physics 3, and continue to develop their understanding in these new contexts of 'How Science Works'. This is one more unit than for GCSE Additional Science (which requires 20% over one year), so teachers would need to plan teaching strategies accordingly. If candidates have already certified in GCSE Science A or B, they will need to take Chemistry 1 and Physics 1 again.

Separate Sciences

As now, some candidates will want, if their centre is able to offer the option, to take all three separate sciences (GCSE Biology, Chemistry and Physics). Doing so meets the KS4 statutory requirement since, taken together, the three specifications include all the content of GCSE Science. With careful planning, it may be possible to cover the three qualifications in the time for two, ie in 20% curriculum time over 2 years. For example, teachers will want to ensure that candidates are beyond the requirements for GCSE Science by the end of Y10. The extra subject content of three sciences is compensated by the fact that 'How Science Works' is common content and this reduces the apparent load. Nonetheless, each separate subject has been designed to occupy 10% of curriculum time over two years.

Entry Level Certificate

ELC Science is available for candidates who are working towards GCSE and are unlikely to obtain grade G for GCSE Science. This is a certificated award which gives recognition to achievement at Entry Levels 1, 2 or 3. Candidates could be entered for both ELC and GCSE Science, as a safeguard against not achieving grade G. Note that Entry Level Certificate qualifies for points for Achievement and Attainment Tables.

ELC Science can be taught independently of GCSE Science, or it can be co-taught, the content being a sub-set of GCSE Science. The assessment of practical work is designed to fit with the requirements of the new centre-assessed units in the GCSE Sciences. Candidates do not have to submit work across the whole breadth of the GCSE specification, but if they are taught the whole breadth, the KS4 statutory requirement will be met. This is important because it is no longer possible to apply for disapplication from the programme of study requirement for science.

Candidates could progress to GCSE Science from ELC Science, or alternatively to GCSE Additional Applied Science which would mean that they did not cover the same programme of study for science content again.

2 Specifications at a Glance

Science A

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

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

GCSE Science A	
Biology 1a Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks	Biology 1b Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks
Chemistry 1a Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks	Chemistry 1b Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks
Physics 1a Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks	Physics 1b Matching/multiple choice questions Objective test 12.5% 30 minutes 36 marks
Science Centre-Assessed Unit (B1, C1 or P1) based on normal class practical work 25% 40 marks Investigative Skills Assignment (an externally set, internally assessed test taking 45 minutes) + Practical Skills Assessment (a holistic skills assessment)	

GCSE Science A
4461

Science B

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

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

GCSE Science B	
Biology 1	
Written paper	25%
45 minutes	45 marks
Chemistry 1	
Written paper	25%
45 minutes	45 marks
Physics 1	
Written paper	25%
45 minutes	45 marks
Science Centre-Assessed Unit (B1, C1 or P1)	
based on normal class practical work	25%
	40 marks
Investigative Skills Assignment (an externally set, internally assessed test taking 45 minutes) + Practical Skills Assessment (a holistic skills assessment)	

GCSE Science B
4462

Additional Science

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

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

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

GCSE Additional Science
4463

Biology

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

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

<table>
<tr><th colspan="2">GCSE Biology</th></tr>
<tr><td colspan="2">Biology 1
Written paper — 25%
45 minutes — 45 marks</td></tr>
<tr><td colspan="2">or</td></tr>
<tr><td>Biology 1a
Matching/multiple choice questions
Objective test — 12.5%
30 minutes — 36 marks</td><td>Biology 1b
Matching/multiple choice questions
Objective test — 12.5%
30 minutes — 36 marks</td></tr>
<tr><td colspan="2">Biology 2
Written paper — 25%
45 minutes — 45 marks</td></tr>
<tr><td colspan="2">Biology 3
Written paper — 25%
45 minutes — 45 marks</td></tr>
<tr><td colspan="2">Biology Centre-Assessed Unit (B1, B2 or B3)
based on normal class practical work — 25%
40 marks
Investigative Skills Assignment
(an externally set, internally assessed test taking 45 minutes)
+ Practical Skills Assessment
(a holistic skills assessment)</td></tr>
</table>

GCSE Biology
4411

Chemistry

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

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

GCSE Chemistry	
Chemistry 1	
Written paper	25%
45 minutes	45 marks
or	
Chemistry 1a – Matching/multiple choice questions; Objective test 12.5%; 30 minutes 36 marks	**Chemistry 1b** – Matching/multiple choice questions; Objective test 12.5%; 30 minutes 36 marks
Chemistry 2	
Written paper	25%
45 minutes	45 marks
Chemistry 3	
Written paper	25%
45 minutes	45 marks
Chemistry Centre-Assessed Unit (C1, C2 or C3)	
based on normal class practical work	25%
	40 marks
Investigative Skills Assignment (an externally set, internally assessed test taking 45 minutes) + Practical Skills Assessment (a holistic skills assessment)	

GCSE Chemistry
4421

Physics

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

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

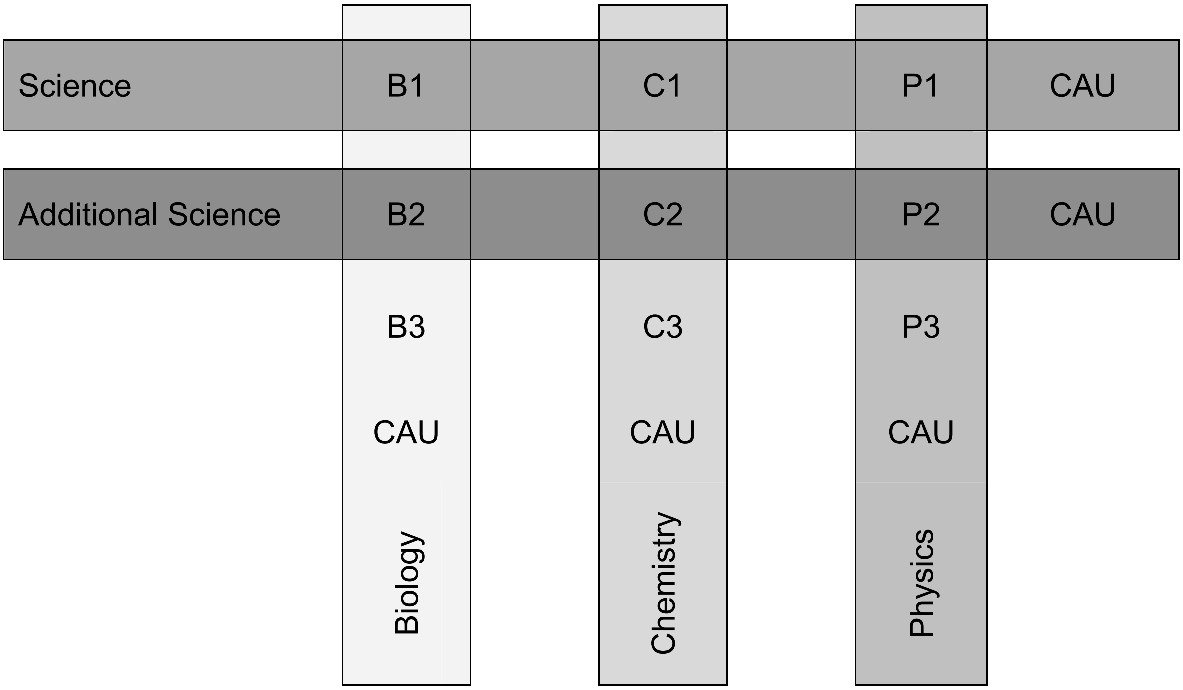
<table>
<tr><th colspan="4">GCSE Physics</th></tr>
<tr><td colspan="4">Physics 1
Written paper — 25%
45 minutes — 45 marks</td></tr>
<tr><td colspan="4">or</td></tr>
<tr><td colspan="2">Physics 1a
Matching/multiple choice questions
Objective test — 12.5%
30 minutes — 36 marks</td><td colspan="2">Physics 1b
Matching/multiple choice questions
Objective test — 12.5%
30 minutes — 36 marks</td></tr>
<tr><td colspan="4">Physics 2
Written paper — 25%
45 minutes — 45 marks</td></tr>
<tr><td colspan="4">Physics 3
Written paper — 25%
45 minutes — 45 marks</td></tr>
<tr><td colspan="4">Physics Centre-Assessed Unit (P1, P2 or P3)
based on normal class practical work — 25%
40 marks
Investigative Skills Assignment
(an externally set, internally assessed test taking 45 minutes)
+ Practical Skills Assessment
(a holistic skills assessment)</td></tr>
</table>

GCSE Physics
4451

3 Background and Administration

3.1 Introduction

The specifications, GCSE Science A, Science B, Additional Science, Biology, Chemistry and Physics, have many features in common. They share an approach to 'How Science Works' (see Section 3.2) and a common model of centre-assessed unit (CAU) (see Section 3.3). In addition, some assessment units are common between specifications.



For example, GCSE Science is made up of four units: Biology 1, Chemistry 1, Physics 1 and a centre-assessed unit. The unit Biology 1 is the same as one of the four units for GCSE Biology (Biology 1, Biology 2, Biology 3 and a centre-assessed unit). For GCSE Science B, Additional Science, Biology, Chemistry and Physics, each unit above is assessed separately and candidates receive a grade, A*–G. For GCSE Science A, in addition to the centre-assessed unit, each of Biology 1, Chemistry 1 and Physics 1 is divided into two subsections which are assessed by an objective test (OT).

3.2 How Science Works

All six specifications take the same approach to 'How Science Works'. This involves a separate section of content, the procedural content, which needs to be taught and learnt to enable candidates to understand how scientists obtain evidence and judge its reliability, and how scientific discoveries impact on society. In each specification, this content is in Section 10 and it is the same in all six specifications. It is expected that this content is delivered in parallel with and through the substantive content. It falls into two areas: Sections 10.3–10.7 which deal with designing investigations, obtaining reliable evidence, presenting data and drawing conclusions, and Sections 10.2 and 10.8–10.9 which deal with how society uses scientific knowledge and understanding.

Each of the nine units (Biology 1, Biology 2, Biology 3, Chemistry 1, Chemistry 2, Chemistry 3, Physics 1, Physics 2, and Physics 3) is associated with a different section of substantive content (the science facts). The substantive content which is assessed by written papers (or objective tests for GCSE Science A) is presented in Sections 11, 12 and 13 of each specification. This content is cross-referenced to the 'How Science Works' content using symbols which indicate where two different aspects of 'How Science Works' can be delivered through the substantive content.

This symbol identifies parts of the content which lend themselves to extended investigative work of the type needed to explore sections 10.3–10.7 of the procedural content. These sections are about obtaining valid and reliable scientific evidence. These parts of the content may form the contexts for the Investigative Skills Assignments part of the centre-assessed units.

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

The cross-referencing is not exhaustive, and is intended to be indicative only.

A further guide to the delivery of 'How Science Works' is given by the organisation of each subsection of Sections 11, 12 and 13 of each specification. Each subsection begins with several statements: 'Candidates should use their skills, knowledge and understanding of how science works to ….'. These identify activities that could be used to enable candidates to practise 'How Science Works'. The subject matter that needs to be delivered to enable these activities to be undertaken is then given in statements with the introduction: 'Their skills, knowledge and understanding of how science works should be set in these substantive contexts'.

The arrangement of the specification content is described in Section 9.1 of each specification, and further details of the 'How Science Works' are given in Section 9 of this Teachers' Guide.

3.3 Centre-Assessed Units

The model for centre assessment (internal assessment or coursework) is the same for all six specifications. It involves two parts, both of which are intended to fit into a normal teaching scheme.

The first and smaller part is the Practical Skills Assessment (PSA) which is a holistic assessment of a candidate's ability to undertake practical work skilfully and safely. The assessment would normally be made towards the end of the course; this part is not moderated.

The second and larger part is the Investigative Skills Assignment (ISA). Candidates undertake an AQA-designed practical, during which they collect a set of results. They then take an AQA-set test in controlled conditions during normal lesson time, which is marked by their teacher using an AQA mark scheme. Marking of the ISA is moderated by an AQA moderator. The whole assignment, including the test, is expected to take around two or three lessons, and the practical work should arise naturally from the teaching of the specification.

Security of ISAs

It might be said that there is significant scope for candidates to gain unfair advantage in the centre-assessed units. Candidates who sit an ISA after other candidates could get to hear about the questions. There is some truth in this. However, the centre-assessed units are 'coursework' so the comparison is not with external examinations, but with coursework tasks, where the same work is often set year after year, or the same task is set for several teaching groups. The ISAs are more secure because around half the questions relate to the candidate's own data, and so the answers are specific to the candidate. AQA expects centres to store ISAs securely and they are valid for just two years, so are less likely to become 'public knowledge'. Candidates who are first to take ISAs in a centre could be reminded that it is not in their interests to help others get better marks since it may downgrade their own achievement. There is an added advantage as all work must be carried out under the teacher's direct supervision: candidates are not allowed to take work home.

Further details of the centre-assessed units are given in Sections 6, 7 and 8 of this Teachers' Guide.

3.4 Administration

This section is presented in the form of FAQs.

How do centres make entries for GCSE Science exams?

Written papers and objective tests

Each examined unit (objective test or written paper) has a separate entry code. This is so that candidates can take the different units in a science GCSE in different exam series. The entry codes for the OTs or written papers stay the same even if the unit could be used towards different science GCSEs.

The centre-assessed unit

The centre-assessed unit entry codes are specific to the subject; therefore it is important that the centre is clear about which subject the candidate is certificating in. For example, if a candidate enters a Physics ISA for GCSE Science (SCYC) it cannot be used towards a GCSE Physics certification. The candidate would need to enter a Physics ISA (PHYC) to be able to certificate in GCSE Physics.

If a centre has a set starting GCSE Science in Y9, then it may wish to submit one of the ISAs that the candidates complete in Y9 for moderation. Once moderated and banked the CAUs remain valid until the end of the specification. The ISAs themselves have a shelf life of two years and therefore a Y9 completed ISA would not be current for moderation in Y11 and therefore must not be submitted in Y11.

How do candidates get results for GCSE subject awards?	Each subject award has an entry code. When a candidate has results for all the units that make up a GCSE qualification (or will have with the exams they are to take in the next exam series), the centre makes a subject award entry. This entry has the effect of telling the AQA computer to look for the marks that a candidate obtained for the units in the subject award and to add them up to give a total mark which is reported together with the equivalent grade (A*–G) for the candidate.
Where do I find entry codes?	To find the definitive list of entry codes for all AQA specifications, go to www.aqa.org.uk/admin/p_entries.html and follow the 'Entry Procedures and Codes' link. The entry codes are also in Section 3.2 of each specification.
Can candidates resit units?	Yes. The number of resits is unlimited (as long as the specification remains available).
How does the AQA computer work out grades when a candidate has more than one result for a unit?	Before the computer adds up the marks, it finds the best mark for each unit, so that the maximum total mark possible is calculated.
What happens about the other results which are not used towards the total mark?	They are 'used up' and cannot contribute towards a different GCSE subject award.
If a candidate gets a poor grade for, for example, GCSE Science, what can they do to improve it?	They can retake one or more units, re-enter for the subject award and obtain a new subject award. If they retake, for example, one unit and perform better, this better mark counts towards the new subject award. If they do less well, their previous result is used again. Unit results can be re-used, but only towards the same subject award for which they were used originally.
How do candidates get, for example, GCSE Science B and GCSE Biology, which have a common unit?	Unit results cannot be re-used for a different subject award, even where the unit can count towards more than one award, as all results for a unit are 'used up' when an award is made. Therefore, candidates who wish to get GCSE Science B followed by GCSE Biology must re-take the common unit (B1) after obtaining the subject award GCSE Science B. The new B1 result can then count towards GCSE Biology. Alternatively, they could take the objective tests B1a and B1b before they obtain GCSE Science B, as these cannot count towards Science B so will not be 'used up'.
For which entries are fees payable?	There is a fee for every unit entry, including resits. There is no fee for subject award entries.
Will total entry costs for centres increase?	The total fee for entering the four units for GCSE Science B, GCSE Additional Science, GCSE Biology, GCSE Chemistry and GCSE Physics (or the seven units for GCSE Science A) will match the fee for a linear single award GCSE. However, resits **will** cause additional costs. Also, since entries will often be made earlier in KS4, fees may be payable earlier, eg if candidates take units towards GCSE Science A or B in Y9 orY10.

Is an entry fee payable for each Investigative Skills Assignment (ISA) in the Centre-assessed units?	No. The minimum requirement is a mark for one ISA, plus a mark for the holistic Practical Skills Assessment, making a centre-assessed unit mark. If several ISAs are undertaken by candidates during the course, only the highest mark is used to calculate the centre-assessed unit mark. Therefore, there is only one fee per submitted CAU. It is possible to submit another CAU for the same unit the next year but this would be a 'resit' and therefore a fee would need to be paid.
Where can I find the dates of exams?	Exam dates are in the AQA Timetable, available at www.aqa.org.uk/admin/timetable.html Wherever possible, AQA timetables exams to cause least inconvenience to centres, and if advised of problems will attempt to take account of centres' requirements. Moving the first new specification exams to the end of the June 2007 series is an example of this, as it avoids current and new exams being on the same dates which could cause problems in exam rooms with both Y10 and Y11 candidates having to be accommodated.
What happens if the examiners set a slightly more difficult paper in one exam series, so the candidates get lower marks? Won't that be unfair?	All raw marks from units will be transferred onto a Uniform Mark Scale (UMS), on which each score represents the same degree of attainment relative to the A*–G grading scale. So a lower mark on a more difficult paper gets the same UMS score as a higher mark on an easier paper which represents the equivalent attainment. The UMS scores are added up to work out the final grade. (See Section 23 of each specification for more details.)
Where can I find more information about the administration of these specifications?	There is a booklet on the AQA website at www.aqa.org.uk/admin/library.html, then follow the 'Administrative Procedures – GCSE Modular Specifications and GCSE in Vocational Subjects' link.

External Assessment

4 Written Papers

4.1 Introduction

Each written paper consists of a number of compulsory questions based on the unit content, and will allow candidates to apply the knowledge, understanding and skills they have gained from practical activities and teaching within the classroom.

All papers are presented as question and answer booklets, are set and marked by AQA and are available in January and June each year.

Two tiers of entry are available for the written paper for each unit:

- Foundation Tier, targeted at grades C–G
- Higher Tier, targeted at grades A*–D.

For all specifications different tiers can be taken for different papers. It is important to target correctly the entry of individual candidates for each paper. Centres should think carefully before entering borderline grade C/D candidates for the Higher Tier paper.

Experience has shown that candidates whose expected performance is unlikely to exceed that expected from a grade C candidate, are more likely to achieve a grade C if they entered for the Foundation Tier. This seems to be as a result of the confidence such candidates gain in being able to answer many of the low demand questions that appear first on the written paper.

The final grades for the award obtained by the candidate are determined by the total UMS score achieved in the three written units and the centre-assessed unit. See Section 23 of the GCSE specifications for further information on UMS scores.

All of the Foundation and the Higher Tier papers are of 45 minutes duration, with a maximum of 45 marks. Approximately 30% of the questions are common. The remaining 70% of the marks on the Foundation Tier paper are targeted at the least able candidates (E, F and G). On the Higher Tier paper approximately 50% of questions are targeted at the more able candidates (A*, A and B). The common elements of these papers are identical standard demand questions and the associated mark schemes are also identical.

For the Science A and Science B specifications there is no specific Higher Tier content. Questions in the Higher Tier papers will be more demanding, thus allowing candidates to access the higher grades. For the Additional Science, Biology, Chemistry and Physics specifications there is additional content for Higher Tier candidates. The Higher Tier content is clearly indicated in the specifications.

4.2 Guide to Command Words in GCSE Sciences

The command words and phrases used in examination papers are there to inform candidates of the style of answer required. Ignorance of the meanings of one or more of these command words or phrases could lose a candidate marks. The list below provides the meanings of many of the most frequently used command words and phrases.

Many questions are best asked as direct questions prefaced by the words 'What?', 'Why?' or 'Where?'. So commonplace are these words and so varied the context in which they might be used that no attempt has been made to define them.

AQA's guiding principle in producing its examination papers is to set questions that are clear and unambiguous. While instructions will normally be taken from the list that follows, AQA reserves the right to substitute alternative expressions if it is felt that they make the meaning of the question clearer.

Calculate / Work out The candidate must produce a numerical answer.

Compare The candidate needs to describe the similarities and/or differences in sets of data.

Complete The candidate needs to enter the answer in the spaces provided in a diagram, table, sentence, etc.

Describe The candidate must state in words, or as diagrams, the important points of the topic.

Draw a bar chart

- Where the axes are labelled and scaled, the candidate needs to plot as bars a series of values.
- Where the axes are labelled and not scaled, the candidate needs to add scales and to plot as bars a series of values.

Draw a graph

- Where the axes are labelled and scaled, the candidate needs to plot as points a series of values, and then to draw a straight or curved line appropriate to the relationship between the points.
- Where the axes are labelled and not scaled, the candidate needs to add scales, to plot as points a series of values, and then to draw a straight or curved line appropriate to the relationship between the points.

Evaluate Candidates should use the information supplied in the form of articles, graphs and/or experimental results within a given context, to consider the evidence for and against and draw conclusions.

Explain The candidate should apply reasoning to the recall of theory. (This command word will **not** be used if the required answer is no more than a list of reasons.)

Give a reason (how/why) The candidate should give a reason that is an application of scientific knowledge based on the recall of content stated in the specification or based on information supplied in the question.

Give/Name/State/Write down	A concise answer is required without supporting evidence.
List	Candidates should give a series of concise answers, each answer being written one after the other.
Predict	The candidate must give a concise answer, without supporting evidence, and should produce their answer by making logical links between various pieces of information.
Sketch a graph	The candidate needs to draw a graph indicating a trend or pattern without the need to first plot a series of points.
Suggest	There is no unique answer: candidates are expected to base their answers on scientific knowledge and/or principles.
Use the information	Candidates should base their answers on information provided within the context of the question.
Use your understanding/ideas of .....to	Candidates should frame their answers around a scientific concept.
What is meant by	The candidate should give a definition, together with some relevant comment on the significance or context of the question.

4.3 Tiering and Level of Demand

In all the written papers, candidates can be entered for one of two tiers. The entry code denotes the tier being entered.

The grades awarded for each tier of the written papers are shown in the table.

Higher Tier	A*	A	B	C	D	(E)		
Foundation Tier				C	D	E	F	G

In all units, candidates may take each written paper at either tier.

The allowable grade E is available for candidates who just fail to achieve a grade D on a Higher Tier paper.

In order to allow candidates from the complete ability range to demonstrate what they know, understand and can do, the style, content and context in which a particular question is presented match one of three levels of demand – low, standard or high.

At each level of demand, questions are written to target a specific grade range:

- low demand questions target grades G, F and E
- standard demand questions target grades D and C
- high demand questions target grades B, A and A*

The essential features of a question that distinguish it as being of low, standard or high demand are shown in the table.

Feature	Low Demand	Standard Demand	High Demand
What knowledge is assessed?	The specification content, excluding any content designated as Higher Tier only	The specification content, excluding any content designated as Higher Tier only	The specification content, including content designated as Higher Tier only
What contexts are used?	Familiar contexts given in the specification content	Familiar contexts given in the specification content and unfamiliar contexts described in the question	Familiar contexts given in the specification content and unfamiliar contexts described in the question
How much cueing is provided?	High degree of cueing provided	Some cueing provided	Limited cueing provided
What tasks are involved in answering the question?	Tasks exemplified by the grade descriptions for grade F candidates*	Tasks exemplified by the grade descriptions for grade C candidates*	Tasks exemplified by the grade descriptions for grade A candidates*

* Details of the grade descriptions are given in Appendix A of each specification.

The table shows the approximate percentage of marks allocated to each level of demand on each of the two tiers of written papers. No questions targeting grade E candidates will be set on the Higher Tier paper.

Foundation Tier	Low demand questions	70% of the marks
	Standard demand questions	30% of the marks
Higher Tier	Standard demand questions	50% of the marks
	High demand questions	50% of the marks

Standard demand questions, where they are common to both tiers, are complete questions appearing in an identical format with an identical mark scheme irrespective of the tier in which they appear.

The common, standard demand questions are written to provide evidence, when matched against the grade descriptions, of grade C performance. Because they are the same questions with the same mark schemes, a similar level of performance can be expected from candidates being awarded grade C on either tier of the written paper.

As part of the move to encourage candidates to be more literate, questions giving candidates the opportunity to write answers in extended prose are set in both tiers of papers.

Questions giving opportunities for extended prose answers can involve:

- a description of a method
- a comparison of a set of data
- an explanation involving more than one step
- the construction of a logical argument.

On Foundation Tier papers, **no more** than 25% of the total marks will be awarded to questions that give candidates the opportunity to write answers in extended prose. On Higher Tier papers, **at least** 25% of the total marks will be awarded to questions that give candidates the opportunity to write answers in extended prose.

Teachers should prepare all candidates to expect questions requiring extended prose answers to appear in both tiers of papers.

4.4 How Mark Schemes are Applied

The stressing of these points to candidates could prevent them from throwing away several valuable marks.

Marking of lists

This applies to any question requiring a set number of responses but for which candidates have provided extra responses or included incorrect responses.

- The principle to be followed in such situations is that 'right + wrong = wrong'.
- Each error/contradiction negates each correct response. So, if the number of errors/contradictions equals or exceeds the number of marks available for the question, no marks will be awarded.
- However, responses considered to be neutral (indicated as * in Example 1) will be ignored.
- The order in which candidates write their responses is irrelevant.

Example 1: 'What is the pH of an acidic solution?' (1 mark)

Candidate	Response	Mark awarded
1	4, 8	0
2	Green, 5	0
3	Red*, 5	1
4	Red*, 8	0

Example 2: 'Name two planets in the solar system' (2 marks)

Candidate	Response	Mark awarded
1	Pluto, Mars, Moon	1
2	Pluto, Sun, Mars, Moon	0

The same principle of 'right + wrong = wrong' will be applied to questions giving the candidates opportunities to write answers in extended prose.

Use of chemical symbols/formulae

If a candidate writes a chemical symbol/formula instead of a required chemical name, full credit will be given if the symbol/formula is correct in every detail and if, in the context of the question, such action is appropriate.

The use of the word 'it'

Answers using the word 'it' will be given credit only if it is clear to the marker that the 'it' refers to the correct subject.

Phonetic spelling

While it is expected that candidates will spell scientific terms correctly, phonetic spelling will be credited unless there is a possible confusion with another technical term.

5 Objective Tests

5.1 Introduction

Objective tests (OTs) are available only for GCSE Science A. Each of the three subject content sections of the specification, Section 11, Biology 1, Section 12, Chemistry 1, and Section 13, Physics 1, is divided into two roughly equal parts, each part being assessed by a separate OT. Each OT is a separate assessment unit so candidates receive a graded result for each OT. Science A, therefore, has seven units (six OTs plus the centre-assessed unit). As with all assessment for these specifications, the OTs assess 'How Science Works'.

5.2 Types of Question

Currently, two types of objective test question are used: matching, in which four items are matched to four responses, and multiple choice, in which the correct answer from four must be identified. Matching questions are worth four marks, and could involve deciding which of four labels is needed for four parts of a diagram or choosing which of four words or phrases fits into four sentences. Multiple choice questions are presented in sets of four, with a common stem or stimulus material. Matching questions are found to be more accessible by candidates and therefore there is a higher proportion of matching questions in the Foundation Tier OTs.

Over time, AQA plans to introduce a wider range of question types and formats. For example, multiple choice questions could involve choosing the right answer from three or five. The mark total for matching questions may be varied so that each is worth three rather than four marks (this is because currently there is effectively a 'free' mark to any candidate making three correct choices as their fourth choice must be correct). Alternatively, there might be more than four responses to match to four items or a response might be the correct answer for more than one item.

None of these changes would be introduced without timely notification to centres to ensure that candidates can be properly prepared.

5.3 Tiering

Each objective test is available at Foundation and Higher Tier. The entry codes are not tier specific. Both tiers are printed in the question paper and each candidate, guided by the teacher, chooses the appropriate tier at the time of the examination. The answer sheet has provision for candidates to answer either tier. Teachers are requested to stress to candidates the need to complete responses for one tier only.

The two tiers target different grade ranges as follows:

- Foundation Tier, targeted at grades C–G
- Higher Tier, targeted at grades A*–D.

Different tiers can be taken for different OTs. The final grades for the award obtained by the candidate are determined by the total UMS score achieved in the six OTs and the centre-assessed unit.

See Section 23 of each specification for further information on UMS scores.

All the OTs are of 30 minutes' duration, with a maximum of 36 marks. Approximately 30% of the questions are common between the tiers. The remaining 70% of the marks on the Foundation Tier paper are targeted at the least able candidates (E, F and G). On the Higher Tier paper, approximately 50% of questions are targeted at the more able candidates (A*, A and B). The common elements of the OTs are identical standard demand questions.

5.4 Answer Sheets

Candidates record their answers for OTs in black pen on answer sheets which are optically-read once submitted to AQA. Candidates can do any rough working in their copy of the question paper. These must therefore be stored at the centre until the final date for submission of enquiries about results. This covers the eventuality that, for example, candidates have not coded their answers properly or in full. Appropriate credit could be deduced from the working on their copy of the question paper.

5.5 On-screen Assessment

Objective tests are a form of assessment which are compatible with the use of ICT. Candidates' OT responses are already collected electronically through optically-read answer sheets and machine marked. An alternative system being developed by AQA with technology partners is on-screen assessment where questions are displayed to the candidate on the screen of a workstation and the candidate enters their responses directly while working at the computer. As with paper-based systems, provision is made for candidates to practise using the interface, so that it is their science knowledge and understanding that is assessed, not their ICT skills.

AQA is planning that on-screen assessment for GCSE Science A is available for three of the six OTs from November 2006. From November 2007, all six OTs will be available on-screen. Interested centres need to have an appropriate ICT infrastructure. Please contact the GCSE Sciences department if your centre wants to consider this option (01483 477742 or science-gcse@aqa.org.uk).

The first on-screen tests will contain the same questions as the paper-based tests and will therefore be available only during the same timetabled sessions. It is hoped that, in time, a sufficiently large question bank can be developed to allow different tests to be set, allowing a longer assessment window than a single morning or afternoon session.

In the on-screen tests, the matching questions will be presented to candidates as 'drag and drop' where the four items have to be moved across the screen and placed at the chosen response position. This has the advantage of avoiding the necessity of matching numbers 1 to 4 to letters A to D. Multiple choice questions are presented as four options, each with an on-off 'radio button'.

A wider range of question types is possible on-screen and questions can make better use of graphics. AQA plans to take advantage of the greater flexibility and sophistication of on-screen assessment, but not in the first few series. Such changes will be introduced gradually and only after timely notification to centres to ensure candidates can be properly prepared.

Internal Assessment

Internal assessment in these six specifications (GCSE Science A, Science B, Additional Science, Biology, Chemistry and Physics) takes the form of a two part centre-assessed unit (CAU). The two parts are a Practical Skills Assessment (PSA) and an Investigative Skills Assignment (ISA). The PSA is a holistic assessment of the candidate's ability to perform practical work skilfully and safely. The ISA is based on normal laboratory work or fieldwork, and involves an AQA-set test, marked by the teacher using marking guidelines provided by AQA. Candidates may take several ISAs and the ISA with the best mark should be submitted for moderation as part of the CAU. ISAs are undertaken at a time chosen by the teacher during a timetabled lesson. The centre-assessed work should be seen as an integral part of the course. It should not be seen as an extra 'bolt on' to the normal scheme of work. Assessment should be treated as part of the course, built into the scheme of work and completed as a part of the routine programme.

6 Practical Skills Assessments

6.1 Introduction

Section 18.3 of the specification explains the way in which teachers should carry out Practical Skills Assessments.

It is important to realise that PSAs are based on a 'can-do' criteria and can take place throughout the course when the candidate is carrying out practical activities. The teacher may find it useful to make use of a checklist when carrying out a piece of practical work so that a record of each candidate's achievement over the course is kept. Over a number of practical activities, this ongoing record would form a secure basis for the award of the final PSA mark. However, this record is not a requirement and no such evidence will be requested by AQA.

The criteria in the following table are used to award a mark in the range of 0–6 to each candidate.

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

6.2 How to Apply the Criteria

The teacher should use these criteria to ensure that the candidates:

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

The descriptors for the Practical Skills Assessment are hierarchical so that **both** descriptors at a particular performance level must be matched before descriptors at the next higher level can be considered. If only **one** of the descriptors at a particular mark performance level is matched, then an intermediate mark of 1, 3 or 5 can be awarded.

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

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

6.3 Awarding Marks for Techniques/Equipment

This section illustrates the types of skill that teachers should expect candidates to demonstrate in order to be able to access the various marks in the PSA range.

The 2-mark band

Safety

Candidates should:

- carry out practical work safely with safety glasses worn at all appropriate times, wear disposable gloves when handling dangerous chemicals, tie hair back and wear protective clothing when appropriate. Candidates may need frequent reminders to follow these instructions.

Using equipment

Candidates should:

- be able to use simple equipment (eg heating equipment, glassware, power supplies) and simple measuring devices (eg rulers, thermometers, digital meters). They may need assistance to assemble the equipment or to take readings from measuring devices.

The 4-mark band

Safety

Candidates should:

- carry out practical work safely with safety glasses worn at all appropriate times, wear disposable gloves when handling dangerous chemicals, tie hair back and wear protective clothing when appropriate. Candidates may need occasional reminders to follow these instructions.

Using equipment

Candidates should:

- take measurements to an appropriate level of accuracy (eg where an instrument shows a large number of digits, the candidate records a reading with the correct number of significant figures or decimal places). Candidates should be able to do this without assistance
- work consistently to their final planned method
- take care to reduce the number of likely sources of error
- present the data collected in a suitable neat table with all of the headings and units shown while the work is in progress.

The 6-mark band

Safety

Candidates should:

- without being reminded, carry out practical work safely with safety glasses worn at all appropriate times, wear disposable gloves when handling dangerous chemicals, tie hair back and wear protective clothing when appropriate
- show a high degree of organisation when carrying out the practical work. This will be seen as an organised workspace with the apparatus arranged in a consistent and planned way and all containers of solutions and solids correctly labelled.

Using equipment

Candidates should:

- demonstrate competence with a range of equipment, some of which is quite complex
- use the apparatus skilfully in a demanding context.

These last two bullet points may be exemplified by the following

- make up their own solutions of their chosen concentrations rather than being given them. This could be done by diluting a stock solution
- collecting and then measuring the volume of a gas rather than counting bubbles
- taking readings from a changing system rather than a fixed system (eg in a rate of reaction experiment there are two ways in which the volume of a gas can be measured over 10 minutes. The volume can be measured every 30 seconds for 10 minutes, ie a changing system, or the volume of gas may be measured once at 10 minutes, ie a fixed system)
- carrying out an experiment where two instruments need to be read simultaneously rather than only one instrument (eg in a resistance of a wire experiment, the resistance of a length of wire can be measured by simultaneously using an ammeter and a voltmeter, ie two instruments, or by using an ohmmeter to measure the resistance directly, ie one instrument)
- carrying out an experiment that needs careful attention to detail to make sure that meaningful results can be obtained (eg in an experiment where living systems are involved, ie photosynthesis or yeast, the candidate will need to get a number of factors correct to get measurable readings)
- controlling or monitoring the variables in an experiment that has a number of variables that could affect the results (eg in a rate of reaction experiment, the rate is affected by temperature, concentration of solutions and surface area of solids. The candidate will need to control or monitor all of the variables except the independent variable. Often, the temperature can only be monitored rather than controlled such as in exothermic conditions).

6.4 Version of the Criteria for Candidates

Marks	**Skills needed**
2	*When I do practical work*: I can work safely when doing the experiment I can put most things in the right place I sometimes need to ask what to do next I need help to set up and use the apparatus and take readings I can use simple apparatus I can write down my readings during the experiment I can produce a record of my readings.
4	*When I do practical work*: I can work safely when doing the experiment I can put apparatus in the right place I know what to do at each stage of the experiment I can use the apparatus without help I can take all the readings I need to I can produce a record of my readings in a table with most of the headings and units shown.
6	*When I do practical work*: I can work safely when doing the experiment I can arrange my apparatus effectively I am well organised and know exactly what to do next I can use the apparatus skilfully and with confidence I can use complex pieces of apparatus I can take all the measurements to the correct level of accuracy I can produce a record of my readings in a neat table with all the headings and units shown.

6.5 Using PSAs in a Formative Way/Negotiated Profiles

Candidates can be told their PSA mark so that they can try to improve it. The teacher should discuss with the candidates the way in which the improvement can be made, ie what aspect of their current performance is not meeting the criteria for the higher marks. It is reasonable to expect an improvement in the candidates' skill level as they proceed through the course and appreciate that the marks gained in a PSA will go towards their overall assessment and hence will affect their final grade for the subject.

6.6 How to Submit the Final PSA Mark

The final PSA mark is determined by the teacher on the basis of the practical work that the candidate has carried out over the course. The PSA mark is recorded on the Candidate Record Form underneath the ISA mark. The ISA mark and the PSA mark are added together to give the total mark that will be submitted to AQA. There is space on the Candidate Record Form to write a comment about the candidate's PSA if it is thought to be appropriate.

7 Investigative Skills Assignments

7.1 Tiering

Investigative Skills Assignments (ISAs) are **not** differentiated into Foundation and Higher tiers. Coursework has never been tiered in this way and there are no plans at present to introduce this to the ISAs.

The ISA test contains a range of questions targeting all levels from A* to F/G. There is also a range of different styles of question. Some are multiple choice questions, simply requiring the candidate to tick a box; others are more demanding and require a free-response answer. Where possible, questions that can be answered at different levels are used so that most candidates should be able to access some marks but only the better candidates are able to access all the marks

7.2 Low Ability or Disadvantaged Candidates

There are several strategies that may be used with low ability candidates. There is a variety of questions in the ISA test some of which will suit lower ability candidates better than others.

All of the usual procedures that apply for other components of the examination for low ability or disadvantaged candidates are available for the ISA: for example, the use of a reader or an amanuensis, allocation of extra time, large size or Braille versions of the test.

The teacher may use his or her discretion regarding the time allowed, providing that the maximum time of 45 minutes is not exceeded. If the teacher judges that **all** of the candidates have finished after, say, 30 minutes, then the scripts may be collected in.

Six marks will be available for the candidate's production of a table of results and graphs or charts during the practical activity undertaken before attempting the ISA test. It should therefore be possible for even the weakest candidates to obtain a good proportion of the marks available, and to be able to feel that they have had a positive experience in attempting the ISA test.

7.3 Practising ISAs

The best strategy is to carry out all practical work in the spirit of 'How Science Works'. Teachers should encourage candidates into the habit of asking themselves questions such as 'What is the variable that I am going to keep the same, deliberately change or monitor?', 'How many repeats should I make?', 'What can I do to make the results more precise or reliable?'

Provided that only an exemplar ISA from the Specimen Assessment Materials or an ISA whose 'shelf life' has expired is used, it is sensible to allow candidates to practise taking an ISA and to give them back their marked work.

An ISA that has operational status **must not** be used for practice purposes.

When practising ISAs, all or part of an ISA can be used. Using practice ISAs will mean that candidates will become familiar with their general layout. Candidates should recognise that ISAs are, essentially, a writing frame for a piece of practical work. They will soon learn that the types of question that they meet in Section 1 are very similar each time.

One of the most important uses of practising ISAs is to allow candidates to become familiar with the terminology. For example, they need to know about the different types of variable, the difference between reliability and validity, and the meanings of the terms precision and accuracy. The AQA definitions can be found in the Glossary of Terms in the Teachers' Guide (Section 9.3) and at the end of each specification (Appendix D or E).

7.4 Operational ISAs

In June, the Examinations Officer will receive a booklet containing the Teachers' Notes for the ISAs to be published in the autumn of that year. This is to enable the Science Department to work on its forward planning and to decide which ISAs are to be taken. The centre can also arrange for the equipment needed for the ISA to be available.

At the start of the autumn term, the Examinations Officer will receive the operational ISAs for the forthcoming year on a password protected CD.

Each CD will contain:

- Teachers' Notes, including a short teacher guide for the administration of the ISA
- the ISA test papers
- Marking Guidelines for each ISA test
- an ISA Explanation Sheet
- an example of a Centre Rank Order form.

Teachers need to look through the available ISAs to see how they fit into their teaching scheme. Teachers may need to liaise with colleagues if candidates have more than one teacher for science. Although candidates may attempt all of the available ISAs, this may not be the best approach to take. For example, a candidate taking GCSE Science could take one ISA in each of Biology, Chemistry and Physics. The ISA yielding the highest mark could then be submitted.

7.5 When to take the ISAs

ISAs can be taken at any time and used with different groups at different times. The following provisos apply:

- an ISA must **not** be used more than once with any candidate
- candidates must **not** be allowed to take ISA tests, whether completed or not, away from the teaching room
- ISAs can be submitted for moderation only in May

- the final date for the submission of marks for the ISAs is 5 May. Remember that moderation of the Centre-Assessed Unit (CAU) will take place only in May/June – if you decide to certificate in January (or November or March for Science A) a CAU should have been 'banked' the previous June.

As the content examined by the ISAs is common to all units and is being taught through the substantive content, it would be advantageous to candidates to take one ISA as late as possible in the course. The candidates will have then benefited from as much teaching as possible.

7.6 Incorporating the ISAs into the Unit Content.

When it has been decided which ISA to do, the practical activity needs to be planned. As practical work is intended to be a key element of the teaching and learning process, candidates should carry out the practical work that they would normally do at this stage to further their understanding of the topic area.

Teachers should ensure that candidates have been taught the substantive content in which the ISA is set. Whilst candidates will not be assessed on the substantive content, an unfamiliar context could lead them to think that they cannot answer the questions; therefore, it is better if they are familiar with the topic area.

Teachers should prepare the practical work by reviewing the ISA to be taken and ensuring that the candidates' work allows them full access to the questions being asked. The Teachers' Notes will identify any specific requirements.

Risk Assessment

It is essential that teacher perform their own risk assessment for each set of candidates that they wish to enter for a particular ISA. Teachers should also ensure that they have all the safety equipment required for a suggested ISA. If it is not available changes may be made to the ISA. Any changes should be noted on the ISA Explanation Sheet which must be attached to every completed ISA test for moderation.

7.7 Organising the ISA

Teachers need to think of the administration of the ISA as a three-stage process. These three stages may or may not correspond to separate lessons.

Stage 1: Preparation for the Practical Activity

Teachers should actively involve candidates in the design of the investigation. There are no marks in the ISA test for the standard of data produced by the candidate, which means that teachers can use procedures that meet the practical capabilities of their candidates. However, a very simplistic procedure might compromise a candidate's ability to access some of the marks in Section 1 of the ISA.

The most important aspect for the teacher is to decide upon the instructions to give to candidates regarding the method. Candidates need to be supplied with a broad outline of the method, but not one that is so detailed that they cannot make any decisions for themselves. For example, a candidate might be expected to decide the range of the independent variable or when to repeat a reading.

The outline method may be given in any format but must not include any direct reference to the questions to be asked in the ISA test. For example, the method may be given verbally, written on the board or issued as a work sheet. An example of a work sheet for an activity is given in the Teachers' Notes.

Teachers may let candidates carry out a rough trial with the equipment to enable them to see and discuss any difficulties that they might encounter in carrying out the investigation.

The use of data logging equipment or computer simulations is permissible. However, science is essentially a practical subject and candidates should experience as much meaningful practical activity as possible. A candidate who takes an ISA test following a computer simulation exercise, or one in which a data logger has done much of the work may be at a disadvantage when answering the questions on the ISA test if they have not had 'hands-on' experience of using the equipment.

At the end of Stage 1, candidates need to have produced a blank table ready to record their results in Stage 2. Candidates must work independently to produce their own table. The table should be sufficient to contain all the relevant data. The teacher should collect the tables at this point and mark them before proceeding to Stage 2. The first mark allocated on the Marking Guidelines for the table is for the ability to draw up a blank table ready for the inclusion of all relevant data. The mark is not given for the quality or insertion of the data.

Stage 2: Carrying out the Practical Activity

The practical activity need not be limited to a single lesson. However, if the teacher intents to allow the candidates to continue the practical work in a subsequent lesson, then candidates must hand in any work that they have done. Candidates should not be allowed to take any of their work out of the room.

It is perfectly permissible for candidates to work in small groups of two or three, just as they did for the previous Sc1 coursework. It is a requirement that all candidates make an active contribution to carrying out the experiment and obtaining results in order to qualify for marks. If a teacher sees that one candidate is sitting out and letting all the others do the work, then the teacher should not allow that candidate to take the ISA test.

The candidates carry out the practical activity and

- either record their results on their tables prepared at Stage 1
- or, if appropriate, record their results on a different group / class results table. This table may be designed by the teacher.

In some practical work, it is likely that class results will be pooled, eg fieldwork. If this is the case, then both teacher and candidate should identify which results a particular candidate has obtained by, for example, highlighting the candidate's results in the table.

Teacher should not worry if candidates appear to be getting poor results. The marks are not given for the quality of the data obtained but for the candidates' interpretation of that data and how they obtained the data.

If candidates wish to record their data on a word processor or use a graph drawing package to draw graphs, then this is acceptable but it must be carried out in the teaching room. Candidates must not be permitted to take work out of the teaching room for any reason whatsoever.

Candidates may be given help during the practical activity, just as they would be helped in any learning situation. The intention is that the ISA should be part of the teaching and learning process, and not a 'bolt-on' extra which is there merely for the purpose of assessment. It is important that candidates are not given the answers to the questions on the ISA. For example, 'leading questions' such as 'How many different values do you think you ought to test?' may be asked, but statements such as 'If you test only two values, you will not be able to draw a best-fit line graph' must not be used.

The drawing of a graph or chart may be carried out at a convenient time. It may be convenient for candidates to produce the graphs / charts during the lesson in which they carry out the practical activity, but this is NOT a requirement. They might also use the time immediately before taking the ISA test, but the graphs/ charts should be done during lesson time under teacher supervision..

If a candidate experiences difficulty in producing a table or a graph, then it would be appropriate to help them to achieve a reasonable standard. This is because access to Section 1 of the ISA is dependent on having a table of results and a graph or chart. However, the teacher should annotate the candidate's work so that credit is not given when marking.

It is important that a candidate's table and graph contain no extra information that would be of direct help in answering questions in the ISA. The title should be the same as the ISA title.

Candidates must hand in their tables of results and any graphs or charts that they have done, with their name written clearly on the work. These will need to be kept ready to hand back to the candidates when they take the ISA test. Candidates **must** not be allowed to take home their tables, graphs or under any circumstances.

Tables and data presentation when using dataloggers

If candidates have used dataloggers to collect data they must still show they can 'draw up a results table such that data can be presented in a meaningful way and should be easy to understand' (Section 17.6 of the specification). This means that the candidates themselves must draw up their own results table and not rely on any table produced automatically by the data logging software. If the data logging software has produced a large number of results then the candidate must reduce the number of results by selection, or redo the experiment with a different interval setting.

Similarly, data presentation software should allow candidates to 'decide on the most appropriate method of presenting and analysing data' (Section 17.6 of the specification). This means that the candidates themselves must make their own decision on the most appropriate presentation method and not rely on any graphs or charts produced automatically by the data logging software.

If a candidate uses a datalogger to produce a graph, then that individual candidate must set up the datalogger to produce it. The equipment should not be set up by the teacher or another candidate. It is far preferable, however, for candidates to produce a graph using pencil and paper. In this way, they are more likely to obtain a better understanding of the relationships involved and will thus be in a better position to deal with questions on the ISA test.

Data Presentation and Computers

The use of computers is acceptable in data presentation but care must be taken in the drawing of best-fit lines on graphs when using spreadsheet software such as Microsoft Excel. Teachers may allow candidates to use the software to draw the points and then to draw in the line of best fit by hand.

It is important that candidates understand how the software works so that they can choose the most appropriate presentation method from the options available within the software. They also need to be aware that, when using software, a simple two-dimensional presentation method is often easier to understand than a more complicated three-dimensional presentation method.

For most candidates, a hand-drawn method of data presentation is the simplest and most appropriate method. This helps the candidates to understand any relationships involved and puts them in a better position to answer questions on the ISA test.

If computers are to be used, the following two points must be remembered:

- each candidate must produce their own graph. This means that the computer program must not be set up by the teacher or another candidate, such that all the candidate has to do is to enter his or her own data
- the production of graphs and charts must be carried out under the direct supervision of the teacher. This means that the candidate must not produce the graph at home, or go a computer in another room.

Stage 3: Taking the ISA Test

The Examinations Officer should be given advance warning of the day of the test, the title of the ISA test, and how many copies are required. The ISA Copies should be kept secure until candidates take the test.

The ISA test should be taken as soon as possible after the conclusion of the practical activity because the activity will then still be fresh in the candidates' minds.

The ISA test should be taken in the normal teaching room. Examination conditions are not required, ie invigilators and 'Warning to Candidates' posters on the walls are not needed. However, controlled conditions **are** required. This means that candidates may not speak to each other or copy from each other while they are taking the test. This is really very similar to the previous conditions for Sc1 when candidates were asked to write their plan, although they may have ended up working in pairs. This is not an 'open book' assignment, so candidates are not permitted to refer to any material other than their own tables of results and graphs, which the teacher should return to them at the beginning of the test session. Any display material in the room that might be of help to candidates during the ISA test must be removed or covered over. Candidates are not allowed to inspect the apparatus or equipment that they used during their practical work.

If the nature of the investigation is such that it would be difficult to observe a pattern from an individual candidate's results alone (eg a fieldwork investigation) then it would be appropriate to give the candidate a copy of group or class results. If this is the case, then the candidate should be told to tick the appropriate box in Section 1 of the ISA. However, the candidate's individual results must always be enclosed with their ISA or identified on the group results.

If a candidate is present for the practical session but is absent for the ISA test then he or she should take the test as soon as they return - either with another class or on their own. Candidates who have missed the practical session may attempt Section 2 of the ISA. The teacher may furnish the candidate with a results table and graph in order to help them to respond to the questions in Section 2, but they may not submit the marks for Section 1. The work should be clearly marked 'Absent for practical session'. However, this strategy should only be used as a last resort – it is better to get the candidate to tackle a different ISA in its entirety if a practical session has been missed.

At the conclusion of the test the teacher must collect in all the papers. The teacher should ensure that the candidate's table of results and graphs or charts are firmly attached to the ISA test.

7.8 After the ISA Test

The ISAs should be marked according to the Marking Guidelines in red ink. The number of marks allocated for each question should be placed in the right-hand margin. The totals for each section are then transferred to the front cover of the ISA and the teacher must add their signature.

Judgement will be needed as to whether or not a candidate deserves a mark. In Section 1 all of the answers should relate to that particular candidate's own, group or class results.

When the ISA test has been marked, the scripts should be stored in a secure place, preferably with the Examinations Officer, and must **not** be returned to the candidates. The candidates may be told their total mark, but they should be warned that this mark could be subject to change after moderation.

During the autumn term of each year, AQA will run a series of standardising meetings to train teachers how to mark the ISAs and PSAs which form the Centre-Assessed Unit (CAU) mark. These meetings will be designed to help with the training of staff and the maintenance of standards across the whole cohort of AQA candidates. Attendance in the first year of a new programme of assessment is compulsory, as is attendance by centres where there has been serious misinterpretation of the requirements of the specifications.

7.9 Annotation of Scripts

Paragraph 5.16 of the GCSE, GCE, VCE, GVNQ and AEA Code of Practice 2006/7 states: 'The awarding body must require internal assessors to show clearly how credit has been assigned in relation to the criteria defined in the specification … The awarding body must provide guidance on how this is to be done'.

To aid both internal standardisation and final moderation of the ISA tests, it is recommended that teachers make brief annotations at any point where it would not be clear why it has been decided to award a particular mark. This annotation enables the moderator to see as precisely as possible where the teacher considers that the candidate has earned the marks awarded.

Any information or guidance provided to candidates when completing their tables and graphs or charts must accompany work that is submitted for moderation.

7.10 Internal Standardisation

Centres need to conduct internal standardisation for the ISA tests. to standardise the marking of **all** the teachers who will be marking ISAs for submission in a particular year. This is to ensure that the sample sent to the moderator is a true representation of the work produced and marked in a centre. The Centre Declaration Sheet (CDS) needs to be completed and signed by the Head of Centre to confirm that Internal Standardisation has been carried out.

7.11 Moderation

Centres are required to submit a sample of the candidates' work for moderation. Details of how many pieces of work are required are given in the AQA booklet *Instructions to Teachers for Submitting Marks and Samples*. When submitting work to the moderator, the following items must be included:

- the results tables and graphs or charts for each candidate whose work is requested. These should be firmly attached to the ISA test paper for the candidate
- a completed copy of the ISA Explanation Sheet for each candidate's activity. This should either confirm that the suggested technique has been carried out or provide details of any changes that were made and, if so, include any changes that the teacher may have made to the marking guidelines.
- a copy of any instruction sheet given to the candidates in order to carry out the practical work. If a printed sheet was not issued, then a brief summary of any verbal instructions that were given should be enclosed
- a spreadsheet showing a rank order of the ISA scores (the moderator will not be moderating the PSA score so it is vital that ISA marks are sent to them). A sample spreadsheet is shown in Appendix A.
- a completed Centre Declaration Sheet.

Paragraph 5.20 of the GCSE, GCE, VCE, GVNQ and AEA Code of Practice 2006/7 states: 'To ensure that standards are aligned within and across centres, the awarding body must moderate the marks submitted by each centre against the specified assessment criteria.' Moderation is carried out by an AQA moderator, who undertakes detailed scrutiny of all the work of a sample of candidates from each centre. On the basis of this inspection, it is decided whether to:

- accept the centre's assessments
- adjust the assessments to bring them into line with national standards
- ask for a further sample
- ask for the work of all candidates or request the centre to reassess or internally standardise their marks.

Normally, a centre's judgement about the order of merit is accepted. However, if major discrepancies are discovered, AQA reserves the right to alter the order of merit and to inform the centre accordingly.

7.12 Keeping Records

Centres need to keep secure records of the marks that the candidate achieves in each of the ISAs that they take, so that their best mark can be submitted to AQA. This can be by any method that the centre thinks appropriate. Commercial software programs may be available for use. An example of a Record for that could be used can be found in Appendix A

7.13 Private Candidates

Private candidates can take the Centre-Assessed Units through, with their agreement, the same centre at which they are taking written papers or Objective Tests.

The private candidate should download the Teachers' Notes from the AQA Website:
http://www.aqa.org.uk/qual/gcse/newscience/teachersnotes.html
or contact the subject department to request the Teachers' Notes for the ISAs that are available for that year.

The private candidate chooses the ISA they wish to do. They do the experiment described or, with help from their tutor, alter the experiment. If they alter the experiment, they must fill in the ISA Explanation Sheet and attach their plan for the experiment. The form will be found with the Teacher's Notes. This does not have to be detailed, but will enable the moderator to see how the experiment was performed when the ISA is marked.

The private candidate completes the experiment and produces tables of results and graphs or charts from the results.

The private candidate contacts the centre through which they have entered and arranges to come in to take the ISA test. It is suggested that they do so on a day when an ISA test or other external examinations are being taken as this reduces the amount of supervision required at the centre. The private candidate attends the centre, on the mutually agreed date, to take the ISA test which the centre provides.

The private candidate submits with the ISA:

- tables of results
- charts or graphs produced from the tables of results
- the Private Candidate Record Form (this can be found on the AQA website http://www.aqa.org.uk/admin/p_private.html). The tutor needs to sign the form to authenticate that the work is that of the candidate and not copied in any way from any other source
- any paperwork regarding Access Arrangements the private candidate has been given (amanuensis, reader, Braille, helper, etc).

The centre retains the work and sends it to the moderator on or before 5 May with the rest of the ISAs from that centre. They should enter PRI on the Centre Mark Sheet for that candidate.

The moderator marks the ISA test. A PSA mark for the private candidate is awarded pro rata with the marks scored in the ISA test.

PSA Score	ISA Score
0	0–5
1	6–10
2	11–15
3	16–20
4	21–25
5	26–30
6	31–34

The moderator submits the private candidate's mark on their Moderator Mark Sheets.

7.14 Centre Assessment Advisers

Each centre is allocated a Centre Assessment Adviser. Centre Assessment Advisers answer telephone or email queries and may look at an example of marked work to give guidance on the standard if a centre is in difficulties. They cannot make any comment on work which was submitted in previous years.

Centre Assessment Advisers cannot prime mark any work.

The advice that a Centre Assessment Adviser gives is restricted to:

- issues related to the carrying out of the assignments
- standards of marking
- administrative issues
- discussion of feedback from moderators.

Centre Assessment Advisers are all moderators. They do not moderate work from centres that they advise.

7.15 Standardising Meetings

Annual meetings are usually held in the autumn term, at venues around the country. At these meetings, teachers have the opportunity to discuss the centre assessment requirements, are given examples of possible approaches and receive instruction on the application of the PSA criteria and the ISA Marking Guidelines.

New centres who wish to take AQA GCSE Science should contact the GSCE Science Department at Guildford to ensure that they are invited to the meetings. They will then be sent the Teachers' Notes, ISA CD and any training material as it becomes available.

Attendance in the first year of examination is compulsory.

8 Administration of the Centre-Assessed Units

8.1 Candidate Record Forms

Candidate Record Forms (CRF) for the centre-assessed units (CAU) are sent out in the autumn term to centres' Examinations Officers based on the previous year's entry numbers. Candidate Record Forms can also be downloaded from the AQA website (www.aqa.org.uk, choose the administration link and then the procedures link which gives a drop down menu).

Both sides of the CRF should be filled in for each candidate and the CRF should be attached to the front of the candidate's work. Each form must be signed by both the candidate and the teacher. If any of the Candidate Record Forms received by the moderator are not signed by the candidate, the moderator writes to the centre and request that a new CRF with the candidate's signature be sent. If no signature is forthcoming then a mark of zero or absent will be given to that candidate. The front cover of the ISA script must also be signed by the candidate and the teacher.

Any extra help given to a candidate should be indicated on the CRF or in the work, eg Access Arrangements, and a copy of the paperwork attached.

8.2 Centre Declaration Sheet

Each centre should submit one Centre Declaration Sheet. It authenticates the candidates' centre-assessed work and confirms that internal standardisation of marking has been completed. All teachers who have marked work for that year should sign the form. The Centre Declaration Sheet is sent out with the CRFs and can also be downloaded from the AQA website.

Please note that the Centre Declaration Sheet must also be signed by the Head of Centre.

8.3 Centre Mark Sheets (CMS) or Electronic Data Interface (EDI)

Centre Mark Sheets (CMS) are sent out in the spring term, along with Supplementary Centre Mark Sheets. These are triplicate forms. The centre-assessed unit (CAU) mark, made up from the Practical Skills Assessment (PSA) mark and the Investigative Skills Assignment (ISA) mark, for each candidate should be written on these sheets which are optically read. Marks may also be submitted by EDI.

Any late entrants or those not listed on the CMS should have their marks recorded on a Supplementary Centre Mark Sheet. These Supplementary Centre Mark Sheets are not specific to science and are kept by Examinations Officers.

It is helpful if centres can provide a spreadsheet of candidates' ISA test scores in rank order. Moderators will not be moderating the PSA part of the total and it is therefore vital that the moderator can see the ISA score. An example of this spreadsheet can be found in Appendix A. Centres with 20 or fewer candidates should send the work of all of the candidates to the moderator.

If a moderator needs to clarify any issues, they will telephone the centre. They may also require extra work if the initial sample has shown erratic marking.

8.4 The Sample

The moderator requests the sample by writing S against the candidate numbers on the CMS or EDI printout.

Teachers must ensure that each piece of work required for the sample includes the signed CRF, the ISA answer booklet and the tables, graphs and charts that the candidate has used to answer the questions. These should be secured to the answer booklet. Please do not use plastic wallets.

If the teacher has given the candidates a worksheet or has produced class results that the candidate has used in addition to their own work, these should be included and clearly marked as such.

If any changes have been made to the investigation suggested, the ISA Explanation Sheet should be completed and submitted with the CMS or EDI printout and the CAU spreadsheet. The ISA Explanation Sheet is included in the Teachers' Notes and on the ISA CD and an example of a CAU spreadsheet is on the CD.

Sample omission

If the sample received by the moderator is not complete then the centre is contacted and asked to send the missing work, which must be sent by return of post.

Lost centre-assessed work

If the piece of work is mislaid by the centre but the mark can be backed up by an entry in a teacher's mark book, then a Lost Coursework Form should be filled in for that candidate. This can be obtained from Examinations Officers.

If work that is lost is requested for moderation then work from another candidate which has the same mark, or is nearest to the mark of the lost work, should be included. Please include a copy of the Lost Coursework Form.

8.5 Feedback Forms

Feedback forms for each ISA are completed by moderators and sent out to Examinations Officers at the time of the results. These give information and advice for the future.

If a centre's marks are found to be out of tolerance, the marks will be regressed (adjusted to bring them into line with the national standard for the component). The moderator ticks the 'NO' box on the feedback form and completes a continuation form to explain why the marks are out of tolerance. Centres can also check the marks on the results sheets against the marks submitted in May to see whether they have changed.

If the moderator notes that a centre's marks are very near or at the tolerance allowed, then a comment to this effect is written on the feedback form. It has been found that some centres gradually move towards being out of tolerance over several years. The marks then become out of tolerance and centres are shocked when marks are regressed. Teachers then feel that they have not been told they are only just in tolerance. Therefore it is advised that centres carefully read any comments made by the moderator on the feedback form.

If there are concerns about any adjustment of centre-assessed unit marks, centres should consult their Examinations Officer for details of the Enquiries about Results procedures. Centres should not contact the moderator or the Centre Assessment Adviser about work that has been completed and submitted.

Any Enquiries about Results should be initiated in writing by 20 September. The sample which was originally sent to the moderator and returned in July is required for any re-moderation.

Teachers are advised to obtain and read a copy of the Report on the Examination which is published on the AQA website after the examination.

8.6 Centres are Reminded:

- to use staples and treasury tags to keep each candidate's work together and not to use plastic wallets or folders
- that the Candidate Record Form should be at the front of the work
- to use the supplied AQA sacks or envelopes, as delays occur when moderators have to make special trips to Post Office sorting centres to collect parcels
- to use the minimum of sticky tape necessary to ensure safe carriage
- to use First Class post only and to ensure that the correct postage is used to avoid delays to delivery.

Course Organisation

9 How Science Works

A general overview of the treatment of 'How Science Works' in the AQA GCSE Sciences specifications is given in Section 3.2.

Further information about Sections 10 and 17 of the specifications and their significance is given below.

9.1 Section 10 – How Science Works

Section 10 details the procedural content that candidates require. They need to know and understand this section in order to be successful in any of the assessment units (written papers, OTs, ISAs).

It has the following sections:

10.1 The thinking behind the doing

10.2 Fundamental ideas

10.3 Observations as a stimulus to investigation

10.4 Designing an investigation

10.5 Making measurements

10.6 Presenting data

10.7 Using data to draw conclusions

10.8 Societal aspects of scientific evidence

10.9 Limitations of scientific evidence

Sections 11–13 in each specification detail the substantive content that candidates require for the different units of the specifications. Section 10 should be read in conjunction with the substantive content of each unit of the specification.

Section 10 is common to all units and all specifications, but different units provide a different range of opportunities for the development of the skills associated with 'How Science Works'. It is important that candidates have opportunities to develop all of the skills associated with Section 10 in a range of different contexts.

Schemes of work and lesson plans should integrate the skills of 'How Science Works' with the substantive content.

The wider the range of practical work undertaken and secondary evidence evaluated, the more able candidates become in handling questions on unfamiliar material that they may meet in both the external examinations and the Investigative Skills Assignments. The symbols used in the substantive content relate to suggested opportunities for the delivery of the skills in Section 10.

This symbol identifies opportunities for extended investigative work of the type needed to explore Sections 10.3–10.7.

There will be many more opportunities for practical work of a less extensive nature. These could include:

- testing of materials
- demonstrations
- surveys
- data analysis
- critical analysis of scientific data
- evaluation of scientific claims

All of these offer different opportunities for teaching different aspects of Section 10.

This symbol identifies the parts of the content which lend themselves to activities allowing Sections 10.2 and 10.8–10.9 to be considered. The substantive content should allow opportunities for candidates to make judgements on, for example, scientific and non-scientific opinions and the consequences of scientific and technological developments.

9.2 Section 17 – Investigative Knowledge and Skills for Centre-Assessed Unit

Section 17 represents a summary of the procedural content from Section 10, How Science Works, which teachers and candidates may find useful in preparing for the ISA. It interprets the Section 10 statements in a format that will be used in the ISA. The subsections are the same or similar and are:

17.2 Fundamental Ideas

17.3 Observation

17.4 Designing an Investigation

17.5 Making Measurements

17.6 Presenting Data

17.7 Identifying Patterns and Relationships in Data

17.8 Societal Aspects of Scientific Evidence

17.9 Limitations of Scientific Evidence

9.3 Version of the Glossary for Candidates

Every individual measurement is subject to two forms of error.

Random error

What is it?
If we repeat a measurement we never get exactly the same result. This is because of poor technique or small variations in the variables we thought we were controlling. Poor technique includes things such as failing to use a timing mark with a stopwatch, or counting bubbles instead of measuring volume. Small variations might be small temperature changes when measuring rate of reaction or resistance. These might be too small to measure, but nevertheless change the last decimal place on a meter, eg depending on a tiny variation 0.015 may appear as 0.01 or 0.02 on a 2dp meter.

How big is it?
In a carefully controlled experiment, the likely random error is ±1 in the last decimal place or scale division on the measuring device (because the other sources of random error have been made smaller than this). Random errors of less than 10% are considered good in GCSE Science work. If the random error is small, the measurements are called 'precise'.

How do you reduce it?
The average of several repeated readings is more accurate than one reading. Using a more sensitive instrument (one with a smaller scale division or more decimal places) will make smaller changes measurable and so can increase precision (if the instrument was the limiting factor and not the procedure).

Systematic error

What is it?
This is a consistently high or low measurement caused by poor instruments or techniques. Examples include a poorly calibrated instrument (a cheap thermometer or metre rule scale will not be correctly marked), a zero offset (such as failing to tare a balance), or poor technique (such as having no lid in a cooling experiment, or starting the stopwatch before adding the marble chips in a rate of reaction experiment).

How big is it?
It cannot usually be estimated because if you knew the error was there you would do something about it. In the case of limitations of a technique (such as adding marble chips before sealing the flask) it might be possible to estimate the error introduced. If you think your systematic errors are small, the measurements are said to be 'accurate'.

How do you reduce it?
You can't, unless you know it's there and have the equipment to avoid the error altogether. Sometimes better equipment can help (eg expensive, well-calibrated rulers), or better technique (eg using a timing mark). It may be possible to re-calibrate the piece of equipment (eg digital balance) or to compare the readings on two instruments to see whether they give the same readings (eg two thermometers).

Reliability

A measurement is 'reliable' if another person, technique or instrument will give the same result. This means any known systematic errors should have been eliminated.

The following tables show some examples of sources of error and what to do about them. Note that some techniques are both inaccurate and imprecise.

Precision

Precision is often determined by the smallest scale division on the measuring instrument. This may be reflected in the number of significant figures quoted. Precision may also be determined by technique. Techniques that have a high degree of precision should yield a set of repeat results that shows little variation.

Accuracy — Accuracy is a measure of how close to the true value the results are. The main cause of lack of accuracy is the existence of random or systematic errors. Accuracy can often be improved by repeating the results and calculating a new mean.

Imprecise technique

Technique	*Source of error*	*Solution*
Using a stopwatch without a timing mark	Judgement by eye	Use a fiducial (timing) mark
Counting oxygen bubbles	Bubble volume unknown	Collect in measuring cylinder
'Disappearing cross' by eye	End point not well defined	Use a light sensor and threshold value
Putting a balance near where people are walking	Vibrations	Position elsewhere
Using a crocodile clip to connect to wire for resistance	Clip thickness or poor contact due to corrosion	Use a needle or jockey

Imprecise equipment — NB Often the technique used introduces a larger error than the equipment.

Equipment	*Source of error*	*Solution*
Using a 2dp ammeter to measure currents below 0.1 A	+/– 0.01 A in 0.1A is immediately 10% error	Use more sensitive ammeter or increase current
Using a 50 ml measuring cylinder to measure volumes below 10 ml	Half a scale division is 0.5 ml (around 10% error)	Use 10 ml measuring cylinder with 0.2 ml divisions
Using a –10 to – 110 °C thermometer to measure over a narrow range	Half a scale division is 0.5 °C (only 1% error in 50 °C range)	Use temperature sensor or thermometer with a narrower range.

Inaccurate technique

Technique	*Source of error*	*Solution*
Measuring oxygen released immediately	Rate of production is not steady	Wait for equilibrium to be reached
Stoppering the flask after adding acid to marble chips	Some product lost and timing consistently low	Add acid via a thistle funnel
Using a stopwatch without a timing mark	Tendency to always stop the watch early	Use a light gate
'Disappearing cross' by eye	Tendency to judge the endpoint too early	Use a light sensor and threshold value
Using a croc clip to connect to wire for resistance	Measuring from the far edge of the clip	Measure from the inner edge

Inaccurate use of equipment

Technique	*Source of error*	*Solution*
Failing to tare a balance	All readings high (or low)	Tare the balance
Using a worn meter rule	Zero error (if zero end is worn out)	Use middle part of ruler (subtract start from end)
Using an analogue meter	Parallax error (reading from one side)	Use the mirrored scale to eliminate parallax

By kind permission - Dr. Jason Welch. County High School, Leftwich

10 Notes on the Scope of the Subject Content

The information presented in this section is intended to indicate the depth and breadth of teaching required for certain topics and should be used in conjunction with the statements of content and the guidance given in the specification. Where a topic area has not been included, it is not possible to add further explanation to the statements given in the specification.

Sections of the specification that refer to the use of data, theories and explanations or that refer to evaluating the applications of science will usually be examined by asking candidates to respond to information provided in the form of tables, charts or text.

The numbers to the left of each subsection refer to the corresponding paragraph in the specifications.

10.1 Unit Biology 1

1 How do human bodies respond to changes inside them and to their environment?

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

- to evaluate the benefits of, and the problems that may arise from, the use of hormones to control fertility, including IVF

Knowledge and understanding of IVF is limited to:

IVF involves giving a mother FSH to stimulate the maturation of several eggs, and LH to stimulate the release of these eggs. The eggs are collected from the mother and mixed with sperm from the father. The fertilised eggs develop into embryos. At the stage when they are tiny balls of cells, two or three embryos are inserted into the mother's womb.

- to evaluate the claims of manufacturers about sports drinks.

Knowledge and understanding of sports drinks is limited to:

Sports drinks contain sugars to replace the sugar used in energy release during the activity. They also contain water and ions to replace the water and ions lost during sweating. If water and ions are not replaced, the ion / water balance of the body is disturbed and the cells do not work as efficiently. An understanding of osmosis is **not** required in this unit.

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

- Receptors detect stimuli which include light, sound, changes in position, chemicals, touch, pressure, pain and temperature

Cells called receptors detect stimuli (changes in the environment). These include:

- receptors in the eyes which are sensitive to light
- receptors in the ears which are sensitive to sound
- receptors in the ears which are sensitive to changes in position and enable us to keep our balance

- receptors on the tongue and in the nose which are sensitive to chemicals and enable us to taste and to smell
- receptors in the skin that are sensitive to touch, pressure, pain and to temperature changes.

(Knowledge and understanding of the structure and functions of sense organs such as the eye and the ear are **not** required.)

- Reflex actions are automatic and rapid. They often involve sensory, relay and motor neurones.
- The role of receptors, sensory neurones, motor neurones, relay neurones, synapses and effectors in simple reflex actions.

In such a simple reflex action:

- impulses from a receptor pass along a sensory neurone to the central nervous system
- at a junction (synapse) between a sensory neurone and a relay neurone in the central nervous system, a chemical is released which causes an impulse to be sent along a relay neurone
- a chemical is then released at the synapse between a relay neurone and motor neurone in the central nervous system, causing impulses to be sent along a motor neurone to the organ (the effector) which brings about the response
- the effector is either a muscle or a gland
- a gland responds by releasing (secreting) chemical substances.

2 What can we do to keep our bodies healthy?

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

- to evaluate information about the effect of food on health

Knowledge and understanding of foods is limited to:

Carbohydrates, fats and proteins are used by the body to release energy and to build cells. Mineral ions and vitamins are needed in small amounts for healthy functioning of the body.

- to evaluate claims made by slimming programmes.

Knowledge and understanding of food slimming programmes is limited to:

A person loses mass when the energy content of the food taken in is less than the amount of energy expended by the body. Exercise increases the amount of energy expended by the body.

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

- A healthy diet contains the right balance of the different foods you need and the right amount of energy. A person is malnourished if their diet is not balanced. This may lead to a person being too fat or too thin. It may also lead to deficiency diseases.

Knowledge and understanding of specific functions of nutrients and the effects of their deficiency in the diet is **not** required.

- High levels of cholesterol in the blood increase the risk of disease of the heart and blood vessels.

Knowledge of the structure of the heart and blood vessels is **not** required.

3 How do we use/abuse medical and recreational drugs?

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

• to evaluate the effect of statins on cardio-vascular disease	Knowledge and understanding of statins is limited to: Statins are drugs that lower the amount of cholesterol in the blood.
• to evaluate the different types of drugs and why some people use illegal drugs for recreation	Classification of drug types is **not** required.
• to evaluate claims made about the effect of cannabis on health and the link between cannabis and addiction to hard drugs	Knowledge and understanding of cannabis is limited to: Cannabis is an illegal drug. Cannabis smoke contains chemicals which may cause mental illness in some people.
• to explain how the link between smoking tobacco and lung cancer gradually became accepted	Knowledge and understanding is limited to: The link between smoking and lung cancer was established mainly by the collection of statistics which showed that the more cigarettes a person smoked, the higher the risk of developing lung cancer.
• to evaluate the different ways of trying to stop smoking.	Knowledge and understanding is limited to: Nicotine is the addictive substance in tobacco smoke. Stopping smoking causes severe withdrawal symptoms. Some of these symptoms may be alleviated by nicotine replacement therapy.

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

• When new medical drugs are devised, they have to be extensively tested and trialled before being used. Drugs are tested in the laboratory to find out if they are toxic. They are then trialled on human volunteers to discover any side effects.	Knowledge and understanding is limited to: New drugs are tested in the laboratory to find out if they are toxic and to find out whether they work. These tests often involve the use of animals. If a drug passes these tests, it is then tested on humans in clinical trials. Very low doses of the drug are given at the start of the trial. If the drug is found to be safe, further clinical trials are carried out to find the optimum dose for the drug. During drug trials, some patients are given a placebo which does not contain the drug. Neither the doctors nor the patients know who has received a placebo and who has received the drug until the trial is complete.
• Some people use drugs recreationally. Some of these recreational drugs are more harmful than others. Some of these drugs are legal, some illegal.	Knowledge and understanding of the specific effects of recreational drugs on the body are **not** required. The legal classification of specific drugs is **not** required.
• Nicotine is the addictive substance in tobacco smoke. Tobacco smoke contains carcinogens.	Knowledge and understanding of lung diseases such as bronchitis and emphysema are **not** required.

4 What causes infectious diseases and how can our bodies defend themselves against them?

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

• to relate the contribution of Semmelweiss in controlling infection to solving modern problems with the spread of infection in hospitals	Knowledge and understanding of the work of Semmelweiss are limited to: Semmelweiss recognised the importance of hand-washing in the prevention of spreading some infectious diseases. By insisting that doctors washed their hands before examining patients, he greatly reduced the number of deaths from infectious diseases in his hospital.
• to evaluate the advantages and disadvantages of being vaccinated against a particular disease	Details of vaccination schedules and the side effects associated with specific vaccines are **not** required.
• to explain how the treatment of disease has changed as a result of increased understanding of the action of antibiotics and immunity	Knowledge and understanding is limited to; Antibiotics kill bacteria inside the body. The use of antibiotics has greatly reduced deaths from infectious bacterial diseases. Overuse of antibiotics has increased the rate of development of antibiotic resistant strains of bacteria. The development of antibiotic-resistant strains of bacteria necessitates the development of new antibiotics. The immune system of the body produces specific antibodies to kill a particular pathogen. This leads to immunity from that pathogen. In some cases, dead or weakened pathogens stimulate antibody production. If a large proportion of the population is immune from a pathogen, the spread of the pathogen is very much reduced.
• to evaluate the consequences of mutations of bacteria and viruses in relation to epidemics and pandemics eg bird influenza.	Knowledge and understanding is limited to: Mutations of pathogens produce new strains. Antibiotics and vaccinations may no longer be effective against a new strain of the pathogen. The new strain will then spread rapidly because people are not immune to it and there is no effective treatment.

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

• Bacteria and viruses may reproduce rapidly inside the body and may produce poisons (toxins) which make us feel ill. Viruses damage cells in which they reproduce.	Knowledge of the structure of bacteria and viruses is **not** required.
• Many strains of bacteria, including MRSA, have developed resistance to antibiotics as a result of natural selection. To prevent further resistance arising it is important to avoid over-use of antibiotics.	Pathogens mutate spontaneously, producing resistant strains. Antibiotics kill individual pathogens of the non-resistant strain. Individual resistant pathogens survive and reproduce. The population of the resistant strain rises. Now, antibiotics are not used to treat non-serious infections such as mild throat infections in order to slow down the rate of development of resistant strains.

5 What determines where particular species live and how many of them are there?

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

• to suggest how organisms are adapted to the conditions in which they live	Examination questions will use examples that are unfamiliar to candidates. Candidates should observe the adaptations, eg body shape, of a range of organisms from different habitats to develop an understanding of the ways in which adaptations enable organisms to survive.
• to suggest the factors for which organisms are competing in a given habitat	Factors limited to light, water and nutrients in plants; food, mates and territory in animals.
• to suggest reasons for the distribution of animals or plants in a particular habitat.	Physical factors which may affect organisms include: • temperature • amount of light • availability of water • availability of oxygen and carbon dioxide. Human influences which may affect organisms include: • pollutants • trampling.

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

• Animals and plants may be adapted for survival in the conditions where they normally live eg deserts, the Arctic.	Animals may be adapted for survival in arctic and dry environments by means of: • changes to surface area • thickness of insulating coat • amount of body fat • camouflage. Plants lose water vapour from the surface of their leaves. Plants may be adapted to survive in dry environments by means of: • changes to surface area • water-storage tissues • extensive root systems.

6 Why are individuals of the same species different from each other? What new methods do we have for producing plants and animals with the characteristics we prefer?

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

• to make informed judgements about the economic, social and ethical issues concerning cloning and genetic engineering, including GM crops.	Candidates should be aware that there are some questions where beliefs and opinions are important. For example, scientists can answer the question 'How can we clone babies?' but the question 'Should we clone babies?' raises religious and ethical issues, and is for society to answer.

Knowledge and understanding of GM crops is limited to:

New genes can be transferred to crop plants. Crops which have had their genes modified in this way are called genetically modified crops (GM crops). Examples of genetically modified crops include ones that are resistant to insect attack or to herbicides. Genetically modified crops generally show increased yields. Concerns about GM crops include the effect on populations of wild flowers and insects, and uncertainty about the effects of eating GM crops on human health.

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

- Modern cloning techniques include:
  - fusion cell and adult cell cloning.

In adult cell cloning, the nucleus is removed from an unfertilised egg cell. The nucleus from an adult body cell, eg a skin cell, is then inserted into the egg cell. An electric shock then causes the egg cell to begin to divide to form embryo cells. These embryo cells contain the same genetic information as the adult skin cell. When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.

In fusion cell cloning, cytoplasm from an egg cell is inserted into a skin cell from an adult body. The adult cell then begins to divide to form cells which behave like embryonic cells. These embryonic cells are clones of the adult cell. They can be made to form many different types of body cells.

7 Why have some species of plants and animals died out? How do new species of plants and animals develop?

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

- to suggest reasons why scientists cannot be certain about how life began on Earth

The uncertainty arises from the lack of enough valid and reliable evidence. Evidence for early forms of life comes from fossils but many early forms of life were soft-bodied which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity.

- to suggest reasons why Darwin's theory of natural selection was only gradually accepted

Reasons include:

- The theory of evolution by natural selection undermined the idea that God made all the animals and plants that live on Earth. (A study of creationism is **not** required.)
- There was insufficient evidence at the time the theory was published to convince many scientists.
- The mechanism of inheritance and variation was not known until 50 years after the theory was published.

- to identify the differences between Darwin's theory of evolution and conflicting theories

Other theories, including that of Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

- to suggest reasons for the different theories.

Scientists may produce different hypotheses to explain similar observations. It is only when these hypotheses are investigated that data will support or refute hypotheses.

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

• Fossils provide evidence of how much (or how little) different organisms have changed since life developed on Earth.	Details of fossil formation are **not** required.
• Studying the similarities and differences between species helps us to understand evolutionary and ecological relationships.	Candidates should understand how evolutionary trees are used to represent the relationships between organisms.

8 How do humans affect the environment?

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

• to evaluate methods used to collect environmental data and consider their validity and reliability as evidence for environmental change.	Candidates should be familiar with the use of quadrats in collecting environmental data, including the idea of sampling.

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

• Living organisms can be used as indicators of pollution: – lichens can be used as air pollution indicators – invertebrate animals can be used as water pollution indicators.	Candidates should know that lichens can be used as indicators of the concentration of sulfur dioxide in the atmosphere. Candidates should know that invertebrate animals can be used as indicators of the concentration of dissolved oxygen in water. Knowledge and understanding of the process of eutrophication is **not** required.
• Improving the quality of life without compromising future generations is known as sustainable development. Planning is needed at local, regional and global levels to manage sustainability.	Candidates should understand that: • recycling paper means that fewer forests are cut down • recycling glass and metals means that fewer quarries are dug • using renewable energy resources and using energy more efficiently, conserves supplies of fossil fuels and reduces pollution. Examples of planning for sustainability include: • at a national level, government targets for implementing, for example, the Kyoto agreement • at a regional level, increasing public transport provision to reduce the number of car journeys • at a local level, provision of schemes for recycling domestic refuse.

10.2 Unit Biology 2

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

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

• to interpret data showing how factors affect the rate of photosynthesis and evaluate the benefits of artificially manipulating the environment in which plants are grown.	Candidates should be able to relate the principle of limiting factors to the economics of enhancing the following conditions in greenhouses: • carbon dioxide concentration • temperature • light intensity.

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

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

• to evaluate the positive and negative effects of managing food production and distribution, and to be able to recognise that practical solutions to human needs may require compromise between competing priorities.	Candidates should consider: • the differences in efficiency between producing food from plants and producing food from animals • the pros and cons of 'factory farming' of animals • the implications of 'food miles'.

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

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

• to evaluate the advantages and disadvantages of using enzymes in home and industry.	Candidates should understand that in industry, enzymes are used to bring about reactions at normal temperatures and pressures that would otherwise require expensive, energy-demanding equipment. In the home, biological detergents are more effective at low temperatures than other types of detergents. However, most enzymes are denatured at high temperatures, and many are costly to produce.

7 How do our bodies keep internal conditions constant?

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

• to evaluate the data from the experiments by Banting and Best which led to the discovery of insulin	Candidates should consider the reliability and validity of these experiments.
• to evaluate modern methods of treating diabetes.	Treatments should include blood sugar testing, attention to diet and exercise.

8 Which human characteristics show a simple pattern of inheritance?

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

• to explain why Mendel proposed the idea of separately inherited factors and why the importance of this discovery was not recognised until after his death	Candidates should be familiar with principles used by Mendel in investigating monohybrid inheritance in sweet peas. They should understand that Mendel's work preceded the work by other scientists which linked Mendel's 'inherited factors' with chromoso
• to interpret genetic diagrams	At Foundation Tier, candidates should be able to interpret genetic diagrams of monohybrid inheritance and gender inheritance.
• to predict and/or explain the outcome of crosses between individuals for each possible combination of dominant and recessive alleles of the same gene	At Higher Tier, candidates should also be able to construct genetic diagrams of monohybrid crosses and to predict the outcomes of monohybrid crosses.
• to construct genetic diagrams.	

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

• Body cells divide by mitosis to produce additional cells during growth or to produce replacement cells.	Knowledge and understanding of the stages in mitosis and meiosis is **not** required.
• Cells from human embryos and adult bone marrow, called stem cells, can be made to differentiate into many different types of cells eg nerve cells. Treatment with these cells may help conditions such as paralysis.	Candidate should understand that human stem cells have the ability to develop into any kind of human cell. Knowledge and understanding of stem cell techniques is **not** required.
• Chromosomes are made up of large molecules of DNA (deoxyribose nucleic acid). A gene is a small section of DNA.	Candidates are **not** expected to know the structure and replication of DNA, including the names of its bases.
• Each person (apart from identical twins) has unique DNA. This can be used to identify individuals in a process known as DNA fingerprinting.	Knowledge and understanding of genetic fingerprinting techniques is **not** required.
• Embryos can be screened for the alleles that cause these and other genetic disorders.	Knowledge and understanding of embryo screening techniques is **not** required.

10.3 Unit Biology 3

1 How do dissolved materials get into and out of animals and plants?

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

• to explain how gas and solute exchange surfaces in humans and other organisms are adapted to maximize effectiveness.	Candidates should understand that the effectiveness of an exchange surface is increased by: • having a large surface area • being thin to provide a short diffusion path • (in animals) being ventilated • (in animals) having an efficient blood supply.

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

• The breathing system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can diffuse out of the bloodstream into the air.	Knowledge of the mechanism of ventilation is **not** required.

2 How are dissolved materials transported around the body?

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

• The heart pumps blood around the body. Blood flows from the heart to the organs through arteries and returns through veins. In the organs, blood flows through capillaries.	Knowledge of the cardiac cycle, the names of heart valves and the names of blood vessels connected to the heart is **not** required. Knowledge of the structure of arteries and veins is **not** required.

4 How do exchanges in the kidney help us to maintain the internal environment in mammals and how has biology helped us to treat kidney disease?

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

• A healthy kidney produces urine by: – first filtering the blood – reabsorbing all the sugar – reabsorbing the dissolved ions needed by the body – reabsorbing as much water as the body needs	Knowledge of the parts of the urinary system and of the structure of the kidney and the structure of a nephron is **not** required.

• To prevent rejection of the transplanted kidney: – a donor kidney with a tissue-type similar to that of the recipient is used – the recipient is treated with drugs that suppress the immune system.	Knowledge and understanding of the ABO blood grouping and compatibility tables is **not** required.

5 How are microorganisms used to make food and drink?

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

• to explain how scientists such as Spallanzani, Schwann and Pasteur were involved in the development of the theory of biogenesis.	Candidates should understand how experiments by these three scientists provided evidence supporting the hypothesis of biogenesis.

6 What other useful substances can we make using microorganisms?

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

• to evaluate the advantages and disadvantages of given designs of biogas generator.	Candidates should have considered a number of biogas generator designs, ranging from third world generators supplying a single family to commercial generators. They should understand how the output of a biogas generator might be affected by climatic conditions.

10.4 Unit Chemistry 1

1 How do rocks provide building materials?

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

• to consider and evaluate the environmental, social and economic effects of exploiting limestone and producing building materials from it	Candidates should know that limestone is needed for buildings and that the positive benefits of using this material should be considered against the negative aspects of quarrying. Knowledge of building materials is limited to limestone, mortar, cement, concrete and glass.
• to evaluate the developments in using limestone, cement, concrete and glass as building materials, and their advantages and disadvantages over other materials.	Knowledge of particular developments is not required, but information may be supplied in examination questions for candidates to evaluate. Knowledge of the properties of other building materials is not required, but candidates may be provided with information about materials such as timber, stone and steels in the examination so that candidates can make comparisons about their uses.

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

• All substances are made of atoms. A substance that is made of only one sort of atom is called an element. There are about 100 different elements. Elements are shown in the periodic table. The groups contain elements with similar properties.	Knowledge of the properties of specific groups or elements is **not** required. Candidates should have learnt during Key Stage 3 that elements can be metals or non-metals.
• Atoms have a small central nucleus around which there are electrons.	Knowledge of the arrangement of electrons in shells or energy levels is **not** required in this unit.
• When elements react their atoms join with other atoms to form compounds. This involves giving, taking or sharing electrons and the atoms are held together by chemical bonds. (No further knowledge of ions, ionic and covalent bonding is required in this unit.)	Candidates are expected to know that compounds consist of two or more elements held together by chemical bonds. They are **not** expected to know any details of the types of bonding, only that chemical bonding involves exchanging or sharing electrons.
• No atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants and we can write balanced equations showing the atoms involved.	Candidates should be able to interpret given symbol equations in terms of numbers of atoms, and Higher Tier candidates should be able to balance equations. Knowledge and understanding of masses in chemical reactions is limited to conservation of mass. Candidates are **not** expected to do calculations based on relative atomic masses or to calculate the masses of individual reactants or products in this unit.

• Carbonates of other metals decompose on heating in a similar way.	Knowledge and understanding of metal carbonates is limited to: Metal carbonates decompose on heating to give carbon dioxide and the metal oxide. Candidates should be aware that not all carbonates of metals in Group 1 of the periodic table decompose at the temperatures reached by a Bunsen burner.
• Limestone and its products have many uses, including slaked lime, mortar, cement, concrete and glass.	Knowledge and understanding of limestone and its products is limited to the main uses of limestone, slaked lime, mortar, cement, concrete and glass.

2 How do rocks provide metals and how are metals used?

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

• to consider and evaluate the social, economic and environmental impacts of exploiting metal ores, of using metals and of recycling metals	Candidates should know that metal ores are obtained by mining and that this may involve digging up and processing large amounts of rock. Knowledge and understanding of obtaining, using and recycling metals is limited to the metals named in the substantive content.
• to evaluate the benefits, drawbacks and risks of using metals as structural materials and as smart materials	Knowledge and understanding of the uses and properties of metals, smart materials and alloys is limited to those specified in the substantive content. Information may be given in examination questions so that candidates can evaluate their uses.
• to explain how the properties of alloys (but not smart alloys) are related to models of their structures.	In examination questions, candidates may be provided with further information about other metals, smart materials, alloys and materials for comparison.

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

• Ores contain enough metal to make it economic to extract the metal and this changes over time.	Knowledge of specific examples is **not** required. Data may be provided in examination questions for candidates to analyse.
• Metals that are less reactive than carbon can be extracted from their oxides by reduction with carbon, for example iron oxide is reduced in the blast furnace to make iron. (Details of the blast furnace is not required.)	Knowledge and understanding is limited to the reduction of oxides using carbon. Technical details of the blast furnace or the extraction of other metals are not required. Examination questions may provide further information about specific processes for candidates to interpret or evaluate.
• Iron from the blast furnace contains about 96% iron. The impurities make it brittle and so it has limited uses.	Knowledge of uses of blast furnace iron is limited to blast furnace iron being used as cast iron because of its strength in compression.

• Removing all of the impurities would produce pure iron. Pure iron has a regular arrangement of atoms, with layers that can slide over each other, and so is soft and easily shaped, but too soft for many uses.	Knowledge and understanding is limited to: Pure metals have structures that consist of regular arrangements of atoms. Candidates can make or be shown models of metal structures using layers of spheres, but knowledge of close packing or body centred cubic structures is **not** required. Knowledge of metallic bonding is **not** required in this unit.
• Most iron is converted into steels. Steels are alloys since they are mixtures of iron with carbon and other metals. The different sized atoms added distort the layers in the structure of the pure metal, making it more difficult for them to slide over each other, and so alloys are harder. Alloys can be designed to have properties for specific uses. Low carbon steels are easily shaped, high carbon steels are hard and stainless steels are resistant to corrosion.	Knowledge and understanding of the types of steel and their properties is limited to those specified in the substantive content. Information about the composition of specific types of steel may be given in examination questions so that candidates can evaluate their uses.
• Many metals in everyday use are alloys. Pure copper, gold, and aluminium are too soft for many uses and so are mixed with small amounts of similar metals to make them harder for everyday use.	Candidates should be familiar with these specified examples but examination questions may contain information about alloys other than those named in the substantive content to enable candidates to make comparisons.
• Smart alloys can return to their original shape after being deformed.	Knowledge and understanding is limited to: Smart alloys or shape memory alloys that return to their original shape are used for applications such as dental braces and spectacles. Names of specific alloys are **not** required.
• The elements in the central block of the periodic table are known as transition metals. Like other metals they are good conductors of heat and electricity and can be bent or hammered into shape. They are useful as structural materials and for making things that must allow heat or electricity to pass through them easily.	Knowledge of the properties of specific transition metals other than those named in this unit is **not** required.

• Copper has properties that make it useful for electrical wiring and plumbing. Copper can be extracted by smelting or by electrolysis. (No details are required of the extraction process.) The supply of copper-rich ores is limited. New ways of extracting copper from low-grade ores are being researched to limit the environmental impact of traditional mining.	Candidates should know and understand that: • copper is a good conductor of electricity and heat, it is bendable and flexible but hard enough to be used as pipes or tanks, it does not react with water • copper is extracted from its ores by chemical processes that involve heat or electricity • copper-rich ores are being depleted and traditional mining and extraction have major environmental impacts • new methods of extracting copper from low-grade ores include leaching and using bacteria, fungi or plants. Knowledge of specific details of methods will **not** be required but information about processes may be given in examination questions for candidates to interpret.
• Low density and resistance to corrosion make aluminium and titanium useful metals. These metals cannot be extracted from their oxides by reduction with carbon. Current methods of extraction are expensive because – there are many stages in the processes – much energy is needed.	Candidates do **not** need to know the details of methods used to extract these metals, but should be able to comment on and evaluate information that is given about the chemical processes that can be used.
• We should recycle metals because extracting them uses limited resources and is expensive in terms of energy and effects on the environment.	Candidates are **not** required to know details of specific examples of recycling, but should understand the benefits of recycling in the general terms specified here.

3 How do we get fuels from crude oil?

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

• to evaluate the impact on the environment of burning hydrocarbon fuels	Knowledge and understanding of the products of burning hydrocarbon fuels and the effects of these products is limited to those named in the substantive content for this section.
• to consider and evaluate the social, economic and environmental impacts of the uses of fuels	Candidates may be given information and data about other fuels and their products of combustion for comparison and evaluation in the examinations.
• to evaluate developments in the production and uses of better fuels, for example ethanol and hydrogen.	Candidates should know and understand the benefits and disadvantages of ethanol and hydrogen as fuels in terms of: • use of renewable resources • storage and use of the fuels • their products of combustion.

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

• Most of the compounds in crude oil consist of molecules made up of hydrogen and carbon atoms only (hydrocarbons). Most of these are saturated hydrocarbons called alkanes, which have the general formula C_nH_{2n+2}.	Candidates should be able to recognise alkanes from their formulae in any of the forms in this section of the specification. Candidates are **not** expected to know the names of specific alkanes.
• The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is fractional distillation.	Candidates should know and understand the main processes in continuous fractional distillation in a fractionating column. Knowledge of the names of specific fractions or fuels is **not** required.
• Some properties of hydrocarbons depend on the size of their molecules. These properties influence how hydrocarbons are used as fuels.	Knowledge of trends in properties of hydrocarbons is limited to: • boiling points • viscosity • flammability.
• Most fuels contain carbon and/or hydrogen and may also contain some sulfur. The gases released into the atmosphere when a fuel burns may include carbon dioxide, water (vapour), carbon monoxide and sulfur dioxide. Particles may also be released.	Candidates should be able to relate products of combustion to the elements present in compounds in the fuel and to the extent of combustion (whether complete or partial). Particles may contain soot (carbon) and unburnt fuels.

4 How are polymers and ethanol made from oil?

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

• to evaluate the social and economic advantages and disadvantages of using products from crude oil as fuels or as raw materials for plastic and other chemicals	Candidates should be aware that crude oil is used to produce fuels and chemicals, and that it is a limited resource.
• to evaluate the social, economic and environmental impacts of the uses, disposal and recycling of polymers	Candidates should be able to evaluate information about the ways in which crude oil and its products are used. Although candidates will probably know the names of some common polymers, these are not required knowledge, unless they are included in the substantive content for this section.

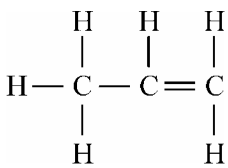
- to evaluate the advantages and disadvantages of making ethanol from renewable and non-renewable sources.

Candidates should know that ethanol can be produced by the reaction of ethene with steam. They should be aware that ethanol can be produced by fermentation of sugar, but do **not** need to know the details of the process. Information may be given in examination questions and candidates asked to compare processes.

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

- The products of cracking include alkanes and unsaturated hydrocarbons called alkenes. Alkenes have the general formula C_nH_{2n}.

Candidates should be able to recognise alkenes from their names or formulae, but do **not** need to know the names of individual alkenes, other than ethene and propene.

- Unsaturated hydrocarbon molecules can be represented in the following forms:
  - C_3H_6
  - 

- Alkenes can be used to make polymers such as poly(ethene) and poly(propene). In these reactions, many small molecules (monomers) join together to form very large molecules (polymers).

Candidates should be able to recognise the molecules involved in these reactions in the forms shown in the substantive content. They should be able to represent the formation of a polymer from a given alkene monomer.

- Polymers have properties that depend on what they are made from and the conditions under which they are made. For example, slime with different viscosities can be made from poly(ethenol).

Candidates do **not** need to know specific examples, but should consider the different types of poly(ethene) that are produced under different conditions (eg high pressure, catalysts) and some of the different types of poly(chloroethene).

The terms 'thermosoftening' and 'thermosetting' should be known and used to explain how different polymers behave when heated.

- Polymers have many useful applications and new uses are being developed, for example: new packaging materials, waterproof coatings for fabrics, dental polymers, wound dressings, hydrogels, smart materials, including shape memory polymers.

Candidates should study the ways in which new materials are being developed and used, but will **not** need to recall the names of specific examples in the examination.

• Many polymers are not biodegradable, so they are not broken down by microorganisms and this can lead to problems with waste disposal.	Knowledge of specific named examples is **not** required, but candidates should be aware of the problems that are caused in landfill sites and in litter.

5 How can plant oils be used?

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

• to evaluate the effects of using vegetable oils in foods and the impacts on diet and health	Knowledge is limited to the high energy content of vegetable oils, the possible health benefits of unsaturated fats compared with saturated fats, and the effects of cooking foods in oil. Information may be provided in examinations for candidates to evaluate.
• to evaluate the benefits, drawbacks and risks of using vegetable oils to produce fuels	Knowledge is limited to: Vegetable oils are produced from plants. Information may be provided in examinations for candidates to evaluate.
• to evaluate the use, benefits, drawbacks and risks of ingredients and additives in foods.	Candidates do not need to recall the names of specific additives, but should be able to recognise additives from lists of ingredients on food labels. Further information will be provided in questions for evaluation and comparison.

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

• Some fruits, seeds and nuts are rich in oils that can be extracted. The plant material is crushed and the oil removed by pressing or in some cases by distillation. Water and other impurities are removed.	Candidates should study the general principles of the extraction of vegetable oils, such as olive oil, rapeseed oil or lavender oil. Knowledge of specific examples or processes is **not** required.
• Vegetable oils are important foods and fuels as they provide a lot of energy. They also provide us with nutrients.	Knowledge of specific nutrients is **not** required.
• Oils do not dissolve in water. They can be used to produce emulsions. Emulsions are thicker than oil or water and have many uses that depend on their special properties. They provide better texture, coating ability and appearance, for example in salad dressings and ice creams.	Candidates should study how emulsions are made and should understand the role of emulsifiers in producing emulsions that are more stable. Knowledge of specific names of ingredients in proprietary products is **not** required.

• Vegetable oils that are unsaturated contain double carbon-carbon bonds. These can be detected by reacting with bromine or iodine.	Candidates should be familiar with a test for unsaturation using either bromine water or iodine solution.
• Vegetable oils that are unsaturated can be hardened by reacting them with hydrogen in the presence of a nickel catalyst at about 60 °C. The hydrogenated oils have higher melting points so they are solids at room temperature, making them useful as spreads and in cakes and pastries.	Candidates should know how and why vegetable oils are hardened for use in foods. Knowledge of trans fats is **not** required. Examination questions may provide further information and candidates asked to make comparisons.
• Processed foods may contain additives to improve appearance, taste and shelf life. These additives must be listed in the ingredients and some permitted additives were given E-numbers.	Candidates should know the general reasons for the use of additives, but do **not** need to know the names of specific additives.
• Chemical analysis can be used to identify additives in foods. Artificial colours can be detected and identified by chromatography.	Knowledge of methods other than paper chromatography is **not** required, but questions may include information based on the results of chemical analysis.

6 What are the changes in the Earth and its atmosphere?

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

• to explain why the theory of continental drift was not generally accepted for many years after it was proposed	Candidates should have studied accounts of Wegener's work. Knowledge is limited to the theories relating to mountain building and continental drift that are described in the substantive content.
• to explain why scientists cannot accurately predict when earthquakes and volcanic eruptions will occur	Candidates should be aware of the limitations of current theories in making predictions about these events in general terms. They may study particular events, but knowledge of specific eruptions or earthquakes will **not** be required.
• to explain and evaluate theories of the changes that have occurred and are occurring in the Earth's atmosphere	Candidates should be aware that there are several theories about the composition of the Earth's atmosphere during its existence. They should be able to compare and evaluate different theories when given suitable information.
• to explain and evaluate the effects of human activities on the atmosphere.	Knowledge of the effects of human activities is limited to those in the substantive content.

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

• The Earth consists of a core, mantle and crust.	Knowledge is limited to the names of the three major parts, and an awareness of the relative sizes of these features.
• The Earth's crust and the upper part of the mantle are cracked into a number of large pieces (tectonic plates). Convection currents within the Earth's mantle driven by heat released by natural radioactive processes cause the plates to move at relative speeds of a few centimetres per year.	Knowledge of the names, shapes or locations of specific plates is **not** required. Candidates should know that the mantle is mostly solid, but that it is able to move slowly.
• The movements can be sudden and disastrous. Earthquakes and/or volcanic eruptions occur at the boundaries between tectonic plates.	Knowledge of the changes that occur at plate boundaries is limited to earthquakes and volcanic eruptions. Candidates may study sea floor spreading and subduction zones as examples of changes at plate boundaries, but are **not** expected to have detailed knowledge of these processes or where they occur.
• The noble gases are in Group 0 of the periodic table. They are all chemically unreactive gases and are used in filament lamps and electric discharge tubes. Helium is much less dense than air and is used in balloons.	Knowledge of the uses of the noble gases is limited to those listed. Candidates do **not** need to know the specific colours produced in electric discharge tubes.
• During the first billion years of the Earth's existence there was intense volcanic activity. This activity released the gases that formed the early atmosphere and water vapour that condensed to form the oceans.	Candidates should be aware that there are different theories about the composition of the early atmosphere. They differ in the amounts and proportions of the main gases present at various times. In particular, there are uncertainties about the amounts and the proportion of nitrogen.
• Some theories suggest that during this period, the Earth's atmosphere was mainly carbon dioxide and there would have been little or no oxygen gas (like the atmospheres of Mars and Venus today). There may also have been water vapour, and small proportions of methane and ammonia.	

• Plants produced the oxygen that is now in the atmosphere.	Candidates should know from Key Stage 3 that plants produce oxygen by photosynthesis and that this process uses carbon dioxide from the atmosphere.
• Most of the carbon from the carbon dioxide in the air gradually became locked up in sedimentary rocks as carbonates and fossil fuels.	Candidates should know that carbon dioxide dissolves in the oceans and that limestone was formed from the shells and skeletons of marine organisms. Fossil fuels contain carbon and hydrocarbons that are the remains of plants and animals.
• Nowadays the release of carbon dioxide by burning fossil fuels increases the level of carbon dioxide in the atmosphere.	Candidates should be aware that this increase in carbon dioxide is thought to be causing global warming but, for this unit, candidates do **not** need to know how CO_2 causes this effect.

10.5 Unit Chemistry 2

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

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

• to represent the electronic structure of the first twenty elements of the periodic table	The forms in which electronic structures and chemical bonds may be represented are limited to those in the specification.
• to represent the electronic structure of the ions in sodium chloride, magnesium oxide and calcium chloride • to represent the covalent bonds in molecules such as water, ammonia, hydrogen, hydrogen chloride, chlorine, methane and oxygen and in giant structures such as diamond and silicon dioxide	Candidates should know how to represent the elements and compounds listed in the specification for this unit and should be able to recognise the specified forms when given for other elements and compounds. They should be able to draw dot and cross diagrams only for the first twenty elements and their compounds. In Higher Tier papers, candidates may be expected to draw similar diagrams for other molecules given additional information.
❖ HT to represent the bonding in metals	
❖ HT to write balanced chemical equations for reactions.	All candidates should be able to recognise given balanced chemical equations, but only Higher Tier candidates will be required to write and balance symbol equations for reactions from given information.

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

• Elements in the same group in the periodic table have the same number of electrons in the highest energy levels (outer electrons).	Candidates should be able to represent the electronic structures of the first twenty elements only. They will **not** be required to know the electronic structures of other elements, but should be able to deduce the number of electrons in the highest occupied energy level (outer shell) for atoms of elements in Groups 1 to 7 and 0.
• When atoms form chemical bonds by transferring electrons, they form ions. Atoms that lose electrons become positively charged ions. Atoms that gain electrons become negatively charged ions. Ions have the electronic structure of a noble gas (Group 0).	Candidates should be able to relate the charge on simple ions to the group number of the element in the periodic table.

• The elements in Group 1 of the periodic table, the alkali metals, have similar chemical properties. They all react with non-metal elements to form ionic compounds in which the metal ion has a single positive charge.	Knowledge of chemical properties is limited to reactions with non-metal elements.
• The elements in Group 7 of the periodic table, the halogens, have similar chemical properties. They react with the alkali metals to form ionic compounds in which the halide ions have a single negative charge.	Knowledge of chemical properties is limited to reactions with alkali metals.
• An ionic compound is a giant structure of ions. Ionic compounds are held together by strong forces of attraction between oppositely charged ions. These forces act in all directions in the lattice and this is called ionic bonding.	Candidates should be familiar with the structure of sodium chloride but do **not** need to know the structures of other ionic compounds.
• When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. Some covalently bonded substances consist of simple molecules such as H_2, Cl_2, O_2, HCl, H_2O and CH_4. Others have giant covalent structures (macromolecules), such as diamond and silicon dioxide.	Candidates should know the bonding in the examples in the specification for this unit, and should be able to recognise similar molecules and giant structures from diagrams that show their bonding.
❖ Metals consist of giant structures of atoms arranged in a regular pattern. The electrons in the highest occupied energy levels (outer shell) of metal atoms are delocalised and so free to move through the whole structure. This corresponds to a structure of positive ions with electrons between the ions holding them together by strong electrostatic attractions.	Higher Tier candidates only need to know the model of metallic bonding in this unit.

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

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

• to relate the properties of substances to their uses • to suggest the type of structure of a substance given its properties	Candidates will be provided with information about the properties of substances that are not specified in this unit to enable them to relate these to their uses. Limited to ionic and covalent (simple molecular and macromolecular (giant covalent)) and for Higher Tier only including metallic.
• to evaluate developments and applications of new materials, eg nanomaterials, smart materials.	Candidates should be familiar with some examples of new materials but do **not** need to know the properties or names of specific new materials.

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

❖ Substances that consist of simple molecules have only weak forces between the molecules (intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils.	Only Higher Tier candidates need to be able to explain that intermolecular forces are weak in comparison with covalent bonds.
• Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces in all directions between oppositely charged ions. These compounds have high melting points and high boiling points.	Knowledge of the structures of specific ionic compounds other than sodium chloride is **not** required.
• Atoms that share electrons can also form giant structures or macromolecules. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures (lattices) of atoms. All the atoms in these structures are linked to other atoms by strong covalent bonds and so they have very high melting points.	Candidates should be able to recognise other giant structures (macromolecules) from diagrams showing their bonding.
• In graphite, each carbon atom bonds to three others, forming layers. The layers are free to slide over each other and so graphite is soft and slippery.	A useful analogy for the structure of graphite is a pack of cards. Higher Tier candidates should be able to explain the properties of graphite in terms of weak intermolecular forces between the layers.

❖ In graphite, one electron from each carbon atom is delocalised. These delocalised electrons allow graphite to conduct heat and electricity.	Higher Tier candidates should realise that graphite is similar to metals in that it has delocalised electrons.
❖ Metals conduct heat and electricity because of the delocalised electrons in their structures.	Higher Tier candidates should know that conduction depends on the ability of electrons to move throughout the metal.
• The layers of atoms in metals are able to slide over each other and so metals can be bent and shaped.	It is useful to show candidates models, for example, using expanded polystyrene spheres or computer animations to show how layers of atoms slide.
• Nanoscience refers to structures that are 1–100 nm in size, of the order of a few hundred atoms. Nanoparticles show different properties to the same materials in bulk and have a high surface area to volume ratio, which may lead to the development of new computers, new catalysts, new coatings, highly selective sensors and stronger and lighter construction materials.	Candidates should know what is meant by nanoscience and nanoparticles and should consider some of the applications of these materials, but do **not** need to know specific examples or properties. Questions may be set on information that is provided about these materials and their uses that assess candidates' skills specified in Section 10.

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

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

• to calculate chemical quantities involving formula mass (M_r) and percentages of elements in compounds	Foundation Tier candidates may be set questions that require simple calculations of formula mass from given formulae of simple compounds and the calculation of percentages of elements in simple compounds.
❖ to calculate the atom economy for industrial processes and be able to evaluate sustainable development issues related to this economy.	Higher Tier candidates should know how to calculate the atom economy of a process from the chemical equations for the reactions that take place in the process. Atom economy can be defined as the percentage of atoms used in the process that end up in useful products and may be calculated by considering the amounts of atoms in either the reactants or the products.

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

❖ The relative atomic mass of an element (A_r) compares the mass of atoms of the element with the ^{12}C isotope. It is an average value for the isotopes of the element.	All candidates are expected to use relative atomic masses in the calculations specified in the substantive content, but only Higher Tier candidates need to know this definition.

• Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because: – the reaction may not go to completion because it is reversible – some of the product may be lost when it is separated from the reaction mixture – some of the reactants may react in ways different to the expected reaction.	Only Higher Tier candidates will be expected to calculate percentage yields of reactions.
• The atom economy (atom utilisation) is a measure of the amount of starting materials that end up as useful products. It is important for sustainable development and for economical reasons to use reactions with high atom economy.	Only Higher Tier candidates will be expected to calculate atom economies.
• In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions.	Only Higher Tier candidates need to study quantitative aspects of reversible reactions and chemical equilibrium.

4 How can we control the rates of chemical reactions?

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

• to interpret graphs showing the amount of product formed (or reactant used up) with time, in terms of the rate of the reaction	Knowledge of specific reactions other than those in the substantive content for this unit is **not** expected, but candidates will be expected to have studied examples of chemical reactions and processes in developing their skills during their study of this section.
• to explain and evaluate the development, advantages and disadvantages of using catalysts in industrial processes.	Information may be given in examination questions so that candidates can make evaluations.

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

❖ Concentrations of solutions are given in moles per cubic decimetre (mol/dm^3). Equal volumes of solutions of the same molar concentration contain the same number of moles of solute, ie the same number of particles.	Although specified as Higher Tier content, Foundation Tier candidates use solutions with concentrations given in mol/dm^3 (M) during practical work as a convenient way of measuring concentrations. Understanding of this concept will **not** be asked for in Foundation Tier papers.
• Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts.	Knowledge of named catalysts other than those specified in the substantive content for this unit is **not** expected, but candidates should study some examples of chemical reactions and processes that use catalysts during their work in this section.

5 Do chemical reactions always release energy?

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

• to describe the effects of changing the conditions of temperature and pressure on a given reaction or process • to evaluate the conditions used in industrial processes in terms of energy requirements.	Foundation Tier candidates should consider reversible reactions qualitatively as required by the substantive content. Higher Tier candidates will be expected to have studied the quantitative aspects specified in the content for chemical reactions and processes, but will **not** need to recall details of specific industrial processes other than those in the substantive content for this unit. Candidates may be given further information so that they can compare and evaluate other industrial processes.

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

• When chemical reactions occur, energy is transferred to or from the surroundings.	Knowledge of delta H (ΔH) conventions and enthalpy changes, including the use of positive values for endothermic reactions and negative values for exothermic reactions, is **not** required.
• An exothermic reaction is one that transfers energy, often as heat, to the surroundings. Examples of exothermic reactions include combustion, many oxidation reactions and neutralisation.	
❖ When a reversible reaction occurs in a closed system, equilibrium is reached when the reactions occur at exactly the same rate in each direction.	See Section 3 of this unit.
❖ The relative amounts of all the reacting substances at equilibrium depend on the conditions of the reaction.	See Section 3 of this unit.

• It is important for sustainable development as well as economic reasons to minimise energy requirements and energy wasted in industrial processes. Non-vigorous conditions mean less energy is used and less is released into the environment.	Quantitative aspects and calculations will appear only in Higher Tier papers. Processes that use non-vigorous conditions take place at temperatures and pressures close to ambient conditions.

6 How can we use ions in solutions?

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

• to predict the products of electrolysing solutions of ions	Candidates should study a range of chemical processes as part of their work in this section, but detailed knowledge of processes other than those in the substantive content is **not** required. Questions may be set in contexts that are unfamiliar to candidates.
• to suggest methods to make a named salt	Knowledge and understanding is limited to the methods indicated in the substantive content.
• to explain and evaluate processes that use the principles described in this unit	
❖ to complete and balance supplied half equations for the reactions occurring at the electrodes during electrolysis.	Only Higher Tier candidates will be expected to complete and balance half equations.

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

• At the negative electrode, positively charged ions gain electrons (reduction) and at the positive electrode, negatively charged ions lose electrons (oxidation).	Candidates should know that oxidation occurs when electrons are lost and that reduction occurs when electrons are gained.
• If there is a mixture of ions, the products formed depend on the reactivity of the elements involved.	Candidates should relate the discharge of positive ions from aqueous solutions containing only one ionic compound at concentrations between about 1.0 and 0.1 mol/dm^3 to the reactivity series. For negative ions in aqueous solutions, they should know that at reasonably high concentrations, only halide ions are discharged in preference to hydroxide ions.

10.6 Unit Chemistry 3

1 How was the periodic table developed and how can it help us understand the reactions of elements?

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

• to explain how attempts to classify elements in a systematic way, including those of Newlands and Mendeleev, have led through the growth of chemical knowledge to the modern periodic table	Knowledge of the history of the periodic table is limited to that specified in the substantive content.
• to explain why scientists regarded a periodic table of the elements first as a curiosity, then as a useful tool and finally as an important summary of the structure of atoms.	

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

• The early periodic tables were incomplete and some elements were placed in inappropriate Groups if the strict order of atomic weights was followed.	Candidates should consider other models, but knowledge is limited to the work of Newlands and Mendeleev. Examination questions may give information about other models so that comparisons can be made.
• Mendeleev overcame some of the problems by leaving gaps for elements that he thought had not been discovered.	
• The modern periodic table can be seen as an arrangement of the elements in terms of their electronic structures. Elements in the same Group have the same number of electrons in their highest occupied energy level (outer shell).	The periodic table that will be used in the examinations is on the Data Sheet, with main groups numbered from 1 to 7 and the noble gases as Group 0. Candidates are **not** expected to know detailed electronic configurations for elements beyond calcium, but should understand that the number of electrons in the highest occupied energy level (outer shell) for elements in the main groups is equal to the group number.

❖ The trends in reactivity within Groups in the periodic table can be explained because the higher the energy level: – the more easily electrons are lost – the less easily electrons are gained.	Knowledge of the properties and trends is limited to those in the substantive content and is required for both tiers, but Higher Tier candidates will be expected to explain trends in these terms.
❖ The transition elements have similar properties and some special properties because a lower energy level (inner shell) is being filled in the atoms of the elements between Groups 2 and 3. This is because the third energy level can hold up to 18 electrons, once two electrons have occupied the fourth level.	Candidates are **not** expected to know or to write electronic structures for transition elements.

2 What are strong and weak acids and alkalis? How can we find the amounts of acids and alkalis in solutions?

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

❖ to evaluate the contributions of Arrhenius, Lowry and Brønsted to our understanding of acid-base behaviour	Candidates should know that Arrhenius proposed that acids dissociate to produce hydrogen ions. Scientists at that time found his ideas difficult to accept because electrons had not been discovered, and there was no model for the structure of atoms.
❖ to suggest why the work of some scientists, for example Arrhenius, took much longer to be accepted than the work of others, for example, Lowry and Brønsted	When Lowry and Brønsted developed their theory of proton transfer, understanding that atoms consist of protons and electrons was well established.
❖ to calculate the chemical quantities in titrations involving concentrations (in moles or mass per unit volume) and masses.	Higher Tier candidates should be able to calculate chemical quantities from titration data using given balanced chemical equations.

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

• Acids produce hydrogen ions in aqueous solution. The H^+ ion is a proton. In water this proton is hydrated and is represented as $H^+(aq)$.	Candidates are **not** expected to use H_3O^+ ions for this unit.

• Acids and alkalis are classified by the extent of their ionisation in water.	Candidates should understand that it is the extent of ionisation and not the pH or concentration of H^+(aq) in a solution that determines the strength of acids. However, comparing the pH of solutions with the same concentration of acids or alkalis can be used to show the extent of ionisation and their relative strengths.
• The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.	Titrations for Foundation Tier are limited to strong acid and strong alkali. Candidates are expected to be familiar with the use of burettes and pipettes.
❖ If the concentration of one of the reactants is known, the results of a titration can be used to find the concentration of the other reactant.	Chemical equations for reactions will be given in questions.

3 What is in the water we drink?

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

• to interpret solubility curves and explain when crystallisation may occur	Candidates will **not** be required to draw solubility curves in the examination.
• to consider and evaluate the environmental, social and economic aspects of water quality and hardness.	Candidates will be expected to interpret and evaluate information and data that is provided in questions set within these contexts. Candidates may be asked to evaluate different methods of softening water, or of providing drinking water of sufficient quality.

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

• A saturated solution is one in which no more solute will dissolve at that temperature. When a hot saturated solution cools, some of the solute will separate from the solution.	Candidates should be encouraged to investigate solubility, saturated solutions and crystallisation both qualitatively and quantitatively.
• Hard water can be made soft by removing the dissolved calcium and magnesium ions. This can be done by: – adding sodium carbonate which reacts with the calcium and magnesium ions forming a precipitate of calcium carbonate and magnesium carbonate	Candidates should understand the principles of how ion exchange resins work but do **not** need detailed knowledge of the structure or chemical nature of specific resins.

– using an ion exchange column containing hydrogen ions or sodium ions which replace the calcium and magnesium ions when hard water passes through the column.	
• Water filters containing carbon, silver and ion exchange resins can remove some dissolved substances from tap water to improve the taste and quality.	Candidates should be encouraged to investigate the various types of water 'filters' that are commercially available, but detailed knowledge of specific water filters is **not** required. Examination questions may give information about water filters so that comparisons can be made.
• Pure water can be produced by distillation.	Candidates should be aware of the large amount of energy needed for distillation and, as a consequence, of the high costs involved.

4 How much energy is involved in chemical reactions?

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

• to compare the energy produced by different fuels and foods • to consider the social, economic and environmental consequences of using fuels • to interpret simple energy level diagrams in terms of bond breaking and bond formation (including the idea of activation energy and the effect on this of catalysts)	Candidates may be provided with information for comparison and evaluation. For example, they may be given information about the ingredients of a particular food or the components of a fuel, but will **not** be expected to have knowledge of the constituents of commercial products beyond that specified in the substantive content for this unit.
❖ to calculate the energy transferred in reactions, using simple energy level diagrams or supplied bond energies.	Calculations on energy transfers will be set only in Higher Tier papers, and candidates will be given values for the data required.

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

• The relative amounts of energy released when substances burn can be measured by simple calorimetry, eg by heating water in a glass or metal container. This method can be used to compare the amount of energy produced by fuels and foods.	Candidates are expected to use simple calorimetry to compare the energy produced by different substances when they burn but are **not** expected to obtain accurate values.

• Energy is normally measured in joules (J). Some dietary information is given in calories, which are equal to 4.2 joules.	For comparison purposes, energy values could be given in kJ or calories for a given mass or amount of substance, eg calories per gram, kJ per mole or kJ per gram. If candidates are required to convert from calories to joules, the conversion factor will be given in questions.
• Different foods produce different amounts of energy. Foods with high proportions of carbohydrates, fats and oils produce relatively large amounts of energy.	Candidates should know some common examples of foods with high proportions of fat and carbohydrate and should be able to recognise such foods from information provided in the form of ingredient lists such as those found on food labels.
• Eating food that provides more energy than the body needs can lead to obesity.	Obesity linked simply to an excess of energy provision.
• The amount of energy produced by a chemical reaction in solution can be found by mixing the reagents in an insulated container and measuring the temperature change of the solution. This method can be used for reactions of solids with water or for neutralisation reactions.	Candidates should be encouraged to carry out some of these reactions and to measure the energy produced, assuming that it is only the water in the solution that is being heated and that 4.2 joules will raise the temperature of 1 cm^3 of water by 1 ^{o}C.
• During a chemical reaction: – energy must be supplied to break bonds – energy is released when bonds are formed. These changes can be represented on an energy level diagram.	Simple energy level diagrams showing only the relative energies of reactants and products with an arrow to show the reaction change as the reaction proceeds.

5 How do we identify and analyse substances?

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

• to interpret results of the chemical tests in this specification	Candidates are expected to know the chemical tests specified in the substantive content and may be asked to interpret results of any of those tests applied to solutions or mixtures of substances in different contexts.
• to evaluate the advantages and disadvantages of instrumental methods of analysis and the features that influence that development	Candidates are **not** expected to know the details of how instrumental methods work, but should have considered the advantages and disadvantages of some examples of such methods, as suggested in the specification.

• to interpret and evaluate the results of instrumental analyses carried out to identify elements and compounds for forensic, health or environmental purposes.	Candidates should apply their 'How Science Works' skills to considerations of results from chemical analysis in different contexts. They should be able to comment on results and data from such analyses that are presented to them. This will **not** include interpretation of detailed information that uses knowledge beyond that expected at GCSE.

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

• Flame tests can be used to identify metal ions. Lithium, sodium, potassium, calcium and barium compounds produce distinctive colours in flame tests.	Flame colours of other metal ions are **not** required knowledge.
• Copper carbonate and zinc carbonate decompose on heating and can be identified by the distinctive colour changes.	Candidates should know that copper carbonate changes from green to black and that zinc carbonate changes from white to yellow when hot and to white again on cooling.
• Aluminium, calcium and magnesium ions form white precipitates with sodium hydroxide solution but only the aluminium hydroxide precipitate dissolves in excess sodium hydroxide solution. Copper(II), iron(II) and iron(III) ions form coloured precipitates with sodium hydroxide solution.	Candidates do **not** need to be aware that other metal ions may react with sodium hydroxide solution to produce precipitates.
• Nitrate ions are reduced by aluminium powder in the presence of sodium hydroxide solution to form ammonia.	Special care is needed when carrying out this test. A risk assessment is necessary (as with all practical procedures).
• Organic compounds burn or char when heated in air.	
❖ The empirical formula of an organic compound can be found from the masses of the products formed when a known mass of the compound is burned.	Candidates, when given relevant data, will be expected to be able to carry out this type of calculation for hydrocarbons and organic compounds consisting of carbon and hydrogen with oxygen or one other element.

• Elements and compounds can be detected and identified using a variety of instrumental methods. Instrumental methods are accurate, sensitive and rapid and are particularly useful when the amount of a sample is very small.	Ideally, candidates should see some examples of instruments in operation and should be shown how the results are displayed or presented.
❖ Some instrumental methods are suited to identifying elements, such as atomic absorption spectroscopy used in the steel industry. Other instrumental methods are suited to identifying compounds, such as infrared spectrometry, ultraviolet spectroscopy, nuclear magnetic resonance spectroscopy, and gas-liquid chromatography. Some methods can be adapted for elements or compounds, such as mass spectrometry. (Details of how the instruments work are not required.)	Only Higher Tier candidates need to be aware of these named instrumental methods.

10.7 Unit Physics 1

1 How is heat (thermal energy) transferred and what factors affect the rate at which heat is transferred?

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

• to evaluate ways in which heat is transferred in and out of bodies and ways in which the rates of these transfers can be reduced.	Examination questions will use examples that are both familiar and unfamiliar to candidates. All applications will use the knowledge and understanding developed through the substantive content. Specific examples should include the design of a vacuum flask, how to reduce the heat transfer from a building and how humans and animals cope with the cold.

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

• The transfer of energy by conduction and convection involves particles and how this transfer takes place.	Conduction: Foundation Tier candidates should understand in simple terms how the arrangement and movement of particles determine whether a material is a conductor or an insulator. Higher Tier candidates need to understand the role of free electrons in determining the conductivity of a metal. Convection: Candidates should be able to use the idea of particles moving apart to make a fluid less dense, to explain simple applications of convection such as heating a room or hot water systems.
• The shape and dimensions of a body affect the rate at which it transfers energy.	Candidates should be able to explain the design of a familiar or unfamiliar device and animal adaptations in terms of heat transfer: for example, the design of the cooling fins on a motorbike engine and the relative ear size of a desert fox compared with an Arctic fox.

2 What is meant by the efficient use of energy?

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

• to describe the intended energy transfers / transformations and the main energy wastages that occur with a range of devices	Common electrical devices found in the house will be examined. Examples may **not** be limited to electrical devices; however, in this case all the information would be given in the question. Candidates should be able to interpret and draw a Sankey diagram. Candidates should be able to use a Sankey diagram to calculate the efficiency of a device.
• to evaluate the effectiveness and cost effectiveness of methods used to reduce energy consumption.	The term 'pay-back time' should be understood. Given relevant data, candidates should be able to make judgements about the cost effectiveness of different methods of reducing energy consumption over a set period of time. This is **not** restricted to a consideration of building insulation but may include: • low energy light bulbs • temperature control • replacing old appliances with energy efficient ones

- ways in which 'waste' energy can be useful
- public transport.

Candidates are **not** expected to recall the term 'U-value'. However they may be expected to interpret relevant data which may be given in U-values. If so, the term will be explained in the question.

3 Why are electrical devices so useful?

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

- to compare and contrast the particular advantages and disadvantages of using different electrical devices for a particular application

Candidates will use knowledge gained from the substantive content and / or supplied data to compare different electrical devices. Examples may include but are not limited to:

- hand held compared with mains fans
- low power tubular heaters compared with high power bar heaters
- clockwork radios compared with battery radios.

- to calculate the cost of energy transferred from the mains using:

  total cost = number of kilowatt-hours x cost per kilowatt-hour.

This should include both the cost of using individual appliances and the interpretation of electricity meter readings to calculate total cost over a period of time.

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

- Electricity is transferred from power station to consumers along the National Grid.

Candidates should be able to identify and label the essential parts of the National Grid.

- The uses of step-up and step-down transformers in the National Grid.
- Increasing voltage (potential difference) reduces current, and hence reduces energy losses in the cables.

Candidates should know why transformers are an essential part of the National Grid.

Details of the structure of a transformer and how a transformer works are **not** required.

4 How should we generate the electricity we need?

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

- to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.

Candidates should consider the financial, environmental, political and social effects of generating electricity from a wide range of energy sources. They should be able to give reasons why different groups of people in different environments and circumstances may argue in favour of or against the use of a specific energy source such as the wind. They should consider the effect on the local and national economy. The use of bio-fuels should be included.

5 What are the uses and hazards of the waves that form the electromagnetic spectrum?

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

• Communication signals may be analogue (continuously varying) or digital (only on and off). Digital signals are less prone to interference than analogue and can be processed by computers.	Higher Tier questions may include an explanation as to why digital signals are less prone to interference than analogue signals. Details of signal transmission, amplitude modulation and frequency modulation are **not** required.

6 What are the uses and dangers of emissions from radioactive substances?

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

• Alpha and beta radiations are deflected by both electric and magnetic fields but gamma radiation is not.	All candidates should know that alpha particles are deflected less than beta particles and in an opposite direction. Higher Tier candidates should be able to explain this in terms of the relative mass and charge of each particle.

7 What do we know about the origins of the Universe and how it continues to change?

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

• If a wave source is moving relative to an observer there will be a change in the observed wavelength and frequency.	The following should be included: • the wave source could be either light or sound • the movement of a wave source towards and away from an observer • when the source moves away from the observer, the observed wavelength increases and the frequency decreases • when the source moves towards the observer, the observed wavelength decreases and the frequency increases.

10.8 Unit Physics 2

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

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

• A number of forces acting on a body may be replaced by a single force which has the same effect on the body as the original forces all acting together. This force is called the resultant force.	Candidates should be able to determine the resultant of opposite or parallel forces.
• The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance.	For a given braking force, the greater the speed, the greater the stopping distance.

4 What is momentum?

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

• to use the ideas of momentum to explain safety features.	Safety features are not limited to vehicles. They may include: • air bags • seat belts • gymnasium crash mats • cushioned surfaces for playgrounds • cycle helmets.

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

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

• to explain why static electricity is dangerous in some situations and how precautions can be taken to ensure that the electrostatic charge is discharged safely.	Situations should include grain flowing through a chute, fuel flowing through a pipe and paper passing through rollers.

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

• Electrical charges can move easily through some substances eg metals.	Candidates should understand the role of electrons in determining the conductivity of a metal.

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

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

• The structure of electrical cable.	Candidates should be familiar with both two-core and three-core cable.

9 What happens to radioactive substances when they decay?

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

• The origins of background radiation.	This should include both natural sources, such as rocks and cosmic rays from space, and man-made sources such as the fallout from nuclear tests and accidents.

10.9 Physics 3

1 How do forces have a turning effect?

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

• Recognise the factors that affect the stability of a body.	Candidates should recognise that objects with a wide base and low centre of mass are more stable than those with a narrow base and a high centre of mass. Objects that are considered could include buses, racing cars, wine glasses, mugs and vases.

2 What keeps bodies moving in a circle?

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

• To identify which force(s) provide(s) the centripetal force in a given situation.	Candidates should understand that a centripetal force does not exist in its own right but is always provided by something else such as gravitational force, electrostatic force, friction or tension.

3 What provides the centripetal force for planets and satellites?

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

• Communications satellites are usually put into a geostationary orbit above the equator.	Candidates should understand that: • a geostationary orbit has a time period of 24 hours • a satellite in such an orbit stays above the same place on the Earth's surface • all geostationary satellites are in orbit at a particular height and above the equator.
• Monitoring satellites are usually put into a low polar orbit.	Candidates should understand that: • a low polar orbit has a short time period, eg 2 or 3 hours • a satellite in a low polar orbit is able to scan the whole surface of the Earth as the Earth rotates beneath it • monitoring satellites are in much lower orbits than communications satellites.

4 What do mirrors and lenses do to light?

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

• Refraction at an interface.	When light crosses an interface from a less optically dense to a more optically dense medium, it refracts towards the normal. When it crosses from a more optically dense to a less optically dense medium, it is refracted away from the normal.
• Refraction by a prism.	This should include the dispersion of white light by a triangular prism.

9 How do transformers work?

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

• The basic structure of a transformer.	Candidates should understand the function of the primary and secondary coils and the laminated soft iron core. They should appreciate why a transformer will work only if there is an alternating current in the primary.

Appendix

A Examples of Forms

Example of a Spreadsheet showing PSA / ISA and CAU Marks

Centre Number **Centre Name**

Year **200__**

Candidate Number	Candidate Name	ISA Title	PSA	ISA	CAU Total

Example of an Optional Progress Record Form

Teacher: Mrs Green **Subject: Science A / B**

Class 10.3

Year 2006 to 2007 **ISA Title**

Cand. No.	Candidate Name	B1.1	B1.2	C1.1	C1.2	P1.1	P1.2	PSA Score	ISA Score to be Used	Total CAU Score	Comments
1001	Ahmed M	25	10	**30**			16	5	30	35	
1002	Jones D	13	**25**			14		6	25	31	
1003	Smith J		15		14		**16**	6	16	22	
1004											
1005											
1006											
1007											
1008											
1009											
1010											
1011											
1012											
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