OCR ADVANCED SUBSIDIARY GCE IN APPLIED SCIENCE (H175)

OCR ADVANCED SUBSIDIARY GCE IN APPLIED SCIENCE (DOUBLE AWARD) (H375)

OCR ADVANCED GCE IN APPLIED SCIENCE (H575)

OCR ADVANCED GCE IN APPLIED SCIENCE (DOUBLE AWARD) (H775)

Qualification Accreditation Numbers:

Advanced Subsidiary GCE:	100/4438/3
Advanced Subsidiary GCE (Double Award):	100/4439/5
Advanced GCE:	100/4440/1
Advanced GCE (Double Award):	100/4445/0

KEY FEATURES

- This is a new broad-based qualification in Applied Science which may be used to give a general vocational introduction to science, or units may be selected to provide an introduction to more specialised areas.
- The flexible structure allows for a variety of vocational pathways, for example in: analysis and detection; the environment; manufacturing; health; communications.
- There are many opportunities for candidates to actively experience the scientific environment through work experience, links with local employers, case studies and research.
- The qualification provides appropriate progression from GCSE Applied Science and from GCSE Science for candidates wishing to follow a vocational pathway.
- The Advanced Subsidiary qualifications may be used to complement other vocational courses or provide a work-related experience for candidates taking non-vocational subjects.
- The Advanced qualifications provide progression to science-related courses in further or higher education.

PART A: GENERAL SPECIFICATION

FOREWORD

This booklet contains OCR Advanced Subsidiary GCE, Advanced Subsidiary GCE (Double Award), Advanced GCE and Advanced GCE (Double Award) specifications in Applied Science for teaching from September 2005.

The Advanced Subsidiary GCEs are assessed at a standard appropriate for candidates who have completed the first year of study of the corresponding two year Advanced GCE course, i.e. between GCSE and Advanced GCE. They form the first half of the Advanced GCE courses in terms of teaching time and content. When combined with the second half of the Advanced GCE courses, known as ‘A2’, the AS awards form 50% of the assessment of the total Advanced GCE. However, the AS (Single and Double Awards) can be taken as ‘stand-alone’ qualifications. A2 is weighted at 50% of the total assessment of the Advanced GCE.

The first year of certification of the OCR Advanced Subsidiary GCE in Applied Science is June 2006.
The first year of certification of the OCR Advanced Subsidiary GCE in Applied Science (Double Award) is June 2006.
The first year of certification of the OCR Advanced GCE in Applied Science is June 2007.
The first year of certification of the OCR Advanced GCE in Applied Science (Double Award) is June 2007.

These specifications meet the requirements of the Common Criteria as set out in the Arrangements for the statutory regulation of external qualifications in England, Wales and Northern Ireland (QCA, ACCAC and CCEA, 2000), the Advanced GCE Qualification Criteria (QCA, ACCAC and CCEA, 2002) and the relevant Subject Criteria (QCA 2002).

Part A Contents

SECTION A: SPECIFICATION SUMMARY

1 SCHEME OF ASSESSMENT

All specifications in this booklet are based on equally-weighted units of assessment, each requiring **60** guided-learning hours (glhs) of delivery.

The Advanced Subsidiary (Single and Double Award) GCEs form 50% of the assessment weighting of the corresponding Advanced (Single and Double Award) GCE.

Advanced Subsidiary GCEs can be taken as stand-alone single or double award specifications or as the first half of an Advanced single or double award GCE course.

Assessment is by means of **three** units of assessment for Advanced Subsidiary GCE (**180** glhs), **six** units of assessment for Advanced Subsidiary GCE (Double Award) and Advanced GCE (**360** glhs), and **twelve** units of assessment for Advanced GCE (Double Award) (**720** glhs).

The Single Award Structure

Advanced GCE (Single Award)		
Advanced Subsidiary GCE (Single Award)		
AS	AS	AS
A2	A2	A2

The Double Award Structure

Advanced GCE (Double Award)					
Advanced Subsidiary GCE (Double Award)					
AS	AS	AS	AS	AS	AS
A2	A2	A2	A2	A2	A2
Advanced GCE (Single Award)					

Relative Standards of Advanced Subsidiary GCE and Advanced GCE

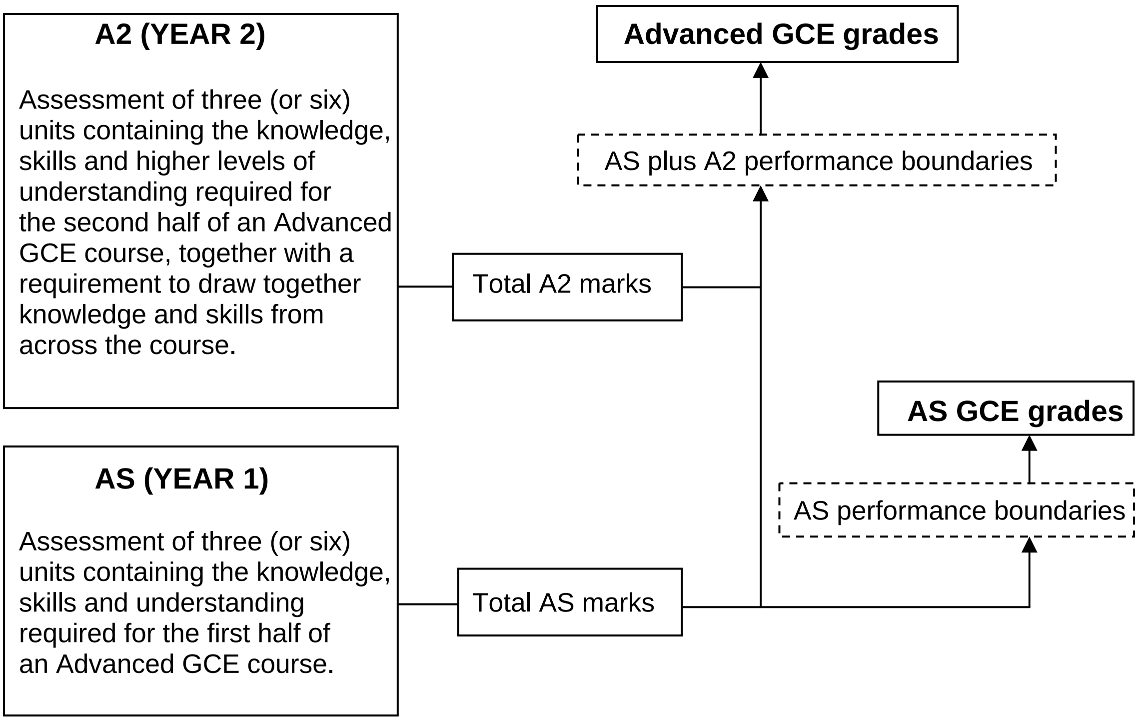
The skills, knowledge and understanding required for the first half of an Advanced GCE course are contained in the 'Advanced Subsidiary' (AS) units. The level of demand of the AS examination is that expected of candidates halfway through a full Advanced GCE course of study.

The skills, knowledge and understanding required for the second half of an Advanced GCE course are contained in the 'A2' units. The level of performance expected, therefore, reflects the more demanding Advanced GCE material, including the higher-level concepts and a requirement to draw together knowledge and skills from across the course. The precise pattern across AS and A2 reflects the nature of individual subjects.

The combination of candidates' attainments on the relatively less demanding AS units and relatively more demanding A2 units lead to an award at Advanced GCE standard.

The Advanced Subsidiary GCE units and qualification and the Advanced GCE units and qualification are graded A to E where A is the highest grade.
The Advanced Subsidiary GCE (Double Award) units and qualification and the Advanced GCE (Double Award) units and qualification are graded AA, AB, BB, BC, CC, CD, DD, DE, EE where AA is the highest grade.

The diagram below summarises how the combined marks from AS and A2 units lead to graded Advanced Subsidiary GCE and Advanced GCE qualifications.



2 UNITS OF ASSESSMENT

Unit Code	Unit Number	Level	Title of Unit	Mode of Assessment	Unit Combinations (mandatory/optional)			
					AS GCE	AS GCE (Double Award)	Advanced GCE	Advanced GCE (Double Award)
G620	1	AS	Science at work	Portfolio	m	m	m	m
G621	2	AS	Analysis at work	Portfolio	m	m	m	m
G622	3	AS	Monitoring the activity of the human body	**External**	m	m	m	m
G623	4	AS	Cells and molecules	**External***		m		m
G624	5	AS	Chemicals for a purpose	Portfolio		o^{2}		o^{2}
G625	6	AS	Forensic science	Portfolio		o^{2}		o^{2}
G626	7	AS	The physics of sport	Portfolio		o^{2}		o^{2}
G627	8	A2	Investigating the scientist's work	Portfolio			m	m
G628	9	A2	Sampling, testing and processing	**External***			o^{1a}	m
G629	10	A2	Synthesising organic chemicals	Portfolio			o^{1b}	o^{3}
G630	11	A2	Materials for a purpose	Portfolio			o^{1b}	o^{3}
G631	12	A2	Electrons in action	Portfolio			o^{1b}	o^{3}
G632	13	A2	The mind and the brain	Portfolio			o^{1b}	o^{3}*
G633	14	A2	Ecology and managing the environment	Portfolio			o^{1b}	o^{3}*
G634	15	A2	Applications of biotechnology	Portfolio			o^{1b}	o^{3}*
G635	16	A2	Working waves	**External**			o^{1a}	m

m candidates must complete those units marked m listed in the relevant column for the award being taken.
o^{1a} candidates choose **one** option from those marked o^{1a} listed in the relevant column for the award being taken.
o^{1b} candidates choose **one** option from those marked o^{1b} listed in the relevant column for the award being taken.
o^{2} candidates choose **two** options from those marked o^{2} listed in the relevant column for the award being taken.
o^{3} candidates choose **three** options from those marked o^{3} listed in the relevant column for the award being taken (**maximum* ***two*** *of these units can be chosen*).
external assessments marked with an * indicate those with pre-released case-study material which will be available to centres approximately **six** weeks prior to the examination dates.

Three unit Advanced Subsidiary GCE:	Candidates take Units 1, 2 and 3.
Six unit Advanced Subsidiary GCE (Double Award):	Candidates take Units 1, 2, 3 and 4 plus **two** of Units 5, 6 and 7.
Six unit Advanced GCE:	Candidates take Units 1, 2, 3 and 8 plus **one** of Units 9 and 16 plus **one** of Units 10, 11, 12, 13, 14 and 15.
Twelve unit Advanced GCE (Double Award):	Candidates take Units 1, 2, 3, 4, 8, 9 and 16 plus **two** of Units 5, 6 and 7 plus **three** of Units 10, 11, 12, 13*, 14* and 15*

* (*maximum **two** of these units can be chosen*)

SECTION B: GENERAL INFORMATION

1 Introduction

1.1 RATIONALE

GCEs in vocational subjects are broad-based vocational qualifications designed to widen participation in vocationally-related learning post-16. They have been designed to contribute to the quality and coherence of national provision and have a clear place in the Government's vision for secondary education.

The specifications have been designed to form qualifications which provide the technical knowledge, skills and understanding associated with the subject at Level 3 of the National Qualification Framework, to equip candidates with the skills they will need in the workplace or in higher education or training. They allow candidates to experience vocationally-related learning at Advanced Level and, as such, provide suitable complementary study for candidates following courses leading to other Level 3 qualifications in the Sciences.

The specifications build upon the broad educational framework supplied by the Qualification and Subject Criteria (QCA, ACCAC and CCEA, 2002) and employ an investigative and problem-solving approach to the study of the subject. In addition to providing a suitable route for progression for candidates completing courses in GNVQ or GCSE Science, or GCSE Applied Science, or First Diploma qualifications, the course of study prescribed by these specifications can also reasonably be undertaken by candidates beginning their formal education in the subject at post-16 level. Progression through the Advanced Subsidiary GCE and Advanced GCE, through either a single or double award, may provide a suitable foundation for study of the subject, or related subjects, in further and higher education.

Key Skills are integral to the specifications and *the main* opportunities to provide evidence for the separate Key Skills qualification are indicated.

These specifications are supported by users and a range of professional institutes and Further and Higher Education Institutions. These include NTOs (National Training Organisations) which support training and development in many different sectors and have been consulted during the development of these specifications.

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

1.2 SPECIFICATION AIMS

All specifications in Applied Science aim to:

- provide candidates with the opportunity to develop appropriate skills, knowledge and understanding and apply these where science is used;
- enable candidates to appreciate and evaluate the social, economic and environmental impact that science work has on society, identifying ethical issues that may arise;
- prepare candidates for further study on a course in a science or in a science-related subject or for training in a science-related occupation;
- support and complement other programmes of advanced level study.

The aims of these specifications in Applied Science are to encourage candidates to:

- acquire knowledge and understanding of the scientific ideas and skills that scientists need in order to be effective in their work and to apply this in a variety of vocational contexts;
- become skilful in carrying out practical techniques and following procedures used in vocational contexts;
- develop knowledge and understanding of the science used by organisations, business and industry;
- further develop their interest in science and its practical applications through exploring and experiencing science in a vocational context;
- understand the nature of science-based work and the contribution this use of science makes to society;
- develop an awareness of the use and importance of ICT in scientific work.

In addition, the aims of the Advanced (Single and Double Award) GCE specifications in Applied Science are to encourage candidates to:

- develop their skills of investigation and problem solving in a vocational context, by applying their knowledge and understanding of scientific ideas and techniques, using skills of primary research, planning, data collection, analysis and evaluation.

1.3 ASSESSMENT OBJECTIVES

Candidates for these qualifications will be expected to demonstrate the following in a range of appropriate vocationally-related contexts:

AO1 Demonstration of knowledge and understanding

Candidates demonstrate their knowledge and understanding by:

- recognising and recalling facts, terminology, principles, concepts and practical techniques;
- selecting, organising and presenting, clearly and logically, information either provided or acquired through systematic research.

AO2 Application of skills, knowledge and understanding

Candidates apply their skills, knowledge and understanding in appropriate vocational contexts:

- by describing, explaining, interpreting and evaluating information and the impact on society of the work of scientists, including beneficial effects and the need for constraints;
- in carrying out relevant calculations.

AO3 Experimentation and investigation

Candidates:

- carry out safely and skilfully practical tasks, making and recording observations and measurements with appropriate precision, processing them appropriately and communicating this information clearly and logically, e.g. in prose, tables and graphs;
- plan, carry out and evaluate investigative work.

The assessment objectives are weighted as follows:

	AS Units	A2 Units	GCE and GCE (Double Award)
AO1	35-50%	15-30%	25-40%
AO2	10-25%	20-35%	15-30%
AO3	25-40%	35-50%	30-45%

Weighting of the assessment objectives within individual units is given in Section 4.8.

1.4 NATURE OF ASSESSMENT

1.4.1 Structure of Assessment

For the Advanced Subsidiary GCE, **two** units will be assessed internally, through a teacher-assessed portfolio (see Section 7) and **one** unit will be assessed externally with the assessment set and marked by OCR. These **three** units will be equally sized and equally weighted.

For the Advanced Subsidiary GCE (Double Award) and the Advanced GCE, **four** units will be assessed internally, through a teacher-assessed portfolio (see Section 7) and **two** units will be assessed externally with the assessment set and marked by OCR. These **six** units will be equally sized and equally weighted.

For the Advanced GCE (Double Award), **eight** units will be assessed internally, through a teacher-assessed portfolio (see Section 7) and **four** units will be assessed externally with the assessment set and marked by OCR. These **twelve** units will be equally sized and equally weighted.

The assessment will be conducted in accordance with the GCE Code of Practice.

1.4.2 External Assessment

External assessment forms 33% of each qualification:

Advanced Subsidiary GCE:	Candidates take **one** unit of external assessment.
Advanced Subsidiary GCE (Double Award):	Candidates take **two** units of external assessment.
Advanced GCE:	Candidates take **two** units of external assessment.
Advanced GCE (Double Award):	Candidates take **four** units of external assessment.

External assessments are 90 minutes except for Unit 4: *Cells and molecules* which is 45 mins. Unit 4 and Unit 9: *Sampling, testing and processing* have pre-released case-study material which will be available to centres (once they have made their *provisional* candidate entries) approximately **six** weeks prior to the examination dates.

OCR has designed external assessments which allow candidates to apply the knowledge and understanding they have gained from teacher-designed activities and assignments based on the *What You Need To Learn* section of the units.

The externally assessed units will be marked by OCR. The maximum raw score will be stated on the front cover of the question paper.

1.4.3 Portfolio Assessment

Internal assessment forms 67% of each qualification. Internally assessed units take the form of a portfolio of work designed to enable the candidate to demonstrate understanding of the content of the unit. Each internal assessment is set by the centre to OCR guidelines, is internally marked and externally moderated by OCR.

2 Administration and Entry

2.1 ADMINISTRATIVE ARRANGEMENTS

2.1.1 The Role of the Examinations Officer

All administrative arrangements regarding entries, submission of marks, moderation, receipt of results documentation etc. are to be made **through the centre's Examinations Officer**. It is important that subject staff liaise with the Examinations Officer and are aware of key dates for examination entry and submission of marks. These dates are supplied to Examinations Officers well before the start of the teaching year.

2.1.2 Provisional Entries

OCR does not require *individual* candidates to be registered at the start of their course, but nevertheless, needs certain information in order to plan effectively.

Provisional entries are *your best guess* of the number of candidates you will be entering for particular units in that session. They are important because they form the basis for the despatch of early assessment materials to you and allow OCR to ensure sufficient examiners/moderators are recruited for a session.

Centres make provisional entries by mid September (for January) and early November (for June). There is no fee for provisional entries.

If your centre does not make provisional entries you will *not* receive despatches of early examination materials, for example, instructions for practical examinations and pre-release materials.

2.1.3 Unit and Certification Entries

Final entries for units (including internally assessed units) are made in October for January units and in March for June units. It is important that entries are received by the deadline date – late entries cause major problems for OCR and attract a substantial penalty fee to reflect this.

To enter for certification, candidates must have a valid combination of unencashed units for that qualification (see Section 2.3).

Note that entry for units will *not* generate a final certificate – a separate certification entry for the qualification code must be made as follows:

Qualification	Entry Code
Advanced Subsidiary GCE	H175
Advanced Subsidiary GCE (Double Award)	H375
Advanced GCE	H575
Advanced GCE (Double Award)	H775

Certification entry is usually made at the same time as the final unit entries. If made at this time, it does not attract a fee.

A candidate who has completed all the units required for a qualification may enter for certification at a later examination series. Again this does not attract a fee.

A candidate who has completed all the required units but who has not entered for certification may do so in the same examination series within a specified period after the publication of results. There is a fee for this late certification service.

2.1.4 Special Requirements

OCR can make special arrangements for candidates in examinations, provided OCR is given sufficient notice. These arrangements should be made through Examinations Officers.

Special arrangements applications must be made by:

- 30 September (for January sessions);
- 15 January (for special question papers required for June session);
- 21 February (for other special arrangements for June session).

If you have candidates who come into this category, you should inform your Examinations Officer well in advance of these dates.

2.1.5 Arrangements for the Assessment and Moderation of Portfolios

Portfolio entries may be made for both the January and June sessions.

Detailed arrangements for the assessment of portfolios are explained in Section 7. Examination Officers will be sent the appropriate forms for completion in November for the January session and in January for the June session, assuming that provisional entries have been received.

Centres wishing to receive earlier feedback or advice on portfolio assessment may arrange with OCR to contact a Portfolio Consultant.

Centres must submit unit marks to OCR and to the moderator by the published OCR submission date. Failure to submit these marks on time can create serious problems for OCR and may jeopardise the issue of results on the published date.

2.2 UNITS OF ASSESSMENT

Unit Code	Unit Number	Level	Title of Unit	Mode of Assessment	Unit Combinations (mandatory/optional)			
					AS GCE	AS GCE (Double Award)	Advanced GCE	Advanced GCE (Double Award)
G620	1	AS	Science at work	Portfolio	m	m	m	m
G621	2	AS	Analysis at work	Portfolio	m	m	m	m
G622	3	AS	Monitoring the activity of the human body	**External**	m	m	m	m
G623	4	AS	Cells and molecules	**External***		m		m
G624	5	AS	Chemicals for a purpose	Portfolio		o^2		o^2
G625	6	AS	Forensic science	Portfolio		o^2		o^2
G626	7	AS	The physics of sport	Portfolio		o^2		o^2
G627	8	A2	Investigating the scientist's work	Portfolio			m	m
G628	9	A2	Sampling, testing and processing	**External***			o^{1a}	m
G629	10	A2	Synthesising organic chemicals	Portfolio			o^{1b}	o^3
G630	11	A2	Materials for a purpose	Portfolio			o^{1b}	o^3
G631	12	A2	Electrons in action	Portfolio			o^{1b}	o^3
G632	13	A2	The mind and the brain	Portfolio			o^{1b}	o^3*
G633	14	A2	Ecology and managing the environment	Portfolio			o^{1b}	o^3*
G634	15	A2	Applications of biotechnology	Portfolio			o^{1b}	o^3*
G635	16	A2	Working waves	**External**			o^{1a}	m

m candidates must complete those units marked m listed in the relevant column for the award being taken.
o^{1a} candidates choose **one** option from those marked o^{1a} listed in the relevant column for the award being taken.
o^{1b} candidates choose **one** option from those marked o^{1b} listed in the relevant column for the award being taken.
o^2 candidates choose **two** options from those marked o^2 listed in the relevant column for the award being taken.
o^3 candidates choose **three** options from those marked o^3 listed in the relevant column for the award being taken (**maximum* ***two*** *of these units can be chosen*).

external assessments marked with an * indicate those with pre-released case-study material which will be available to centres approximately **six** weeks prior to the examination dates.

Three unit Advanced Subsidiary GCE:	Candidates take Units 1, 2 and 3.
Six unit Advanced Subsidiary GCE (Double Award):	Candidates take Units 1, 2, 3 and 4 plus **two** of Units 5, 6 and 7.
Six unit Advanced GCE:	Candidates take Units 1, 2, 3 and 8 plus **one** of Units 9 and 16 plus **one** of Units 10, 11, 12, 13, 14 and 15.
Twelve unit Advanced GCE (Double Award):	Candidates take Units 1, 2, 3, 4, 8, 9 and 16 plus **two** of Units 5, 6 and 7 plus **three** of Units 10, 11, 12, 13*, 14* and 15*

* (*maximum **two** of these units can be chosen*)

2.3 MAKING ENTRIES FOR CERTIFICATION

Candidates following a course over a number of examination sessions have a variety of options open to them that allow them to certificate part-way through their course. All three- and six-unit qualifications are automatically ‘banked’ by OCR to enable the candidate to use them towards larger qualifications at a later date. Once banked, however, candidates may not re-sit any units within that qualification.

Candidates may enter for:

- Advanced Subsidiary GCE aggregation;
- Advanced Subsidiary GCE aggregation, bank the result, and complete the Advanced Subsidiary GCE (Double Award) assessment at a later date;
- Advanced Subsidiary GCE aggregation, bank the result, and complete the A2 assessment at a later date for either an Advanced GCE or an Advanced GCE (Double Award);
- Advanced Subsidiary GCE (Double Award) aggregation;
- Advanced Subsidiary GCE (Double Award) aggregation, bank the result, and complete the A2 assessment at a later date for either an Advanced GCE or an Advanced GCE (Double Award);
- Advanced GCE aggregation;
- Advanced GCE aggregation, bank the result, and complete the Advanced GCE (Double Award) assessment at a later date;
- Advanced GCE (Double Award) aggregation.

Candidates must enter the appropriate Advanced Subsidiary units to qualify for the Advanced Subsidiary GCE (Double Award).

Candidates must enter the appropriate AS and A2 units to qualify for the Advanced (Single or Double Award) GCE.

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

2.4 AVAILABILITY OF UNITS OF ASSESSMENT

First Availability of Units and Certificates (and then every January and June thereafter)	**2006**		**2007**	
	Jan	**June**	**Jan**	**June**
External assessment of AS units	✓	✓	✓	✓
Portfolio moderation for AS units*	✓	✓	✓	✓
External assessment of A2 units			✓	✓
Portfolio moderation for A2 units*			✓	✓
AS GCE certification (Single and Double Awards)		✓	✓	✓
GCE certification (Single and Double Awards)				✓

*Centres wishing to receive earlier feedback or advice on portfolio assessment may arrange with OCR to contact a Portfolio Consultant.

2.4.1 Sequence of Units

Units may be taken in any order, though centres are strongly advised to cover AS Units 1, 2 and 3 early in the course, since they form a core on which other units are based.

AS units are designed to be taught and assessed in the first year of a **two** year course and A2 units are designed to be studied and assessed in the second year although centres should use their own discretion to create a delivery pattern that suits their particular circumstances.

Details are provided within each unit of any dependencies or advised progression routes.

Centres should also ensure all authentication documentation for every candidate is completed and kept securely with the work until moderation takes place.

2.4.2 Synoptic Assessment

Synoptic assessment at Advanced GCE is designed to ensure that candidates have a good understanding of the subject as a whole and are able to address issues within the subject from a range of perspectives and in an integrated way. The emphasis is on strategic understanding and on the ability to draw evidence together from any relevant areas of the specifications. Assessment focuses on the breadth, depth and quality of candidates' analysis and evaluation. Synoptic assessment will be drawn from across the specifications.

It is expected that candidates completing portfolio work for later units will draw upon their knowledge, understanding and skills gained in earlier units, as advised within the units concerned. Synoptic assessment will involve candidates bringing together, and making connections between, the areas of skills, knowledge and understanding covered within the specifications and applying this when carrying out the substantive investigation.

2.5 RE-SIT RULES

2.5.1 Re-sits of Units

There is no restriction on the number of times a candidate may re-sit each unit before entering for certification for an Advanced Subsidiary (Single or Double Award) GCE or Advanced (Single or Double Award) GCE.

2.5.2 Retaking a Qualification

There is no restriction on the number of times a candidate may retake the whole qualification.

2.6 RESTRICTIONS ON CANDIDATE ENTRIES

There are no restrictions on candidates who enter for these GCE specifications.

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

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

The classification code for these specifications is 0008.

2.7 SPECIAL ARRANGEMENTS

Candidates with special requirements must cover the assessment objectives. There may be more suitable ways of doing this than those used by the centre with other candidates. Any centre wishing to start candidates with special requirements on the course who might not be able to meet the requirements of the assessment must consult the Special Requirements Unit before doing so (telephone 01223 552505). For these candidates, or those whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*.

3 Certification and Results

3.1 ISSUE OF RESULTS

Individual unit Statements of Results will be issued in March for January entries and in August for June entries for all units (both portfolio units and external units). Statements of Results will include, for each unit, the unit title, the unit UMS mark, the grade and the date the unit was taken.

Certification is **not** an automatic process, since OCR is unable to determine at which point a candidate wishes to complete their course. Candidates **must** be entered for the appropriate certification code (see Section 2.1.3) to claim their overall grade.

Entry for units will *not* generate a final certificate – a separate certification entry must be made at the appropriate time. If it is not, there will be a delay in issuing the candidate's final grade.

3.2 AWARDING AND REPORTING ATTAINMENT

3.2.1 General Principles

The qualifications will comply with the grading, awarding and certification requirements of the GCE section of the Code of Practice.

The Advanced Subsidiary GCE and the Advanced GCE qualifications are graded A to E where A is the highest grade.

The Advanced Subsidiary GCE (Double Award) and the Advanced GCE (Double Award) qualifications are graded AA, AB, BB, BC, CC, CD, DD, DE, EE where AA is the highest grade.

All GCE units are graded a to e where a is the highest grade.

The OCR awarding committee will consider both externally assessed and portfolio based units and will determine the grade thresholds for each unit.

3.2.2 Uniform Marks

In order that candidates' performance can be compared across units and across sessions, a Uniform Mark Scale (UMS) will be used to aggregate the results of individual assessment units to generate qualification grades.

Once the raw mark and raw mark boundaries for each unit have been established, the raw marks are converted to the UMS by OCR and reported to candidates as a *uniform mark* out of 100.

Uniform marks correspond to *unit* grades as follows:

Unit Grade	a	b	c	d	e
UMS (max 100)	80-100	70-79	60-69	50-59	40-49

Candidates who fail to achieve the standard for a grade e will be awarded a Uniform Mark in the range 0-39 and will be recorded as u (unclassified).

3.2.3 Overall Grade

The uniform marks awarded for each unit will be aggregated and compared to pre-set boundaries.

Uniform marks correspond to overall grades as follows.

Advanced Subsidiary GCE:

Overall Grade	A	B	C	D	E
UMS (max 300)	240-300	210-239	180-209	150-179	120-149

Advanced GCE:

Overall Grade	A	B	C	D	E
UMS (max 600)	480-600	420-479	360-419	300-359	240-299

Results for these qualifications will be awarded on a scale of A to E and will be recorded on the certificate as such.
Candidates who fail to achieve the standard for a grade E will be awarded a Uniform Mark in the range 0-119 for the Advanced Subsidiary GCE and 0-239 for the Advanced GCE and will be recorded as U (unclassified). This does not lead to a certificate.

Advanced Subsidiary GCE (Double Award):

Overall Grade	AA	AB	BB	BC	CC	CD	DD	DE	EE
UMS (max 600)	480-600	450-479	420-449	390-419	360-389	330-359	300-329	270-299	240-269

Advanced GCE (Double Award):

Overall Grade	AA	AB	BB	BC	CC	CD	DD	DE	EE
UMS (max 1200)	960-1200	900-959	840-899	780-839	720-779	660-719	600-659	540-599	480-539

Results for these qualifications will be awarded on a scale of AA to EE and will be recorded on the certificate as such.

Candidates who fail to achieve the standard for a grade EE will be awarded a Uniform Mark in the range 0-239 for the Advanced Subsidiary GCE (Double Award) and 0-479 for the Advanced GCE (Double Award) and will be recorded as U (unclassified). This does not lead to a certificate.

3.3 RESULT ENQUIRIES AND APPEALS

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

For procedures relating to enquiries on results and appeals, centres should consult the *Handbook for Centres* and the document *Enquiries about Results and Appeals – Information and Guidance for Centres* produced by the Joint Council. Further copies of the most recent edition of this paper can be obtained from OCR or they can be accessed from the Joint Council website www.jcgq.org.uk.

4 Technical Information

4.1 CERTIFICATION TITLES

These specifications will be shown on a certificate as:

OCR Advanced Subsidiary GCE in Applied Science.
OCR Advanced Subsidiary GCE in Applied Science (Double Award).
OCR Advanced GCE in Applied Science.
OCR Advanced GCE in Applied Science (Double Award).

4.2 LEVEL OF QUALIFICATION

These qualifications are approved by QCA at Level 3 of the National Qualifications Framework.

4.3 RECOMMENDED PRIOR LEARNING

Candidates entering this course should have achieved a general educational level equivalent to Level 2 in the National Qualifications Framework, or Levels 7/8 of the National Curriculum. Skills in Numeracy/Mathematics, Literacy/English and Information and Communication Technology will be particularly relevant.

However, there is no prior knowledge required for this specification. Prior study of the GCSE in Applied Science or GCSE Science or GNVQ Science will be of benefit to candidates, but is not mandatory. Those who have achieved at Intermediate Level in Science or Applied Science (e.g. GCSE Double Award Science or Applied Science at grades CC or above) will be well prepared to undertake a course in GCE Applied Science.

4.4 PROGRESSION

4.4.1 Progression into Employment

These specifications are designed to give a broad introduction to this sector and aim to prepare candidates for further study in higher education or further training which might be whilst in employment. However, these qualifications are not designed for candidates' direct entry into employment.

4.4.2 Progression to Further Qualifications

Candidates who achieve these qualifications may be prepared to enter a variety of HND or degree level courses in science-related subjects.

4.5 RELATED QUALIFICATIONS

4.5.1 Relationship to other GCEs

The units of these qualifications have significant overlap of content with other OCR GCEs in the sciences. A full mapping is available from the Science, Technology and Maths Council.

4.5.2 Relationship to NVQs

These specifications introduce the candidate to skills relevant to a range of science-related NVQs, though the assessment methods are not designed to guarantee occupational competence. However, this qualification will support candidates working towards National Occupational Standards, detailed guidance for which was issued by QCA in early 2002.

In particular, there are links to units from the Laboratory and Associated Technical Activities (LATA) standards that form the basis of NVQs in the science area. Examples of these NVQs include: Laboratory Operations; Process Operations; Laboratory Technicians Working in Education.

4.6 CODE OF PRACTICE REQUIREMENT

The assessment will be conducted in accordance with the GCE Code of Practice.

4.7 STATUS IN WALES AND NORTHERN IRELAND

This specification has been approved by ACCAC for use by centres in Wales and by CCEA for use by centres in Northern Ireland.

Candidates in Wales or Northern Ireland should not be disadvantaged by terms, legislation or aspects of government that are different from those in England. Where such situations might occur, including in the external assessment, the terms used have been selected as neutral, so that candidates may apply whatever is appropriate to their own situation.

OCR will provide specifications, assessments and supporting documentation in English only and can accept candidate portfolios and examination scripts in English only. Further information concerning the provision of assessment materials in Welsh and Irish may be obtained from the Information Bureau at OCR (telephone 01223 553998)[1].

[1] The OCR Information Bureau is open to take your calls between 8.00am and 5.30pm. Please note that as part of our quality assurance programme your call may be recorded or monitored for training purposes.

4.8 WEIGHTING OF ASSESSMENT OBJECTIVES

The full set of Assessment Objectives and their weightings within the qualification are listed in Section 1.3. The relationship between assessment objectives and the units of assessment is shown in the grids below.

Unit of Assessment	Mandatory or Optional	Level	Percentage of AS GCE			Total
			AO1	AO2	AO3	
1	m	AS	38	20	42	100
2	m	AS	38	20	42	100
3	m	AS	64	36	-	100
		Total	**140**	**76**	**84**	**300**

Unit of Assessment	Mandatory or Optional	Level	Percentage of AS GCE (Double Award)			Total
			AO1	AO2	AO3	
1	m	AS	38	20	42	100
2	m	AS	38	20	42	100
3	m	AS	64	36	-	100
4	m	AS	16	34	50	100
One of 5-7	o	AS	42	20	38	100
One of 5-7	o	AS	42	20	38	100
		Total	**240**	**150**	**210**	**600**

Unit of Assessment	Mandatory or Optional	Level	Percentage of GCE			Total
			AO1	AO2	AO3	
1	m	AS	38	20	42	100
2	m	AS	38	20	42	100
3	m	AS	64	36	-	100
8	m	A2	20	28	52	100
9 or 16	o	A2	50	50	-	100
One of 10-15	o	A2	20	28	52	100
		Total	**230**	**182**	**188**	**600**

Unit of Assessment	Mandatory or Optional	Level	Percentage of GCE (Double Award)			Total
			AO1	AO2	AO3	
1	m	AS	38	20	42	100
2	m	AS	38	20	42	100
3	m	AS	64	36	-	100
4	m	AS	16	34	50	100
One of 5-7	o	AS	42	20	38	100
One of 5-7	o	AS	42	20	38	100
8	m	A2	20	28	52	100
9	m	A2	50	50	-	100
One of 10-15	o	A2	20	28	52	100
One of 10-15	o	A2	20	28	52	100
One of 10-15	o	A2	20	28	52	100
16	m	A2	50	50	-	100
		Total	**420**	**362**	**418**	**1200**

4.9 QUALITY OF WRITTEN COMMUNICATION

Quality of Written Communication is assessed in all units where candidates are required to produce extended written material and credit may be restricted if communication is unclear.

Candidates will:

- select and use a form and style of writing appropriate to purpose and to complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate;
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear.

4.10 DIFFERENTIATION

In the question papers, differentiation is achieved by setting questions which are designed to assess candidates at their appropriate levels of ability and which are intended to allow all candidates to demonstrate what they know, understand and can do.

In portfolio work, differentiation is by task and by outcome. Candidates undertake assignments which enable them to display positive achievement.

4.11 GUIDED LEARNING HOURS

All units in these specifications require **60** guided learning hours (glhs) *each* of delivery time. Thus:

Advanced Subsidiary GCE awards require **180** glhs of delivery time;
Advanced Subsidiary GCE double awards require **360** glhs of delivery time;
Advanced GCE awards require **360** glhs of delivery time;
Advanced GCE double awards require **720** glhs of delivery time.

5 Structure of Units

Please see Part B for the unit specifications. Units will have some or all of the following sections:

About this unit

This includes a brief description for the candidate of the content, purpose and vocational relevance of the unit.
It states whether the unit is assessed externally or through portfolio evidence.

What you need to learn

This specifies the underpinning knowledge, skills and understanding candidates need to apply in order to meet the requirements of the portfolio evidence or external assessment.

Assessment evidence

This specifies the evidence candidates need to produce in order to meet the requirements of each portfolio unit. It is divided into the following parts:

- *You need to produce* – this banner heading sets the context for providing the evidence, e.g. a report, an investigation, etc;
- *Evidence Descriptors* – these describe the qualities of the work which will achieve each mark range specified.

Guidance for teachers

This provides advice on teaching and assessment strategies.

There is advice on:

- the provision of the vocational context of the unit;
- accurate and consistent interpretation of national standards;
- the use of appropriate internal assessments, taking into account the full range of grades to be covered.

There may also be advice on:

- exploiting local opportunities (e.g. information sources, events, work experience);
- resources.

SECTION C: PORTFOLIOS

6 Delivery and Administration of Portfolios

6.1 SUPERVISION AND AUTHENTICATION OF PORTFOLIOS

6.1.1 Supervision of Candidates

OCR expects teachers to supervise and guide candidates who are producing portfolios. The degree of teacher guidance in candidates' work will vary according to the kind of work being undertaken. However, it should be remembered that candidates are required to reach their own judgements and conclusions.

When supervising candidates, teachers are expected to:

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

Work on portfolios may be undertaken outside the centre and in the course of normal curriculum time. As with all internally assessed work, the teacher must be satisfied that the work submitted for assessment is the candidate's own work. This does not prevent groups of candidates working together in the initial stages, but it is important to ensure that the individual work of a candidate is clearly identified separately from that of any group in which they work.

Throughout the course, the teacher should encourage the candidate to focus on achieving the criteria listed in the *Assessment Evidence Grids*.

Once the mark for the unit portfolio has been submitted to OCR, no further work may take place. However, the portfolio can be improved and resubmitted under the re-sit rule (Section 2.5).

6.1.2 Authentication of Candidates' Work

Teachers may comment on a candidate's unit portfolio and return it for redrafting without limit until the deadline for the submission of marks to OCR.

Teachers must record details of any assistance given and this must be taken into account when assessing candidates' work.

Teachers must complete and sign the *Centre Authentication Form* to confirm that the work submitted for moderation was produced by the candidates concerned. Once completed this form must be sent to the moderator along with candidates' work.

6.1.3 Avoiding Plagiarism

Plagiarism in coursework is the equivalent of cheating in written examinations.

Candidates should be taught how to present material taken directly from other sources and must observe the following when producing portfolios:

- any copied material must be suitably acknowledged;
- quotations must be clearly marked and a reference provided wherever possible.

6.1.4 Late Work

Teachers may set internal deadlines for candidates submitting work to them. However, should candidates fail to meet this deadline, they may only be penalised if they fail to achieve one or more of the criteria in the *Assessment Evidence Grid* for that unit. A candidate whose work is submitted so late that the teacher is unable to meet OCR's deadline for receipt of marks should be warned by the teacher that failure to submit marks by this deadline may result in OCR failing to issue grades on the agreed date.

6.2 ADMINISTERING PORTFOLIO ASSESSMENT AND MODERATION

Portfolio units are internally assessed by centres and externally moderated by OCR. There are **three** key points in the administrative cycle that require action by the teacher:

- the centre enters candidates who wish to submit portfolios (October for January examinations, March for June examinations);
- the centre sends OCR and the moderator a set of provisional marks by a set deadline (to be determined – currently 10 January and 15 May);
- the moderator contacts the centre on receipt of marks and asks for a sample of work.

Further details of submission of marks and portfolio moderation are given in Sections 7.3 and 7.4.

OCR will conduct all administration of the GCE through the Examination Officer at the centre. Teachers are strongly advised to liaise with their Examination Officer to ensure that they are aware of key dates in the administrative cycle.

Assessment-recording materials and full details of administrative arrangements for portfolio assessment, will be forwarded to Examination Officers in centres in Autumn 2005, following receipt of provisional entries. At the same time the materials will be made available within *Portfolio Assessment Packs* and on the OCR website (www.ocr.org.uk). The materials will include master copies of mandatory *Unit Recording Sheets* on which to transfer your assessments from each candidate's *Assessment Evidence Grids*. Forms may be photocopied and used as required.

7 Assessment of Portfolios

7.1 THE ASSESSMENT EVIDENCE GRIDS

Centres are required to carry out internal assessment of portfolios using the *Assessment Evidence Grids* in accordance with OCR procedures. The process of using these grids is described in Section 8.2. Candidates' marks are recorded on these grids. **One** grid should be completed for each candidate's **unit** portfolio. The information on each of these grids should eventually be transferred onto a *Unit Recording Sheet* and attached to the front of the candidate's portfolio for the unit for inspection by the Moderator when the moderation process takes place.

When candidates are given their assignments, they should also be issued with a reference copy of the appropriate *Assessment Evidence Grid*.

Candidates' portfolios should be clearly annotated to demonstrate where, and to what level, criteria have been achieved. This will help in the moderation process. If teachers do this well it will be very much in the interests of their candidates. On completion of a unit, the teacher must complete the *Assessment Evidence Grid* and award a mark out of **50** for the unit. Details of this process are described in Section 8.2.

7.2 INTERNAL STANDARDISATION

It is important that all teachers, working in the same subject area, work to common standards. Centres are required to ensure that internal standardisation of marks across teachers and teaching groups takes place using an appropriate procedure.

This can be done in a number of ways. In the first year, reference material and OCR training meetings will provide a basis for centres' own standardisation. In subsequent years, this, or centres' own archive material, may be used. Centres are advised to hold a preliminary meeting of staff involved to compare standards through cross-marking a small sample of work. After most marking has been completed, a further meeting at which work is exchanged and discussed will enable final adjustments to be made.

7.3 SUBMISSION OF MARKS TO OCR

The involvement of OCR begins on receipt of entries for a portfolio unit from a centre's Examinations Officer. Entries for units to be included in any assessment session must be made by the published entry date from OCR. Late entries attract a substantial penalty fee.

By an agreed internal deadline the teacher submits the marks for the unit to the Examinations Officer. Marks will need to be available by the portfolio mark submission dates published by OCR and internal deadlines will need to reflect this. OCR will supply centres with MS1 Internal Assessment Mark Sheets to record the marks and instructions for completion. It is essential that centres send the top copy of these completed forms to OCR, the second copy to the Moderator and keep the third copy for their own records.

7.4 PORTFOLIO MODERATION

7.4.1 Preparing for Moderation

Moderation for all units will be available in the January and June sessions and will take place by post.

After the unit portfolio is internally marked by the teacher and marking has been internally standardised, marks are submitted to OCR by a specified date, published in the Key Dates poster, after which moderation takes place in accordance with OCR procedures.

The purpose of moderation is to ensure that the standard of the award of marks for internally assessed work is the same for each centre and that each teacher has applied the standards appropriately across the range of candidates within the centre.

Shortly after receiving the marks, the moderator will contact the centre and inform them of the sample of candidates' work that will be required, as outlined in Section 7.4.2.

Work submitted for moderation must be marked with the:

- centre number;
- centre name;
- candidate number;
- candidate name;
- specification code and title;
- unit code.

For each (portfolio) unit, centres must complete the appropriate *Unit Recording Sheet* (see Section 6.2) sent out annually by OCR and downloadable from the OCR website (www.ocr.org.uk) and attach it to each piece of work for moderation.

It is essential that the rank order of marks supplied to a moderator is correct. If centre assessment is inconsistent, work will be returned to the centre for re-assessment.

The sample of work which is presented to the moderator for moderation must show how the marks have been awarded in relation to the marking criteria defined in the unit.

7.4.2 Principles of Moderation

The following principles, agreed by the Awarding Bodies and QCA, indicate, in broad terms, how portfolio units will be moderated. OCR has detailed procedures that moderators will follow to implement the moderation process:

- centres submit unit marks to OCR and to the moderator by the published OCR submission date;
- the moderator will select, from each unit, a sample of candidates' portfolios which cover a range of grades;
- if the work seen overall has been assessed accurately and consistently to agreed national standards, within agreed tolerances, all unit marks submitted by the centre are accepted with no adjustments;
- adjustments, where required, will be carried out by OCR using its normal procedure. Centres are not required to amend marks except if administrative issues, errors or order of merit problems are discovered.

Whilst moderators may seek clarification from a centre, they cannot negotiate portfolio marks in any way. OCR will inform centres of the outcome of the moderation process at the time of publication of results. This will include a written report on any significant issues that arose during this process.

8 Instructions for Marking

8.1 SOURCES OF GUIDANCE

The starting point in assessing portfolios is the *Assessment Evidence Grid* within each unit. These contain levels of criteria for the skills, knowledge and understanding that the candidate is required to demonstrate. The *Guidance for Teachers* within the unit expands on these criteria and clarifies the level of achievement the assessor should be looking for when awarding marks.

Before the start of the course OCR will produce a *Teacher Guide*. At INSET sessions OCR will provide exemplar material which is work that best illustrates a particular mark band description.

OCR will hold training meetings on portfolio assessment led by senior GCE moderators. Details of these are in the OCR INSET booklets which are sent to centres in the Summer term or they may be obtained from the Training and Customer Support Division (tel. 01223 552950). They are also published on the OCR website (www.ocr.org.uk).

OCR also operates a network of Portfolio Consultants. Centres can obtain advice on assessment of portfolios from an OCR Portfolio Consultant. These are both subject specialists and senior moderators. Details may be obtained from the OCR Subject Officer.

8.2 DETERMINING A CANDIDATE'S MARK

It must be stressed that teachers determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

Each portfolio should be marked by the teacher according to the assessment objectives and content requirements in the *Assessment Evidence Grid* in each unit specification (a sample of which is repeated in Section 8.3).

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

Teachers use their professional judgement to determine which descriptor in a strand best suits the candidate's work and from the range of marks available within that particular mark band, they circle the mark that best fits the work. They then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Centres should use the full range of marks available to them. Centres must award full marks in any strand of work which fully meets the criteria. This is work which is the best one could expect from candidates working at AS or A2 level.

Only one mark per AO strand will be entered (although this may be the sum from several rows – one mark per row – for that particular AO strand). The final mark for the candidate is out of a total of 50 and is found by totalling the marks for each AO strand.

8.3 SAMPLE ASSESSMENT EVIDENCE GRID

Unit 1: Science at work

What you need to do:

You need to produce a research portfolio related to information on organisations that use science [**50** marks].

This evidence needs to include:

AO1: records of your survey of **five** science-based organisations; an in-depth study of **one** of them, including information on health and safety issues [**19**];

AO2: information showing an understanding of the impact on society of your **one** chosen organisation, with evidence that you have completed relevant calculations *either* using provided data *or* on at least **one** practical procedure carried out [**10**];

AO3: evidence that you have completed safely **two** practical procedures and recorded, processed and evaluated the results [**21**].

How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will demonstrate you have carried out a survey on **five** science-based organisations with some information selected and presented; **[0 1 2]**	you will demonstrate a researched survey on **five** science-based organisations with the relevant information selected and clearly presented; **[3 4]**	you will demonstrate a thorough researched survey on **five** science-based organisations with evidence that relevant information has been selected from a range of sources and is clearly and logically presented. **[5 6]**	
	You will produce a study on **one** science-based organisation which shows some information has been selected and presented; **[0 1 2]**	you will produce a researched study based on **one** science-based organisation with relevant information selected and clearly and logically presented; **[3 4 5]**	you will produce a thorough researched in-depth study on **one** science-based organisation, with evidence that relevant information has been selected from a range of sources and is clearly and logically presented with accurate use of grammar; you will include some evaluation and justification of the material used. **[6 7]**	
	You will demonstrate a basic knowledge and understanding of health and safety laws and regulations; **[0 1 2]**	you will demonstrate knowledge and understanding of the appropriate health and safety laws and regulations; there will be few omissions or inaccuracies; **[3 4]**	you will demonstrate a comprehensive knowledge and understanding of health and safety laws and regulations with information on how organisations comply with the legislation. **[5 6]**	**/19**

Unit 1: Science at work (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	You will include some understanding of the impact **one** organisation has on society; this lacks detail and includes some omissions; **[0 1 2]**	you will include a detailed and researched study of the impact of **one** organisation on society; the report will have few errors or omissions; **[3 4]**	you will produce a comprehensive and thoroughly researched study of the impact of **one** organisation on society focusing on all the issues stated. **[5 6]**	
	You will perform a number of straightforward calculations using provided data, or data obtained from **one** practical procedure, and generally obtain the correct solutions; **[0 1]**	you will perform a number of straightforward and complex calculations using provided data, or data obtained from at least **one** practical procedure, and generally obtain the correct solutions; **[2 3]**	you will perform a number of straightforward and complex calculations using researched data, or data obtained from at least **one** practical procedure, and obtain the correct solutions to an appropriate degree of accuracy. **[4]**	**/10**
AO3	You will record the completion of **two** practical tasks linked to a vocational context in which risk assessments have been used; **[0 1 2 3 4]**	you will record the confident completion of **two** practical tasks linked to a vocational context in which risk assessments have been developed and used, **[5 6]**	you will record the accurate completion of **two** practical tasks linked to a vocational context in which risk assessments have been produced with evidence that equipment has been used safely and to the appropriate degree of accuracy. **[7 8]**	
	You have made some relevant observations or measurements; **[0 1 2]**	you have made all relevant observations or measurements; **[3 4]**	you have made all relevant observations or measurements with the appropriate precision. **[5 6]**	
	You have suitably processed results, with some interpretation; **[0 1 2]**	you have accurately processed and interpreted some results; **[3 4 5]**	you have accurately processed and interpreted all results and evaluated where appropriate. **[6 7]**	**/21**
			Total mark awarded:	**/50**

SECTION D: OPPORTUNITIES FOR TEACHING

9 Spiritual, Moral, Ethical, Social and Cultural Issues

Applied Science offers a wide range of opportunities for the exploration of spiritual, moral, ethical, social and cultural issues.

For example*:*

- the importance to the community of organisations that use science is covered in detail in Unit 1*: Science at work*;
- the ethical and social issues connected with genetic engineering are integral to Unit 15: *Applications of biotechnology;*
- issues affecting society, which are often perceived as being of scientific origin, are explored in many units, e.g. pollution in Unit 14: *Ecology and managing the environment;*
- these specifications include many examples of the endeavour of scientists in applying their knowledge to the benefit of society, e.g. the use of new materials in Unit 11: *Materials for a purpose*;
- the culture of science-based learning is explored throughout these specifications, but in particular in Unit 8: *Investigating the scientist's work;*
- it is hoped that a sense of awe and wonder at the scale and impact of natural processes and phenomena is engendered by a study of these specifications.

Legal issues are addressed in each unit, where appropriate.

10 Citizenship

This section offers guidance on opportunities for delivering knowledge, skills and understanding of citizenship issues during the course.

By taking courses based on these specifications, candidates will develop their 'scientific literacy' such that they are able to make informed decisions as citizens about the issues of the day wherever they meet them – in the workplace, the media, the home etc.

For example:

- a study of the work of people in organisations that use science as part of Unit 1: *Science at work.*

11 Environmental Issues

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

For example:

- there are opportunities to study environmental issues in depth in Unit 14: *Ecology and managing the environment.*

12 The European Dimension

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

The application of science is a global activity. Many science-based industries are multi-national, operating from bases across Europe and other parts of the world. European health and safety legislation and regulations concerning environmental issues affect the work of scientists.

Teachers are expected to take appropriate opportunities to consider issues in the European context.

13 Health and Safety

Candidates are introduced to health and safety issues in the context of this sector and should be made aware of the significance of safe working practices.

For example:

- the importance of health and safety in organisations that use science is integral to *Unit 1: Science at work;*
- the uses of therapeutic drugs and medicines are covered in Unit 10: *Synthesising organic compounds;*
- the use of imaging techniques in medical diagnosis is covered in Unit 16: *Working waves;*
- the use of genetic engineering in medicine is covered in Unit 15: *Applications of biotechnology.*

14 Key Skills

These specifications provide opportunities for the development of the Key Skills of *Communication* (C), *Application of Number* (AoN), *Information and Communication Technology* (ICT), *Working with Others* (WwO), *Improving Own Learning and Performance* (IoLP) and/or *Problem Solving* (PS) as indicated in the table below. Please note that this table includes only the *main opportunities* in those units which are portfolio assessed. Further guidance on Key Skills opportunities is given in the Teachers' Guide accompanying these specifications.

Unit	**C2**				**C3**				**AoN2**			**AoN3**			**ICT2**			**ICT3**			**WwO2**			**WwO3**			**IoLP2**			**IoLP3**			**PS2**			**PS3**			**Unit**
	.1a	**.1b**	**.2**	**.3**	**.1a**	**.1b**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	
1				P				P	P	P	P	P	P	P	P	P	P				P	P	P																**1**
2				P				P	P	P	P	P	P	P	P	P	P										P	P	P	F	F	F							**2**
5				P				P	P	P	P	P	P	P	P	P	P										P	P	P	F	F	F							**5**
6	F			P				P	P	P	P	P	P	P	P	P	P	P	P	P							P	P	P	F	F	F							**6**
7				P				P	P	P	P	P	P	P	P	P	P	P	P	P																			**7**
8				P				P	P	P	P	P	P	P	P	P	P	P	P	P													P	P	P	F	F	F	**8**
10				P				P	P	P	P	P	P	P	P	P	P													F	F	F							**10**
11				P				P	F	F	F	F	F	F	P	P	P																						**11**
12			F				F		P	P	P	P	P	P	P	P	P																						**12**
13		F				F		F	P	P	P				P	P	P										P	P	P	F	F	F							**13**
14									P	P	P				P		P										P	P	P	F	F	F							**14**
15			F	P			F	P	P	P	P	P	P	P	P	P	P																P	P	P	F	F	F	**15**
Unit	**.1a**	**.1b**	**.2**	**.3**	**.1a**	**.1b**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**.1**	**.2**	**.3**	**Unit**
	C2				**C3**				**AoN2**			**AoN3**			**ICT2**			**ICT3**			**WwO2**			**WwO3**			**IoLP2**			**IoLP3**			**PS2**			**PS3**			

F: full coverage of that criterion of the key skill possible;

P: partial coverage of that criterion of the key skill possible.

Working with Others (WwO) opportunities may exist in units where extensive practical work is undertaken and is a key part of the assessment.

15 Generic Resources

Please see Part B of this specification for specific unit resources.

16 Further Information and Training for Teachers

To support teachers using this specification, OCR will make the following materials and services available:

- a full programme of In-Service Training (INSET) meetings arranged by its Training and Customer Support Division (tel. 01223 552950);
- a website that will include materials to assist with delivery (www.ocr.org.uk);
- an e-list for teachers to share good practice/resources and to ask/answer questions and generally make contact with colleagues delivering these qualifications – to join, simply go to http://community.ocr.org.uk/lists/listinfo/gceappliedscience;
- teacher support material;
- exemplar candidate work;
- specimen assessments;
- past external examinations;
- a report on the examination, compiled by senior examining personnel after each examination session;
- individual feedback to each centre on the moderation of portfolios;
- a portfolio consultancy service.

The Learning and Skills Development Agency, LSDA, has a website (www.vocationallearning.org.uk) with a variety of subject-specific resources and information in their teachers' section, as well as more general material about planning/teaching vocational courses.

17 Contacting OCR

Many straightforward enquiries may be resolved by visiting the OCR website (www.ocr.org.uk). The website contains copies of the specification, example assessments, support materials and current information of relevance to centres.

General administrative enquiries should be made to the OCR Information Bureau:
tel. 01223 553998
e-mail: helpdesk@ocr.org.uk

The OCR Publications Catalogue may be obtained from OCR's publications department:
tel. 0870 870 6622
fax 0870 870 6621
e-mail: publications@ocr.org.uk

Appendix A: Performance Descriptions

The performance descriptions for GCE Applied Science aim to describe learning outcomes and levels of attainment likely to be shown by a representative candidate performing at the A/B and E/U boundaries for the AS and A2. They illustrate the expectations at these boundaries for the AS and A2 as a whole; they have not been written at specification or unit level. Each performance description is aligned to **one** assessment objective. An alphabetical system has been used to denote each element of a performance description. There is no hierarchy of elements.

Performance descriptions are designed to assist examiners in exercising their professional judgement at awarding meetings where the grade A/B and E/U boundaries will be set by examiners using professional judgement. This judgement will reflect the quality of the candidates' work, informed by the available technical and statistical evidence. Performance descriptions will be reviewed continually and updated where necessary.

Teachers may find performance descriptions useful in understanding candidates' performance across qualifications as a whole but should use the marking criteria identified in the specification when assessing candidates' work.

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3	Quality of Written Communication
Assessment Objectives for both AS GCE and Advanced GCE	Candidates demonstrate their knowledge and understanding by: • recognising and recalling facts, terminology, principles, concepts and practical techniques; • selecting, organising and presenting, clearly and logically, information either provided or acquired through systematic research.	Candidates apply their skills, knowledge and understanding in appropriate vocational contexts: • by describing, explaining, interpreting and evaluating information and the impact on society of the work of scientists, including beneficial effects and the need for constraints; • in carrying out relevant calculations.	Candidates: • carry out safely and skilfully practical tasks, making and recording observations and measurements with appropriate precision, processing them appropriately and communicating this information clearly and logically, e.g. in prose, tables and graphs; • plan, carry out and evaluate investigative work.	
AS A/B boundary Performance Descriptions	Candidates: • demonstrate their knowledge and understanding of science with few omissions; • use scientific terminology and conventions accurately in all their work; • select relevant information, present it clearly and logically, and then evaluate it.	Candidates: • describe, interpret and explain phenomena and effects using scientific principles; • apply scientific facts and principles to familiar and unfamiliar situations; • describe, interpret and evaluate quantitative and qualitative data; • identify and explain issues arising from scientific activities, which impact on society; • carry out straightforward calculations, obtaining correct solutions to an appropriate degree of accuracy.	In given practical tasks, candidates: • produce risk assessments, consistent with COSHH guidelines, and use them to carry out given tasks safely, using a range of techniques and equipment with an appropriate degree of accuracy; • make and record relevant observations and measurements with appropriate precision and process these accurately; • interpret their results and draw conclusions.	Candidates use written expression which: • conveys appropriate meaning; • uses appropriate specialist vocabulary.
AS E/U boundary Performance Descriptions	Candidates: • demonstrate some knowledge and understanding of science. There may be significant omissions; • use basic scientific terminology and conventions in their work; • select and clearly present information.	Candidates: • describe phenomena and effects using scientific principles; • apply scientific facts and principles to familiar situations; • describe and give limited interpretation of quantitative and qualitative scientific data; • describe issues arising from scientific activities, which impact on society; • carry out straightforward calculations sometimes obtaining correct solutions.	In given practical tasks, candidates, with guidance: • use risk assessments and carry out given tasks safely using a range of techniques and equipment; • make and record relevant observations and measurements; • provide some interpretation of their results.	Candidates use written expression which: • is adequate to convey meaning; • may be expressed in a non-specialist way.

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3	Quality of Written Communication
Assessment Objectives for both AS GCE and Advanced GCE	Candidates demonstrate their knowledge and understanding by: • recognising and recalling facts, terminology, principles, concepts and practical techniques; • selecting, organising and presenting, clearly and logically, information either provided or acquired through systematic research.	Candidates apply their skills, knowledge and understanding in appropriate vocational contexts: • by describing, explaining, interpreting and evaluating information and the impact on society of the work of scientists, including beneficial effects and the need for constraints; • in carrying out relevant calculations.	Candidates: • carry out safely and skilfully practical tasks, making and recording observations and measurements with appropriate precision, processing them appropriately and communicating this information clearly and logically, e.g. in prose, tables and graphs; • plan, carry out and evaluate investigative work.	
A2 A/B boundary Performance Descriptions	Candidates: • demonstrate their knowledge and understanding of science from most parts of the specification; • use scientific terminology and conventions accurately in all their work; • select relevant information, present it clearly and logically, and then evaluate and justify it.	Candidates: • describe, interpret and explain phenomena and effects using scientific principles; • apply scientific facts and principles to familiar and unfamiliar situations; • describe, interpret and evaluate quantitative and qualitative data; • identify and explain issues arising from scientific activities, which impact on society; • carry out complex calculations, obtaining correct solutions to an appropriate degree of accuracy.	In all practical tasks, candidates: • produce risk assessments, consistent with COSHH guidelines, and use them to carry out their tasks safely, using a range of techniques and equipment with an appropriate degree of accuracy; • make and record relevant observations and measurements with appropriate precision and process these accurately; • interpret their results and draw conclusions, discussing their significance. In the synoptic investigation, candidates also: • independently make a realistic and achievable plan for an investigation, linked to other areas of the AS GCE/Advanced GCE specification; • critically evaluate their investigation, incorporating amendments into the plan where appropriate; • produce a logical and well-structured report of their investigation, showing detailed scientific understanding of their work.	Candidates use written expression which: • conveys appropriate meaning; • uses appropriate specialist vocabulary.

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3	Quality of Written Communication
Assessment Objectives for both AS GCE and Advanced GCE	Candidates demonstrate their knowledge and understanding by: • recognising and recalling facts, terminology, principles, concepts and practical techniques; • selecting, organising and presenting, clearly and logically, information either provided or acquired through systematic research.	Candidates apply their skills, knowledge and understanding in appropriate vocational contexts: • by describing, explaining, interpreting and evaluating information and the impact on society of the work of scientists, including beneficial effects and the need for constraints; • in carrying out relevant calculations.	Candidates: • carry out safely and skilfully practical tasks, making and recording observations and measurements with appropriate precision, processing them appropriately and communicating this information clearly and logically, e.g. in prose, tables and graphs; • plan, carry out and evaluate investigative work.	
A2 E/U boundary Performance Descriptions	Candidates: • demonstrate some knowledge and understanding of science. There may be significant omissions; • use some scientific terminology and conventions in their work; • select and clearly present information.	Candidates: • describe phenomena and effects using scientific principles; • apply scientific facts and principles to familiar situations; • describe and give limited interpretation of quantitative and qualitative scientific data; • describe issues arising from scientific activities, which impact on society; • carry out straightforward calculations, generally obtaining correct solutions.	In all practical tasks, candidates: • use risk assessments to carry out their tasks safely, using a range of techniques and equipment; • make and record relevant observations and measurements; • provide, with guidance, some interpretation of their results in terms of their scientific knowledge and understanding. In the synoptic investigation, candidates also: • make a plan for an investigation, linked to other areas of the AS GCE/Advanced GCE specification; • make an appropriate evaluation of the investigation; • produce a clear and accurate report of their investigation.	Candidates use written expression which: • is adequate to convey meaning; • may be expressed in a non-specialist way.

Appendix B: Mathematical Requirements

This appendix provides general guidance on the range of mathematical skills that candidates may be expected to use during a course in GCE Applied Science. Candidates need to demonstrate these skills, where appropriate, in their portfolio work for internally-assessed units, and questions in the written papers for externally-assessed units may require their use.

In addition to these general skills, specific mathematical requirements for individual units, e.g. the use of statistical techniques, or particular formulae or equations, are given in the units themselves and will form part of the assessment of these units.

ARITHMETIC AND COMPUTATION

Candidates should be able to:

- recognise and use expressions in decimal and standard form;
- use ratios, fractions and percentages;
- make estimates of the results of calculations (without using a calculator);
- use calculators to find and use x^2, $\frac{1}{x}$, $\sqrt{x}$.

HANDLING DATA

Candidates should be able to:

- use an appropriate number of significant figures;
- find arithmetic means;
- construct and interpret bar charts, pie charts and histograms.

ALGEBRA

Candidates should be able to:

- understand and use the following symbols: $<$, $>$, $\approx$, $\propto$;
- understand use the prefixes: giga (G), mega (M), kilo (k), milli (m), micro (μ), nano (n);
- change the subject of an equation;
- substitute numerical values into algebraic equations using appropriate units for physical quantities.

GRAPHS

Candidates should be able to:

- translate information between graphical, numerical and algebraic forms;
- plot and interpret graphs of two variables from experimental or other data.

CALCULATIONS

There are references in the *Assessment Evidence Grids* to ‘straightforward’ and ‘complex’ calculations.

Straightforward calculations

Generally these have **one** or **two** steps, for example:

- percentages;
- percentage increases;
- mean;
- mode;
- range;
- calculations involving 1:1 ratios (volumetric analysis);
- simple substitution into straightforward equations without rearrangement, e.g. $F = ma$ to find F;
- gradients of straight-line graphs.

Complex calculations

Generally these have **two** or more steps, for example:

- percentages;
- percentage increases;
- mean;
- mode;
- calculations involving ratios more complex than 1:1 ratios, e.g. 1:2, 2:5;
- statistical analysis, e.g. chi-squared or t-test, calculation of standard deviation;
- substitution into equations with rearrangement or use of powers or standard form (giving answers to appropriate numbers of significant figures);
- gradients of curves (tangents) and use of gradients in equations of the form $y = mx + c$.

PART B: UNIT SPECIFICATIONS

Part B Contents

STRUCTURE OF UNITS

Units will have some or all of the following sections:

About this unit This includes a brief description of the content, purpose and vocational relevance of the unit.
It states whether the unit is assessed externally or through portfolio evidence.

What you need to learn This specifies the underpinning knowledge, skills and understanding you need to apply in order to meet the requirements of the portfolio evidence or external assessment.

Assessment evidence This specifies the evidence you need to produce in order to meet the requirements of each portfolio unit. It is divided into the following parts:

- *You need to produce* – this banner heading sets the context for providing the evidence, e.g. a report, an investigation, etc;
- *Evidence Descriptors* – these describe the qualities of the work which will achieve each mark range specified.

Guidance for teachers This provides advice **to teachers** on teaching and assessment strategies.

There is advice on:

- the provision of the *vocational* context of the unit;
- accurate and consistent interpretation of the national standards;
- the use of appropriate internal assessments, taking into account the full range of grades to be covered.

There may also be advice on:

- exploiting local opportunities (e.g. information sources, events, work experience);
- resources.

1 Unit 1: Science at Work
[AS level, mandatory, internally assessed]

1.1 ABOUT THIS UNIT

This AS level unit is mandatory and is internally assessed.

Scientific research, development and production bring major benefits to improving health care, raising the standard of living and contributing to almost every aspect of daily life. There is a growing awareness of the fragility of the world in which we live, due to pollution, global warming and ozone depletion of the upper atmosphere. Having accepted the benefits of industrial activity, many companies now embrace the need to consider sustainability and environmental impact as part of their long-term development.

In addition to environmental factors, any scientific activity needs to take into account the health and safety of its employees and of the community surrounding it. Industry and governments have long recognised the potential dangers involved in the running of organisations, and there are detailed and comprehensive regulations which cover the raw materials, products, the work and the staff.

This unit will give you the opportunity to investigate the importance of science, and the people involved, in a wide range of organisations. You will have the opportunity to investigate the science really used, the type of work actually carried out and to carry out some standard procedures.

The work in this unit extends knowledge and skills covered in GCSE Applied Science and/or GCSE Science.

This unit links to all other units in this qualification. It also links with other GCEs, including Applied Business and Health and Social Care. It can also complement AS units in GCE Chemistry, Biology, Physics and Geography.

This unit will help you to prepare for higher education courses in science or for science-related NVQs or for work in science-related occupations.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will produce a research portfolio related to information on organisations that use science. Your evidence will include:

- records of your survey of **five** science-based organisations, an in-depth study of **one** of them and information on health and safety issues;
- information showing an understanding of the impact on society of your **one** chosen organisation, with evidence that you have completed relevant calculations *either* using provided data *or* on at least **one** practical procedure carried out;
- evidence that you have completed safely **two** practical procedures and recorded, processed and evaluated the results.

1.2 WHAT YOU NEED TO LEARN

You need to learn about:

- the importance of health and safety;
- organisations using science;
- science and the community;
- practical techniques and procedures.

1.2.1 The Importance of Health and Safety

Health and safety regulations protect both people who work in an organisation, and people who may be affected by the products or services of the organisation. Regulations, which can be enforced by law, govern the working environment, the processes used and the products made. For individuals working in an organisation, the most important aspect of health and safety is understanding the requirements of the regulation.

The relevant laws and regulations related to health and safety in the workplace include:

- Health and Safety at Work Act, 1974;
- Management of Health and Safety at Work Regulations, 1999;
- Provision and Use of Work Equipment Regulations, 1998;
- Hazard and Critical Control Points as part of the Food Safety Act, 1990;
- Control of Substances Hazardous to Health, 2002;
- Codes of Practices and Recommendations Used in Education (CLEAPSS).

Anything that can cause harm if things go wrong is called a *hazard*. The chance (big or small) of harm actually being done is called a *risk*. Managers make regulations specifically for an individual organisation, based on the knowledge of hazards involved and an assessment of the risks associated with them. Scientific workers need to be able to complete a risk assessment, know the correct action to take to reduce the chance of accidents, and know what to do if an accident does happen.

Throughout the unit, you need to demonstrate a knowledge of:

- the relevant laws and regulations used by organisations (college, school or place of work);
- how these regulations are monitored;
- the hazards that are involved;
- risk assessments that are completed.

1.2.2 Organisations Using Science

Organisations that use science can be either those that manufacture or process products for sale, or those that provide a service.

Production organisations might include those which produce:

- items from plants or from animals, e.g. foods, leather, flowers and plants themselves;
- items from micro-organisms, e.g. beer, wine, dairy foods;
- items from natural raw materials, e.g. ceramics, glass, paper, cement, building materials;
- chemicals and items derived from chemicals, e.g. fertilisers, paints, dyes, plastics, pharmaceuticals;
- mechanical, electrical or electronic devices, e.g. telephones, computer technology, flat screen TV, liquid crystals;
- items used for packaging.

Other production organisations produce materials by:

- extracting or refining resources, e.g. water, gas, oil, coal, gravel, clay;
- generating energy resources, e.g. gas, electricity, nuclear.

Service organisations might include the provision of:

- health care, e.g. hospitals, dentists, opticians;
- health and fitness centres, e.g. gyms, leisure facilities, swimming pools;
- education in science and technology, e.g. in schools, colleges, universities;
- public services, e.g. fire service, police, environmental health, transport, water;
- animal care and welfare, e.g. veterinary surgeries, zoos;
- communications, e.g. TV, radio, mobile phones, satellites, printing and publishing;
- energy, e.g. gas, electricity, nuclear.

Organisations which manufacture or process products may have used scientists in the research and development stages, but the people who produce the products do not need to be scientists, e.g. production workers in the ceramics industry or in a brewery. Sometimes, however, the processes used require scientifically-qualified people to carry them out, e.g. in hospitals, scientifically-qualified staff are needed in improving health care.

You need to demonstrate your research skills by surveying **five** organisations which involve science. Your survey needs to include both production and service providers.

For each organisation you survey, you need to:

- state the products made or the service offered;
- describe the type of work that takes place;
- identify the science that is involved;
- state any legal/health and safety constraints on the organisation.

You need to study **one** of these organisations in depth and:

- explain the nature of the work done, i.e. details of what is produced or the service provision;
- give the number of people employed and the range of staff that are employed;
- focus on the roles, responsibilities, skills and qualifications of the scientifically-qualified staff and how these staff are used within the organisation;
- discuss the science involved in the daily running of the organisation, in any services or products used or made, and its importance;
- describe how the work is supported, e.g. research, quality control, training, use of ICT;
- describe the relevant health and safety laws and regulations used by the organisation and how they are monitored.

1.2.3 Science and the Community

Science is involved in all aspects of our lives, and the organisations that use science impact on the environment and the community. In general, people do not have the background knowledge which would enable them to make balanced judgements regarding the global effects of new research and technology. However, organisations are still required to manage their impact on both the community and the environment.

Applications of scientific knowledge can be detrimental as well as beneficial. We are often faced with a bewildering amount of data relating to issues that concern us, such as synthetic drugs, food additives, genetic engineering, irradiation of food etc., which often leads to disagreement between scientists over the benefits of science.

The impact of an organisation on society is important; your in-depth study needs to include how the organisation you have chosen:

- contributes to the economy;
- manages its waste materials;
- uses ICT in data management;
- controls energy consumption;
- makes demands on transport and communication systems;
- effects on the community and the environment;
- impacts in terms of employment;
- manages relevant costs (if available);
- benefits our society (include local, national and global if possible).

1.2.4 Practical Techniques and Procedures

Scientific knowledge and skills may be applied in many different ways within organisations, e.g. many people are involved with science to support education, whereas others could be analytical scientists, or involved in research. It is, however, extremely important that standard procedures are followed and health and safety guidelines are enforced.

You need to demonstrate your practical skills by performing **two** procedures that relate to production or service organisations involved with science.

For these tasks you need to:

- identify hazards and carry out a risk assessment;
- follow set procedures;
- make and record any observations or measurements;
- process and evaluate the results;
- carry out any relevant calculations;
- present information clearly and logically.

1.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 1: Science at work				
What you need to do:				
You need to produce a research portfolio related to information on organisations that use science [**50** marks]. This evidence needs to include: **AO1:** records of your survey of **five** science-based organisations; an in-depth study of **one** of them, including information on health and safety issues [**19**]; **AO2:** information showing an understanding of the impact on society of your **one** chosen organisation, with evidence that you have completed relevant calculations *either* using provided data *or* on at least **one** practical procedure carried out [**10**]; **AO3:** evidence that you have completed safely **two** practical procedures and recorded, processed and evaluated the results [**21**].				
How you will be assessed:				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO1	You will demonstrate you have carried out a survey on **five** science-based organisations with some information selected and presented; **[0 1 2]**	you will demonstrate a researched survey on **five** science-based organisations with the relevant information selected and clearly presented; **[3 4]**	you will demonstrate a thorough researched survey on **five** science-based organisations with evidence that relevant information has been selected from a range of sources and is clearly and logically presented. **[5 6]**	
	You will produce a study on **one** science-based organisation which shows some information has been selected and presented; **[0 1 2]**	you will produce a researched study based on **one** science-based organisation with relevant information selected and clearly and logically presented; **[3 4 5]**	you will produce a thorough researched in-depth study on **one** science-based organisation, with evidence that relevant information has been selected from a range of sources and is clearly and logically presented with accurate use of grammar; you will include some evaluation and justification of the material used. **[6 7]**	
	You will demonstrate a basic knowledge and understanding of health and safety laws and regulations; **[0 1 2]**	you will demonstrate knowledge and understanding of the appropriate health and safety laws and regulations; there will be few omissions or inaccuracies; **[3 4]**	you will demonstrate a comprehensive knowledge and understanding of health and safety laws and regulations with information on how organisations comply with the legislation. **[5 6]**	**/19**

Unit 1: Science at work (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	You will include some understanding of the impact **one** organisation has on society; this lacks detail and includes some omissions; **[0 1 2]**	you will include a detailed and researched study of the impact of **one** organisation on society; the report will have few errors or omissions; **[3 4]**	you will produce a comprehensive and thoroughly researched study of the impact of **one** organisation on society focusing on all the issues stated. **[5 6]**	
	You will perform a number of straightforward calculations using provided data, or data obtained from **one** practical procedure, and generally obtain the correct solutions; **[0 1]**	you will perform a number of straightforward and complex calculations using provided data, or data obtained from at least **one** practical procedure, and generally obtain the correct solutions; **[2 3]**	you will perform a number of straightforward and complex calculations using researched data, or data obtained from at least **one** practical procedure, and obtain the correct solutions to an appropriate degree of accuracy. **[4]**	**/10**
AO3	You will record the completion of **two** practical tasks linked to a vocational context in which risk assessments have been used; **[0 1 2 3 4]**	you will record the confident completion of **two** practical tasks linked to a vocational context in which risk assessments have been developed and used; **[5 6]**	you will record the accurate completion of **two** practical tasks linked to a vocational context in which risk assessments have been produced with evidence that equipment has been used safely and to the appropriate degree of accuracy. **[7 8]**	
	You have made some relevant observations or measurements; **[0 1 2]**	you have made all relevant observations or measurements; **[3 4]**	you have made all relevant observations or measurements with the appropriate precision. **[5 6]**	
	You have suitably processed results, with some interpretation; **[0 1 2]**	you have accurately processed and interpreted some results; **[3 4 5]**	you have accurately processed and interpreted all results and evaluated where appropriate. **[6 7]**	**/21**
			Total mark awarded:	**/50**

1.4 GUIDANCE FOR TEACHERS

1.4.1 Guidance on Delivery

The intention is that this unit will provide candidates with an introduction to the importance of how science impacts on the society in which they live. It has been designed to focus on important aspects of science used in the work place. Sub-section 1.2.2 (Organisations using science) will allow candidates the opportunity to find out more about the organisations that employ scientists, and the involvement of science in these organisations, to enable them to understand the significance of the work they are studying. The success of parts of this unit will depend upon the availability of (potentially sensitive) data from organisations. If candidates find difficulty in obtaining suitable information, case-study material can be used. This unit should also help candidates see the relationship between what they learn, and what they may experience in a working environment. The importance of health and safety, both in a working and educational environment is introduced to support both the practical work and the way in which organisations may impact upon society and the environment. Finally, this leads onto Sub-section 1.2.3 (Science and the community).

Sub-section 1.2.4 (Practical techniques and procedures) gives candidates the opportunity to carry out experimental work within a vocational context, which hopefully will relate to the work in the organisations they are researching. This practical work also gives an opportunity to put into practice risk assessment and some of the health and safety laws and regulations they have researched. In some circumstances, it may be difficult to transfer practical procedures from industry to the classroom. In these cases, it would be advisable to have some practicals available, pitched to the ability of candidates. The use of ICT plays an important role in practical procedures and, hopefully, candidates will be able to incorporate the use of dataloggers, or appropriate software packages, into their practical work.

Examples of some experimental work might be:

- titrations for acid/base calculations;
- testing quality of products (quality assurance);
- biological action of enzymes;
- food testing procedures;
- material testing techniques;
- microscopy;
- opthalmic work.

This unit does offer the opportunity to introduce a period of appropriate work experience, if so required. This will then allow candidates to draw on their own experiences, to find out about individual organisations, and to illustrate and display knowledge and understanding that they obtained during their involvement in their individual research.

1.4.2 Guidance on Assessment

Candidates need to carry out research for this unit; they need to be taught how to find and select the relevant correct information and be aware of the various types of material available. Candidates need to demonstrate analysis and evaluation and will need to be taught these skills if they are to achieve the higher marks.

Regular, early and constructive feedback to candidates on their performance is essential and crucial. Help with planning and structuring their portfolio work in a logical manner throughout the course will lead to better understanding of their work and is likely to achieve higher marks.

Giving candidates deadlines for the completion of the various sections of their work and encouraging them to adhere to them, is also essential if candidates are not going to rush to complete and possibly finish up with marks below their potential.

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 1.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at AS level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• Candidates produce a leaflet, information package or basic information on a survey carried out for **five** science-based organisations; • examples of the types of organisations to be covered are listed in Sub-section 1.2.2 (Organisations using science); in the **five** organisations, candidates include at least **one** of each type (service provider and production); • the information includes basic information on all the bullet points listed in the specification – some omissions are acceptable for this level – each candidate completes his/her own piece of assessment evidence but the research work can be a team effort; evidence of how material was selected is shown; • candidates carry out an in-depth study of **one** chosen organisation to include bullet points in the final part of Sub-section 1.2.2 (Organisations using science); some omissions are acceptable for this level; • candidates learn about the importance of health and safety in the work place and in the laboratory and select provided information on health and safety laws and regulations and relate these to their survey and the in-depth study of **one** organisation; work is also done on risk assessments and links made to both the workplace situations and laboratory practical work; • at this level a basic coverage of the health and safety laws and regulations listed in Sub-section 1.2.1 (The importance of health and safety) – could alternatively be answers to questions from worksheet(s) or a basic report, summary or leaflet (in addition, basic information on risks, hazards and risk assessments are included); • some scientific terminology has been used and candidates should have attempted some individual research; they also select and present information;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	**2**	• candidates produce a leaflet, information package or information on a researched survey carried out for **five** science-based organisations; • evidence shows relevant information has been selected and work is clearly presented; • examples of the types of organisations to be covered are listed in Sub-section 1.2.2 (Organisations using science) – the information includes some detailed information on all the bullet points listed in the specifications for the **five** organisations; candidates include at least **one** of each type (service provider and production); • although the visits show teamwork, each candidate completes his/her own piece of assessment evidence and shows evidence of individual research; • candidates carry out a detailed case study of **one** chosen organisation to include all bullet points in the final part of Sub-section 1.2.2 (Organisations using science); information presented shows competent use of researched information; • candidates present work which shows a detailed understanding of the health and safety laws and regulations listed in Sub-section 1.2.1 (The importance of health and safety) – information is appropriately linked to the survey and their in-depth study; • in addition, information on the risks, hazards and risk assessments shows links to an industrial/service provider and to laboratory work (as detailed in the specifications); • this evidence has few omissions or inaccuracies, though some areas may not be as extensively covered as others; • scientific terminology has been used and they have individually researched, selected and presented information;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	**3**	• candidates produce a leaflet, information package or detailed information on a thoroughly researched survey carried out for **five** science-based organisations; • evidence shows that a variety of sources have been used and relevant information has been selected and work is clearly and logically presented – examples of the types of organisations to be covered are listed in Sub-section 1.2.2 (Organisations using science) – the information includes detailed and logical information on all the bullet points listed in the specifications for **five** organisations; • although the visits can still show teamwork, each candidate completes his/her own piece of assessment evidence and shows evidence of individual and thorough research with some evaluation and justification; • candidates carry out a comprehensive and thoroughly researched case study of a chosen organisation to include all bullet points in the final part of Sub-section 1.2.2 (Organisations using science); • candidates show a comprehensive knowledge and understanding of the health and safety laws and regulations listed in Sub-section 1.2.1 (The importance of health and safety) – work shows how the health and safety information is linked to organisation(s) and how they comply with the legislation; • in addition, candidates include detailed information on risks, hazards and how risk assessments are implemented and linked to legislation, in the appropriate organisation; • this evidence shows a clear indication of systematic research, clear and logical presentation of work and correct and accurate use of scientific terminology and accurate use of grammar; • there is adequate evaluation and justification of the research used.
AO2	**1**	• Candidates describe, within their report, the impact on society of their **one** chosen organisation – information to be included is listed in Sub-section 1.2.3 (Science and the community) – not all aspects or details are covered; • research work which describes, and shows some understanding of, the impact on society of their **one** chosen organisation; • information lacks detail, with some omissions; • in addition, evidence to show competence in completion of some *straightforward* calculations (see Appendix B) – this can be in the form of set worksheets, appropriately linked to work studied, or calculations based on results from **one** practical carried out by the candidate; • explanations may be simplistic or contain some inaccuracies, the evidence may not be well structured or logical in presentation; • there is evidence that a number of straightforward calculations have been completed, generally obtaining the correct solutions;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	2	• candidates identify and describe, within their report, the impact on society of their **one** chosen organisation – information to be included is listed in Sub-section 1.2.3 (Science and the community) – most aspects or details are covered; • research work which describes, and shows understanding of, the impact on society of their **one** chosen organisation; • in addition, evidence to show competence in the successful completion of a number of *straightforward* and *complex* calculations (see Appendix B) – this can be in the form of worksheets, appropriately linked to work studied; calculations based on results obtained from at least **one** practical carried out by the candidate; • the explanations are clear and there are few or no inaccuracies; • there is evidence of logical presentation and structure to the work; • there is evidence that a number of straightforward calculations have been completed obtaining the correct solutions;
	3	• candidates identify and explain, within their report, the impact on society of their **one** chosen organisation – information to be included is listed in Sub-section 1.2.3 (Science and the community) – all aspects and details are covered; • work presented is comprehensive and thoroughly researched and includes all bullet points in Sub-section 1.2.3 (Science and the community); • in addition, evidence to show competence in the successful completion to the appropriate degree of accuracy of a range of calculations (more complex calculations are included – not an increase in the number from mark bands 1 and 2) – this can be in the form of worksheets or using results of their practical work; • the material is well organised and information is presented in clear, logical form, there are inaccuracies; • evidence that a range of calculations have been completed to the appropriate degree of accuracy, obtaining the correct solutions.
AO3	1	• A record of the safe completion of **two** practical tasks, which includes coverage of most of the bullet points from Sub-section 1.2.4 (Practical techniques and procedures) – **one** can be a basic set practical exercise with some link to a vocational context, with direct instructions on what to do, and the second with less guidance and a possible link to the research work the candidate has completed; • in both practical tasks, candidates have used risk assessments, followed given instructions and used given equipment; • candidates have, with guidance, made and recorded relevant observations and/or measurements, processed some results and provided some interpretation of their results;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	2	• a record of the safe completion of **two** different types of practical tasks, which includes detailed coverage of all the bullet points from Sub-section 1.2.4 (Practical techniques and procedures) for both practical tasks – **one** can be a set practical exercise with some link to a vocational context and the second linked to the research work the candidate has completed; • in both practical tasks, candidates have developed and used risk assessments and a range of techniques and equipment; • they have made and recorded relevant observations and/or measurements and processed them accurately; • they have interpreted the results, drawn any conclusions and discussed their significance, where appropriate;
	3	• a record of the safe completion of at least **two** different types of practical tasks, which includes high quality coverage of all the bullet points from Sub-section 1.2.4 (Practical techniques and procedures) for both practical tasks – **one** can be a set practical exercise linked to a vocational context, the second linked to the research work the candidate has completed; • in both practical tasks, candidates have produced and used risk assessments and a range of techniques and equipment to the appropriate degree of accuracy; • they have made and recorded all relevant observations and/or measurements to the appropriate precision and processed them accurately; • they have interpreted the results, drawn conclusions and evaluated where appropriate.

1.4.3 Resources

Organisations and Websites	Department of Trade and Industry: 151 Buckingham Palace Road, London SW1W 9SS www.dti.gov.uk Health and Safety at Work: www.vts.rdn.ac.uk – gives information on a range of health and safety sites and how to use the Internet effectively; (free tutorial created by subject specialists from Universities and professional organisations) Health and Safety for TWITS: www.rboocock.freeserve.co.uk – good basic work on laws and regulations Natural Environment Research Council: Polaris House, North Star Ave., Wiltshire SN2 1EU www.nerc.ac.uk Office for National Statistics: 1 Drummond Gate, London SW1V 2QQ www.statistics.gov.uk Royal Society of Chemistry: Burlington House, Piccadilly, London W1V 0BN www.rsc.org Soap and Detergent Industry Association: 3/5 Clair Road, West Sussex RH16 3PP www.chemsoc.org
Publications	Connexions Service: www.connexions.gov.uk; leaflets from National Health Service; leaflets from main utilities – gas, water, electricity (available locally); it is advisable to form a collection of suitable leaflets, brochures etc., from careers areas at schools and colleges.
Textbooks	*GNVQ Science Advanced* Heinemann 043 563 2531 Gadd K & Holman J (eds) *Nuffield Science in Practice Advanced Science* Nelson 017 448 2353 *(Both books are based on old specifications, but content is still useful).*

2 Unit 2: Analysis at Work
[AS level, mandatory, internally assessed]

2.1 ABOUT THIS UNIT

*This AS level unit is mandatory and is internally assessed***.**

Whether your industry is a producer, or a service provider, there will always be a need for analysis and quality assessment to track efficiency and provide positive feedback for continued improvement and productivity. In a science-based industry, other forms of analysis may well be utilised for process monitoring and research and development.

Scientists are employed to analyse and identify all kinds of substances. These may be samples taken from the environment (air, water, rocks, soil), living organisms and from production processes in the laboratory or industrial manufacture. They also compare efficiencies of energy resources (consumable and renewable), research environmental impact, and control energy transfers within their processes.

In recent years, the uses of ICT in the scientific industry have increased enormously. Most chemical analyses, both qualitative and quantitative, have a large measure of computer input. This includes applications in mass spectroscopy and in emission and absorption spectroscopy. Much use is made of computer library data in the identification of compounds and in the interpretation of spectra.

Computer control is an essential part of the complex electrical generating and transmission systems, both in this country and, increasingly, with other European countries.

By studying this unit, you will understand the principles of analytical techniques used in forensic, pathology and research laboratories, and also in the chemical and energy industries.

In this unit you need to:

- learn about chemical tests in qualitative analysis and their uses and limitations;
- learn about quantitative chemical analysis and its uses;
- study the principles of chromatography and its uses;
- explain the uses and limitations of qualitative and quantitative data; interpretation, explanation and evaluation of data;
- investigate energy changes in chemical reactions;
- study practical techniques and procedures, particularly risk assessments for hazardous procedures;
- learn about energy transfer and its applications;
- study the consequences of wasteful energy transfer and efficiency.

The work in this section extends knowledge and skills acquired in GCSE Science and Applied Science.

There are links between this section and AS and A2 units in GCE Geography, Chemistry and Physics. There are also links with Unit 1 : *Science at work*, Unit 5: *Chemicals for a purpose*, Unit 6: *Forensic science*, Unit 7: *Physics of sport* and Unit 12: *Electrons in action*.

The section will help you to prepare for higher education courses in physics, chemistry, environmental science, economics or geography, or for work relating to the energy industry, materials technology, forensic science, or analysis techniques. It could also prepare you for work in the materials industry, forensic science service or environmental protection services. It will also provide background for evaluating energy policies in all areas of work.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will produce a portfolio related to information on organisations that use science to analyse processes. Your evidence will include:

- relevant research, understanding and detail in a study of **one** organisation to produce a report for that organisation which considers their energy policy and includes considerations of their energy efficiency and environmental impact;
- an in-depth study of a chosen method of producing electricity – the study will include relevant calculations of the energy transfers involved and concise comparison of large-scale and small-scale generation;
- evidence that you have safely completed **four** practical analyses – **two** physical (**one** using colorimetry and **one** using chromatography) and **two** chemical (**one** qualitative and **one** quantitative) – each will be appropriately recorded, processed and evaluated.

2.2 WHAT YOU NEED TO LEARN

You need to learn about:

- qualitative chemical analysis;
- quantative chemical analysis;
- physical analysis;
- energy transfer;
- efficiency.

2.2.1 Qualitative Chemical Analysis

There are many molecules that may be identified using relatively simple chemical tests and/or by the use of infrared spectroscopy.

You need to:

- carry out chemical tests (including flame tests) to identify the following cations: iron II, iron III, copper, aluminium, sodium, potassium, calcium, zinc, ammonium;
- carry out chemical tests to identify the following anions: chloride, bromide, iodide, sulphate, nitrate, carbonate;
- carry out chemical tests to identify the following functional groups: >C=C<, $-CH_2OH$, -CHO, >C=O, -COOH;
- use infrared spectroscopy to identify the presence of the following functional groups: $-CH_2OH$, -CHO, -COOH;
- describe the chemical reactions that are involved in the tests listed above;
- identify uses of chemical tests in qualitative analysis and their limitations.

2.2.2 Quantitative Chemical Analysis

Titrations have been the `bread and butter` of quantitative analysis for a long time. They are still used extensively in environmental, industrial and research laboratories, e.g. the purity of aspirin samples is checked by volumetric analysis in pharmaceutical laboratories.

You need to know how to:

- describe, carry out and interpret the results of simple volumetric analyses;
- find the limits of detection of a volumetric analysis;
- prepare standard solutions;
- carry out a normal titration (acid-base, redox, complexometric);
- carry out the necessary calculations using balanced chemical equations and amounts of substance (moles).

2.2.3 Physical Analysis

Mixtures of compounds may be separated and the components identified using a technique called chromatography. This is a method of physically separating mixtures. Colorimetric analysis can be used to find the percentage of a particular metal in an alloy.

You need to:

- use chromatography to separate mixtures and identify their components;
- explain the basic principles of chromatographic separation (absorption and distribution), its uses and limitations;
- carry out chromatographic separations using thin layer chromatography and paper chromatography;
- describe gas-liquid chromatography and high performance gas-liquid chromatography and their applications in industry;
- interpret simple chromatograms;
- describe the principles of colorimetric analysis;
- use colorimetric analysis to find the percentage of a particular metal in an alloy.

You need to be able to demonstrate your practical skills by performing **four** different analyses, **two** physical and **two** chemical. Each analysis needs to be linked to an industry that employs such a technique.

In each of your reports, you need to:

- carry out a risk assessment;
- make and record any observations or measurements;
- process and evaluate the results;
- present information clearly and logically;
- clearly discuss the industry link with your analysis method.

2.2.4 Energy Transfer

In chemical reactions, energy can be transferred from molecule to molecule by the making and breaking of chemical bonds. **One** key area that depends on such energy releases is in the burning of fossil fuels. The rate of consumption of fossil fuels continues to rise. Their supply is limited and, despite discoveries of new resources under the ground, their prices will rise in future. The continuing expansion in fossil fuel use also correlates with continuing global climate change, with likely catastrophic consequences for future well-being of ourselves and our global environment.

You need to:

- use ideas of transfer of energy during breaking and making of chemical bonds between particles to explain why some chemical reactions are exothermic and some are endothermic;
- assess simple data on calorific values and fuel prices;
- describe how cycles of expansion and contraction of gases can be used to do work in systems such as power stations and car engines.

You need to write a report describing the different type of energy transfers that might be present in the process of generating electricity.

You need to:

- discuss the forms of energy transfer involved;
- do any calculations from data researched;
- include a comparison of relative benefits and problems of large-scale (large power station) and small-scale (small community use of wind or solar generation) electrical generation, based on quantitative information.

2.2.5 Efficiency

The efficiency of a system is an important measure as to how well energy is transformed from **one** form to another. The efficiency of burning fossil fuels is, therefore, of enormous immediate, and future, economic and environmental importance, due to their limited supply.

You need to:

- explain what is meant by the efficiency of a system;
- explain why actual efficiency will always be less than the theoretical maximum;
- explain the importance of temperature difference to the efficiency of energy transfer between simple systems;
- describe how combined heat and power systems make use of energy that would be otherwise uselessly dissipated;
- investigate steps that could be taken by a non-domestic consumer to maximise their efficiency of electrical supply.

You need to produce an energy efficiency report, on an organisation you have chosen to study. You need to use accurate nomenclature, terminology, and units.

Your report needs to include:

- information gathered from a specified non-domestic consumer stating their energy policy;
- a description of their energy efficiency policy;
- an assessment of the economic and environmental impacts of your chosen industry.

2.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 2: Analysis at work
What you need to do:
You need to produce a portfolio related to information on organisations that use science to analyse processes [**50** marks]. This evidence needs to include: **AO1** relevant research, understanding and detail in a study of **one** organisation to produce a report for that organisation which considers their energy policy and includes considerations of their energy efficiency and environmental impact [**19**]; **AO2** an in-depth study of a chosen method of producing electricity – the study needs to include relevant calculations of the energy transfers involved and concise comparison of large-scale and small-scale generation [**10**]; **AO3** evidence that you have safely completed **four** practical analyses – **two** physical (**one** using colorimetry and **one** using chromatography) and **two** chemical (**one** qualitative and **one** quantitative) – each needs to be appropriately recorded, processed and evaluated [**21**].
How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will show information obtained from a non-domestic consumer of energy and give a brief description of their energy policy; **[0 1 2]**	you will show selected information obtained from a non-domestic consumer of energy and give a description of their energy policy; **[3 4]**	you will show selected, relevant information obtained from a non-domestic consumer of energy and give a detailed description of their energy policy. **[5 6]**	
	You will show some indication that energy efficiency has been considered; **[0 1 2]**	you will show that energy efficiency has been considered in some detail; **[3 4]**	you will show that energy efficiency has been considered and evaluated in some detail, using accurate terminology and nomenclature. **[5 6]**	
	You will show that economic and environmental impacts have been considered; **[0 1 2]**	you will show that economic and environmental impacts have been considered in some detail; **[3 4 5]**	you will show that economic and environmental impacts have been considered in some detail, using accurate terminology and nomenclature. **[6 7]**	**/19**
AO2	You will show the forms of energy transfer involved in the generation of electricity, displaying information on calorific values and costs of different fuels; **[0 1]**	you will show the forms of energy transfer involved in the generation of electricity in detail, displaying information on calorific values and costs of different fuels; **[2 3]**	you will show a comprehensive study into the forms of energy transfer involved in the generation of electricity, displaying information on calorific values and costs of different fuels, both renewable and non-renewable. **[4 5]**	
	You will show a number of straightforward calculations using provided data on costs involved in the generation of electricity, generally obtaining the correct solutions; also, you have included a brief comparison of relative benefits and problems of large-scale and small-scale electrical generation; **[0 1]**	you will show a number of straightforward calculations using researched data on costs involved in the generation of electricity, generally obtaining the correct solutions; also, you have included a comparison of relative benefits and problems of large-scale and small-scale electrical generation, based on quantitative information; **[2 3]**	you will show a number of straightforward and complex calculations using researched data on costs involved in the generation of electricity, obtaining the correct solutions to an appropriate degree of accuracy; also, you have included a comparison and evaluation of relative benefits and problems of large-scale and small-scale electrical generation, based on quantitative information. **[4 5]**	**/10**

Unit 2: Analysis at work (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO3	You will produce a report of **two** physical analyses you have carried out, linked to a vocational context in which risk assessments have been used; relevant observations or measurements have been made and results suitably processed, with some interpretation; **[0 1 2 3 4]**	you will produce a detailed report of **two** physical analyses you have carried out, linked to a vocational context in which risk assessments have been completed; relevant observations or measurements have been made and results accurately processed and interpreted; the information is presented clearly and logically; **[5 6]**	you will produce a detailed report of **two** physical analyses you have carried out, linked to a vocational context in which risk assessments have been produced with evidence equipment has been used safely and to the appropriate degree of accuracy; relevant observations or measurements have been made with the appropriate precision and results accurately processed and interpreted; the information is presented clearly, logically and has been evaluated. **[7 8]**	
	You will produce a report of a qualitative chemical analysis you have carried out, linked to a vocational context in which risk assessments have been used; relevant observations have been made and results suitably processed, with some interpretation; **[0 1 2]**	you will produce a detailed report of a qualitative chemical analysis you have carried out, linked to a vocational context in which risk assessments have been completed; relevant observations have been made and results accurately processed and interpreted; the information is presented clearly and logically; **[3 4]**	you will produce a detailed report of a qualitative chemical analysis you have carried out, linked to a vocational context in which risk assessments have been produced with evidence equipment has been used safely and to the appropriate degree of accuracy; relevant observations have been made and results accurately processed and interpreted; the information is presented clearly, logically and has been evaluated. **[5 6]**	
	You will produce a report of a quantitative chemical analysis you have carried out, linked to a vocational context in which risk assessments have been used; relevant observations have been made and results suitably processed, with some interpretation; **[0 1 2]**	you will produce a detailed report of a quantitative chemical analysis you have carried out, linked to a vocational context in which risk assessments have been completed; relevant observations have been made and results processed and interpreted accurately; the information is presented clearly and logically; **[3 4 5]**	you will produce a detailed report of a quantitative chemical analysis you have carried out, linked to a vocational context in which risk assessments have been produced, with evidence that equipment has been used safely and to the appropriate degree of accuracy; relevant observations have been made and results processed and interpreted accurately; the information is presented clearly and logically and has been evaluated. **[6 7]**	**/21**
			Total mark awarded:	**/50**

2.4 GUIDANCE FOR TEACHERS

2.4.1 Guidance on Delivery

The intention is that this unit will provide candidates with an introduction to the importance of testing and analysis within many industries and work places. It begins by focusing on the more obvious methods of testing, and then considers the importance of analysing procedures for quality control and improving efficiency.

This unit should also help candidates learn how to do simple tests in the laboratory and to be able to link them to realistic testing methods within **one** of the industries they have been researching. From there, they can be led into less overt testing methods which relate to the monitoring of standards. Quality control is a major consideration for a lot of businesses and many will spend a lot of money to analyse their output.

Another expenditure might be considering ways in which to improve productivity or efficiency. When investigating efficiency, it should be natural for candidates to start discussing energy in terms of flow and changes, saving energy and the sources of energy. This helps link back to the environmental concepts of Unit 1: *Science at work*, and encourages them to look at how their industries are contributing to the global situation.

Throughout this unit, candidates need to be given the opportunity to carry out experimental work within a vocational context, which hopefully will relate to the work in the organisations they have researched. This practical work also gives an opportunity to put into practice risk assessment and some of the health and safety laws and regulations they have studied in Unit 1. It is suggested that a specific assessment session be provided for the purpose of the practical assessment AO3. Candidates then have the opportunity to try and learn about all the different tests before being tested. For more able candidates, you may wish to assess using ‘unknown’ substances for candidates to discover and draw conclusions from.

Qualitative analysis

This allows candidates to build on their skills, knowledge and understanding from GCSE Science or Applied Science with specific regard to simple test-tube reactions for the anions and cations listed.

Many of the cations can be identified by their reactions with aqueous sodium hydroxide and/or aqueous ammonia. Metal ions from Groups 1 and 2 can be identified by flame tests.

The usual test for the ammonium ion is to heat its aqueous solution with an alkali and to detect the ammonia gas evolved.

Qualitative tests for the anions are a continuation of GCSE work. It is recommended that an aqueous nitrate is identified by gently heating it with aluminium powder and aqueous sodium hydroxide and identifying the ammonia gas evolved. The traditional 'brown ring' test, with its use of concentrated sulphuric acid, is less safe for use by candidates.

A primary alcohol can be identified by the colour change which occurs when it is oxidised on warming with acidified potassium dichromate(VI) or potassium manganate(VII) solutions.

Aldehydes and ketones may be identified by the coloured precipitates given with the 2,4-dinitrophenylhydrazine reagent. A distinguishing test for an aldehyde might use Benedict's, Fehling's or Tollens' reagents.

Carboxylic acids can be identified using any of the characteristic reactions given by acids.

Centres may not have the use of an infrared spectrometer but primary alcohols, aldehydes and carboxylic acids can be identified by looking for the presence or absence of frequencies corresponding to the -OH and C=O groups and most text books of AS standard will give diagrams showing the required spectra.

Quantitative analysis

Candidates need to have experience of simple titrations that involve making and using standard solutions. They should have carried out straightforward acid-base, redox and complexometric titrations.

The titrations performed should have a vocational slant. Suggested exercises include finding the:

- concentration of commercial vinegars;
- % of iron in 'iron tablets';
- % of copper in brass samples;
- hardness of water using a solution of EDTA.

Physical analysis

Although candidates need to be aware of the applications of gas-liquid chromatography and HPLC in industry, it is expected that laboratory work will concentrate on separations using thin-layer and/or paper chromatography.

Suitable exercises might include the separation and identification of common analgesics using TLC and the separation of metal cations using paper chromatography. Exercises need to be linked to industrial needs as far as possible.

Candidates need to be aware of the principles behind colorimetry and to have tried a colorimetric procedure. This might be to find the percentage of copper in a sample of brass, or to determine the percentage of iron in samples of iron filings.

They need to be aware of the great importance of colorimetric techniques in industry and in hospital laboratories.

Details of these procedures may be found in books of qualitative and quantitative analysis, and the *Sigma* catalogue from the *Aldrich* company lists reagents and some details for aspects of colorimetry in hospital laboratories.

Candidates need to be aware that much of the routine analysis in industrial and medical laboratories is automated and computer-linked. This can be discussed when comparing industrial applications with their own analytical work.

Energy transfer

Candidates will be aware of exothermic and endothermic processes from previous work and this can be extended to show why the burning of fuels is a net exothermic process.

On heating, gases expand and this idea should be extended to describe how vehicle engines cause movement when hydrocarbon fuels are burnt. This theme should be developed on a larger scale so that candidates are aware that the burning of fossil fuels in power stations leads to the formation of steam and, finally, electricity. This latter feature forms part of the assessment for this unit and candidates should link this to the calorific value and outline costs of different fuels.

Candidates should be aware of small-scale electricity generation by renewable sources, e.g. by using wind or solar power, and be able to compare the benefits and problems of large- and small-scale generation in a simple quantitative way.

Efficiency

There is much interest in the efficiency of power-generation processes and candidates should be aware of the meaning of the term efficiency and realise that many electrical-generation processes are not highly efficient in terms of the useful energy produced.

It is of great interest to consumers to have their heat and power systems as efficient as possible.

Candidates need to produce a report from information gathered from a non-domestic consumer that outlines their energy policy and include some detail about how this consumer uses their energy as efficiently as possible.

It is not intended that this report should be very detailed; indeed many companies may be reluctant to provide specific, detailed information. Smaller companies and local educational establishments may be a useful source of information for this sub-section. If candidates find difficulty in obtaining this information, case study material can be used.

Many companies are, however, very willing to disclose information about the environmental impacts of their work and the impact the company has on the local economy, and this information should form part of the report outlined above.

2.4.2 Guidance on Assessment

Candidates need to carry out a great deal of research for this unit; they need to be taught how to find and select the relevant correct information and be aware of the various types of material available. Candidates need to demonstrate analysis and evaluation and will need to be taught these skills if they are to achieve the higher marks.

Giving candidates deadlines for the completion of the various sections of their work and encouraging them to adhere to them, is also essential if candidates are not going to rush to complete and possibly finish up with marks below their potential.

Regular, early and constructive feedback to candidates on their performance is essential and crucial. Help with planning and structuring their portfolio work in a logical manner throughout the course will lead to better understanding of their work and is likely to achieve higher marks.

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 2.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than **one** row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at AS level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• A brief report that gives information about a non-domestic consumer of energy and brief details of their energy policy; • the report includes brief comments about how the non-domestic consumer ensures that the efficient use of energy has been considered; • the report outlines how the non-domestic consumer has considered the economic and environmental impacts of their energy policy;
	2	• a report that gives information about a non-domestic consumer of energy and details of their energy policy; • the report includes comments about how the non-domestic consumer ensures that the efficient use of energy has been considered; • the report shows how the non-domestic consumer has considered the economic and environmental impacts of their energy policy;
	3	• a report that gives information about a non-domestic consumer of energy and a more detailed account of their energy policy; • the report includes more detailed comments about how the non-domestic consumer ensures that the efficient use of energy has been considered; • the report shows, in more detail, how the non-domestic consumer has considered the economic and environmental impacts of their energy policy.
AO2	**1**	• A report that shows the forms of energy involved in the generation of electricity and includes outline information on the calorific values and costs of different fuels; • some *straightforward* calculations that use provided data on the costs of generating electricity, with generally correct solutions; • a brief report that compares the relative benefits and problems of the generation of electricity on large- and small-scales;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	**2**	• a report, in more detail, that shows the forms of energy involved in the generation of electricity and includes information on the calorific values and costs of different fuels; • some *straightforward* calculations, using researched data, on the costs of generating electricity, with generally correct solutions; • a report, based on quantitative information, that compares the relative benefits and problems of the generation of electricity on large- and small-scales;
	3	• a comprehensive study into the forms of energy transfer involved in the generation of electricity that includes information on the calorific values of a variety of fuels, both renewable and non-renewable; • a number of *straightforward* and more *complex* calculations (see Appendix B), using researched data, on the costs of generating electricity, with correct solutions that are given to an appropriate degree of accuracy; • a detailed report, based on quantitative information, that compares and evaluates the relative problems and benefits of the generation of electricity on large- and small-scales.
AO3	**1**	• A report of a colorimetric analysis of a material that is linked to a vocational context – this includes a risk assessment, relevant observations and calculations – the results are processed with some interpretation; • a report of a chromatographic exercise that is linked to a vocational context – this includes a risk assessment, relevant observations and, where necessary, calculations – the results are processed with some interpretation; • a report of a qualitative chemical analysis carried out on a material that is linked to a vocational context – this includes a risk assessment, relevant observations and some interpretation; • a report of a quantitative chemical analysis carried out on a material that is linked to a vocational context – this includes a risk assessment, relevant observations and calculations – the results are processed with some interpretation;
	2	• a report of a colorimetric analysis of a material that is linked to a vocational context – this includes a more detailed risk assessment, relevant observations and calculations – the results are processed with an interpretation of the results and the information is presented clearly and logically; • a report of a chromatographic exercise that is linked to a vocational context – this includes a more detailed risk assessment, relevant observations and, where necessary, calculations – the results are accurately processed and interpreted and the information is presented clearly and logically; • a report of a qualitative chemical analysis carried out on a material that is linked to a vocational context – this includes a more detailed risk assessment, relevant observations and a detailed interpretation of the results, and the information is presented clearly and logically; • a report of a quantitative chemical analysis carried out on a material that is linked to a vocational context – this includes a more detailed risk assessment, relevant observations and more detailed calculations – the results are processed with detailed interpretations and the information is presented clearly and logically;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	**3**	• a detailed report of a colorimetric analysis of a material that is linked to a vocational context – this includes a detailed risk assessment, relevant observations and detailed calculations – the results are processed with a detailed interpretation of the results and evaluated, and the information is presented clearly and logically; • a report of a chromatographic exercise that is linked to a vocational context – this includes a detailed risk assessment, relevant observations and, where necessary, calculations – the results are processed with a detailed interpretation of the results and an evaluation, and the information is presented clearly and logically; • a report of a qualitative chemical analysis carried out on a material that is linked to a vocational context – this includes a detailed risk assessment, relevant observations and a detailed interpretation of the results and, where necessary, an evaluation – the information is presented clearly and logically. • a report of a quantitative chemical analysis carried out on a material that is linked to a vocational context – this includes a detailed risk assessment, relevant observations and detailed calculations carried out to the correct level of accuracy – the results are processed with a detailed interpretation and evaluated – the information is presented clearly and logically.

2.4.3 Resources

Organisations	The Centre for Alternative Technology Machynlleth Powys Mid Wales SY20 9AZ www.cat.org.uk Chemical Industry Education Centre York University York YO10 5DD www.uyseg.org/ciec_home.htm
Textbooks	Vogel — *Vogel's Textbook of Quantitative Chemical Analysis* — Longman — 058 244 693 7 *Modern Chemical Techniques* — The Royal Society of Chemistry — 187 034 319 0
Websites	Electrical generation and supply companies: www.powergen.co.uk www.scottishpower.co.uk www.swalec.co.uk www.southern-electric.co.uk www.sweb.co.uk The Institute of Physics www.iop.org The Royal Society of Chemistry www.rsc.org

3 Unit 3: Monitoring the Activity of the Human Body
[AS level, mandatory, externally assessed]

3.1 ABOUT THIS UNIT

This AS level unit is mandatory and is externally assessed

People working in the health care and related industries need to gather data and information about their clients, in order to give treatment, care and advice.

There are a lot of important techniques that are used to collect valid data and information about the functioning of the human body. This information is essential for the diagnosis and care of many disorders. Monitoring the activity of organs, and analysing samples of body tissue and fluids, can produce information about what is happening inside the human body. This section also introduces elementary ideas about image formation and digital imaging used in the medical context.

Data and information needs to be collected reliably. It also needs to be related to norms based on the expected performance of healthy bodies of the same age, gender and physical dimensions. These norms will have a variety of ranges of performance.

The work in this unit extends the knowledge and skills acquired in GCSE Science and Applied Science. It is supported by Unit 1: *Science at work*, Unit 4: *Cells and molecules*, Unit 6: *Forensic science* and Unit 7: *The physics of sport*, and complements Unit 16: *Working waves*.

This unit will help to prepare you for vocational or higher education courses that include work on human biology, health or sport science. It could also prepare you for work in the health or leisure areas, or in sports.

This unit is assessed through an external assessment. The mark on that assessment will be your mark for the unit.

3.2 WHAT YOU NEED TO LEARN

The chemical reactions that take place in every cell in the body are needed to sustain life. Many of these reactions require an input of energy. You need to learn how cells obtain energy from respiration, and how this process is linked to the activity of the body as a whole, and particularly the role the circulatory and respiratory systems play in the transfer of energy. You need to learn about some of the substances carried by the blood, and how the levels of these substances vary and are regulated.

You need to learn about:

- respiration in energy terms;
- structure and function of the circulatory and respiratory systems;
- uses of physiological measurements;
- methods of taking physiological measurements;
- imaging methods;
- regulations governing specific procedures and data management;
- ethical issues related to monitoring, diagnosis and treatment.

3.2.1 Respiration in Energy Terms

Respiration is the process by which every living cell obtains energy for its activities. This makes it a useful process to target when monitoring the general state and activity of the human body.

You need to:

- compare respiration and burning fuels;
- describe the circulatory and respiratory systems as part of the respiration process;
- explain why respiration is so important to the function of all cells in the body;
- state the differences between aerobic and anaerobic respiration in terms of substrates, products and quantity of energy made available to a respiring cell;
- relate cellular respiration to what happens in a muscle cell during various levels of physical activity;
- explain how monitoring a person's circulatory and respiratory systems and analysing their blood provides information about a person's state of health or fitness.

3.2.2 Structure and Function of the Circulatory and Respiratory Systems

The way in which the heart and lungs of an individual are functioning can give a good indication of the general state of health of that person. Heart rate, ventilation rate and the chemical state of the blood in circulation are useful physiological indicators. Therefore it is important that you know something about the structure of the cardiovascular and respiratory system and the way they work.

You need to:

- describe the structure of the heart, the roles of the **four** chambers, the valves in double circulation, and the characteristic features of arteries, veins and capillaries;
- explain how heart rate is affected by nervous and hormonal inputs;
- explain how blood pressure changes with the activity of the body;
- describe the structure of the lungs, trachea and bronchial tubes, and how breathing movements are brought about by muscles;

- explain how gases are exchanged between the atmosphere and the blood, through the respiratory surfaces of the lungs;
- explain how oxygen and nutrients reach the cells within tissues, and how carbon dioxide is removed from the cells and from the bloodstream.

3.2.3 Uses of Physiological Measurements

Physiological indicators measured in a hospital or a fitness clinic can be used to check a person's state of health and general fitness, to check whether they are recovering from an injury or operation or to help follow the progress of a clinical condition.

You need to:

- explain why you need to know the average values for the indicators that are regarded as 'normal' for male and female adults at rest;
- describe how blood counts of, for example, red blood cells, can lead to diagnosis, e.g. anaemia;
- state the principles of how blood-sugar monitoring is used in the treatment of diabetes;
- state the principles of how breathing tests of, for example, tidal volume and peak flow rate are used in the treatment of asthma;
- state the principles of how blood tests are used to find the following chemicals in the blood:
  – alcohol;
  – a named recreational drug;
  – a named performance-enhancing drug;
- state the principles of how blood tests, including ELISA tests, are used to find antibody indicators for, for example, hepatitis, AIDS;
- state that an electrocardiogram, spirometer and peak-flow meter can be used to monitor the activity of the heart and lungs;
- for each instrument, recognise a normal trace, or the average value in the case of a peak-flow meter, and describe what it shows;
- recognise traces for normal heart, sinus tachycardia, bradycardia, sinus arrhythmia and ventricular fibrillation;
- describe what electrocardiogram and spirometer traces and peak-flow meter readings show about the probable physiological status of people;
- recognise the normal body temperature for an average adult at rest, the range that a healthy body can withstand, and body temperatures that are dangerously high or low.

3.2.4 Methods of Taking Physiological Measurements

Physiological indicators are measured in a variety of ways. Measuring equipment used in this area varies in complexity. However, in general they are relatively user-friendly.

This sub-section provides many opportunities to explore the use of ICT in physiological investigation. Physiological data collected using electronic equipment can be stored for information as patient records, presented as graphs or charts for use in diagnosis or general health assessment.

You need to:

- explain how to take pulse rate and/or heartbeat measurements;
- assess a person's current level of fitness, and whether their performance is improving, using pulse-rate measurements taken before, during and after exercising;
- explain how to measure blood-pressure data (using a manual sphygmomanometer **or** an electronic digital sphygmomanometer);
- explain how to measure breathing rate;
- explain how to measure tidal volume and vital capacity of the lungs (using a simple spirometer);
- explain how to measure peak expiratory flow rate using a peak flow meter;
- explain how to measure body temperature accurately;
- outline the principles for measuring blood-sugar level using clinisticks or a blood-sugar metering device;
- use graphs to monitor changes in pulse rate, blood pressure, temperature and breathing rate.

3.2.5 Imaging Methods

Technology has provided us with some very important diagnostic tools. Surgery is more successful thanks to information gained from pre-operative, non-invasive diagnosis.

This sub-section concentrates on the production of images using electronic monitoring devices. You will become acutely aware of the significance of ICT in modern medicine in terms of data attainment, management and use in diagnosis.

You need to:

- explain the basic principles of medical X-ray radiography;
- describe how CAT scans and MRI scans are used for diagnosis;
- explain the basic principles of how ultrasound scans are used in diagnosis;
- distinguish between different types of medical scanner used in diagnosis, to include X-ray, ultrasound, CAT and MRI.

3.2.6 Regulations Governing Specific Procedures and Data Management

Health and Safety issues in the work place make it essential that good practice guidelines are clearly stated and understood.

You need to describe and explain:

- regulations for the disposal of hazardous biological waste, e.g. sharps and hypodermic needles used in obtaining blood for testing;
- procedures for the treatment of material that may be contaminated with microbiological hazards, e.g. used petri dishes, materials from antibody testing;
- how to carry out a risk assessment for a blood test, state what the hazards are, and explain how to minimise the risk from these hazards to the person carrying out the blood test;
- how to carry out a risk assessment for any other non-invasive physiological measurement, e.g. blood pressure measurement, state what the hazards are, and explain how to minimise the risk from these hazards to the person being tested;
- how to choose and evaluate relevant sources of data;
- how to obtain and use primary and secondary data.

3.2.7 Ethical Issues Related to Monitoring, Diagnosis and Treatment

It is important to be aware that the decision to carry out a program of diagnosis and treatment involves consideration of other issues that might affect the patient. It may not be a simple case of medical expedience.

You need to:

- discuss the risks, benefits and ethical issues involved in using imaging methods;
- identify the risks and benefits arising from the diagnosis and/or treatment of patients with circulatory or respiratory disorders;
- identify situations where it may be considered inappropriate to diagnose and/or treat patients.

3.3 GUIDANCE FOR TEACHERS

3.3.1 Guidance on Delivery

Respiration in energy terms

Candidates may well have met the basic biology involved in this section in their science studies at Key Stage 4. They are not expected to give detailed descriptions of the chemistry involved in aerobic and anaerobic respiration. However, they need to understand enough about the processes to say how they differ. Candidates need to relate changes in heart rate and depth and frequency of ventilation to changes taking place at a cellular level in the muscle during various levels of physical activity.

Structure and function of the circulatory and respiratory systems

Once more, many candidates will have an adequate grounding in this area from their Key Stage 4 Science. They may well benefit from reviewing their knowledge about the mammalian cardiovascular and lung system. Candidates might be encouraged to dissect a sheep's or pig's heart and lungs to gain a fuller understanding of the **two** major organ systems involved in this section. This activity could also provide an opportunity to discuss any ethical issues arising from dissection, transplant surgery in general, use of a pig's heart in transgenic transplant surgery etc. It might also provide an opportunity for candidates to do a risk assessment for the dissection/surgery.

As far as written assessment is concerned, candidates will be expected to relate data obtained by monitoring to what must have been going on at an organ level in the patient providing the data. They need to identify structures and processes correctly so they can, for example, relate what an ECG trace shows about the rate and rhythm of the heart to the structures of the heart, or account for a rise in blood pressure.

Uses of physiological measurements

Candidates are likely to find different 'normal' values quoted in different sources and values given in 'non-standard' units.

For the purposes of assessment, values quoted in 'Guidance for Teachers' will be used as normal values in the resting state.

Blood-glucose
The typical blood plasma concentration (fasting level) is 3.5-7.5 mmol/dm^3. Glucose appears in urine when the blood plasma concentration exceeds 9.0 mmol/dm^3.

Candidates need to know the way the human body regulates blood-glucose concentration. They need to know that **two** hormones, insulin and glucagon, are produced by cells in the pancreas in response to changes in blood-glucose concentration. These hormones control the relative rate at which blood-glucose is stored in the liver or released for use by respiring cells. Diabetics need to monitor their blood-glucose concentrations. Candidates need to distinguish between insulin dependent and non-insulin dependent diabetes.

Breathing

Breathing rate	15-18 per min
Tidal volume	0.4-0.5 dm^3
Vital capacity (male)	6.00 dm^3
Vital capacity (female)	4.25 dm^3
Peak flow	400-600 dm^3/min

Blood pressure

Subject	**Blood pressure mmHg**
Typical 18-year-old adult	120/80
Male, aged 20 years	125/80
Female, aged 20 years	123/80
Male, aged 40 years	135/85
Female, aged 40 years	133/85

Pulse rate
The typical range for pulse rate is 60-80 beats per minute.

Candidates should be aware of ELISA tests as **one** way in which substances can be found in the blood.

Body temperature
Candidates need to describe the mechanisms available to the body to maintain a stable body temperature. These include shivering, sweating, vasoconstriction and vasodilation.

The following body temperature values (mouth) will be used in the external assessment.

Condition	Temperature °C
Normal	36.8°; range 36.5°-37.2°
Death	Below 25°
Hypothermia	32°
Fever	Above 37.2°
Hyperthermia/heat exhaustion/ heatstroke	Likely if above 38° in absence of infection
High temperatures that would lead to death	Above 43°

Methods of taking physiological measurements

Candidates need to analyse data they have obtained from their own measurements and data from secondary sources. Many of the monitoring devices involved in this unit are sophisticated, expensive and not readily accessible to candidates. However, where possible, they should be provided with the opportunity to use monitoring equipment.

Difficulties associated with collecting data from people are recognised, but at this level of study, candidates need to collect data that is relevant, sufficient and reliable. When measuring physiological status, they will need to choose their subjects carefully and agree what they can monitor, over what time scale, and at what intervals. It would be useful if the group as a whole covered a wide range of individuals to get a spread of results and a sufficiently large enough sample to show the range of variation.

If it is possible to collect data from people who have to manage particular conditions (for example asthma or diabetes), this would add interest and meaning to the study. If not, candidates should make comparisons with published data.

They could use a spirometer to measure tidal volume and vital capacity and take measurements using a peak flow meter, obtaining more detailed ventilation performance data from secondary sources.

If they use a manual sphygmomanometer they must be supervised.

Imaging methods

X-rays

- Place of X-rays in the electromagnetic spectrum.
- Qualitative – relative penetration for different atomic masses.

CAT scans

- Advantage of 3D image.
- Diagram of rotating source.
- Idea that computer is used to convert the image.

MRI

- Detects hydrogen, and hence water, in cells.
- Strong magnetic field needed – obtainable by using superconducting magnet.
- Radiation causes oscillation in nucleus.
- Excited nuclei re-radiate signalling their positions.
- Detector picks up radiation emitted by nucleii.

Ultra sound

- Frequencies used compared with normal range of hearing.
- Reflection at interfaces between layers.
- Need for gel between probe and skin so that signal not reflected at skin surface.

A visit to a hospital would complement work on secondary sources.

Regulations governing specific procedures and data management

Any practical work undertaken during the course will provide opportunities for much of the work in this section. Candidates also need to be made aware of the question of reliability when considering secondary sources of data.

Ethical issues related to monitoring, diagnosis and treatment

This unit focuses on the way in which very personal data can be obtained and used. Therefore it is likely that numerous opportunities for candidates to consider ethical issues will arise as they progress through the unit.

Candidates need to be aware of the risks associated with imaging techniques. They could consider, for example, the potential effect of X-ray radiography on the fertility of a patient balanced against the possible benefits. This topic could also lead to discussion of the health and safety implications of working in a radiography department from a technician's point of view.

3.3.2 Guidance on Assessment

This unit is assessed through a 1½ hour question paper with **90** marks which assesses AO1 (**64** %) and AO2 (**36** %).

3.3.3 Resources

Publications	Biological Sciences Review New Scientist Scientific American Good references to ethical issues can be found in SATIS units:			
		What is Science?		086 357 158 1
		What is Technology?		086 357 159 X
		How Does Society Decide?		086 357 160 3
Textbooks	Standard Advanced Level Biology/Human Biology texts			
	Howley ET & Franks BD	*Health Fitness Instructor's Handbook*	Human Kinetics	0 873 229 584X
	McArdle WD Katch FI & Katch VL	*Essentials of Exercise Physiology*	Lippincott Williams & Wilkins	0 683 305 077X
	Powers SK & Howley ET	*Exercise Physiology*	McGraw-Hill Higher Education	0 071 180 850X
	Wilmore JH & Costill D	*Physiology of Sport and Exercise*	Human Kinetics	0 736 000 844X
Websites	www.asthma-help.co.uk www.asthma.org.uk www.bhf.org.uk www.brit-thoracic.org.uk www.chemsoc.org www.concept2.co.uk www.doh.gov.uk www.ecglibrary.com www.e-san.co.uk www.food.gov.uk www.lunguk.org www.medicinenet.com www.netdoctor.co.uk www.phls.co.uk www.polar-uk.com www.powerjog.co.uk www.pponline.co.uk www.rsc.org www.sciencenet.org.uk/browse/bioresources www.statistics.gov.uk www.studentbmj.com www.who.int www.winhealth.co.uk			

4 Unit 4: Cells and Molecules

[AS level, double award, mandatory, externally assessed]

4.1 ABOUT THIS UNIT

This AS level unit is a mandatory part of the double award only and is externally assessed.

Molecular Biologists study how cells work at the molecular level, and try to understand how the relationship between all of the different molecules can produce a functioning, living unit – the cell.

In recent years, this branch of science has become increasingly important in our understanding of disease, and in finding ways to treat and even cure some of the major diseases that affect human beings. Research into DNA has given us a greater understanding into the way living organisms work. The *Human Genome Project* has finally produced a database of the coding of DNA for a human being. This knowledge has provided us with great power, but also great responsibility as to how this knowledge should be used. It is only by understanding the science behind these discoveries that society will be in a position to make responsible decisions as to how this knowledge should be used.

By studying this unit, you will understand some of the principles involved in how cells work, and investigate some of the molecules that are found within the cell. You will also learn some of the techniques used when studying cells within industrial research and pathology laboratories. Finally, you will consider some of the moral and ethical implications of such research and how this can affect individuals within society.

The work in this unit extends the knowledge and skills covered in GCSE Science and Applied Science.

There are strong links between this unit and units in GCE Biology and Chemistry. There are also strong links with Unit 3: *Monitoring the activity of the human body* and Unit 8: *Investigating the scientist's work*.

This unit will help you to prepare for higher education courses in biology, chemistry, or molecular biology, or for work into medical-related occupations. It will also provide the background and understanding to make rational, moral and ethical decisions about the implementation of some aspects of genetic and cellular research.

This unit is assessed through an external assessment which consists of an external examination (50%) and the preparation of a plan for an investigation (50%).

The nature of the investigation will be specified by OCR and should be presented to you **six** weeks before the external examination.

You will be expected to hand in your investigation plan on a date specified by your teacher which will be not later than the date of the examination.

4.2 WHAT YOU NEED TO LEARN

You need to learn about:

- planning an investigation;
- the structure of the cell;
- some molecules found within the cell;
- investigating cells and cell types, measuring them and counting cell numbers;
- investigating the work of Molecular Biologists in cellular research.

4.2.1 Planning an Investigation

Professional Biologists, Chemists and Molecular Biologists are continually carrying out research into the structure and functioning of the cell.

You need to plan a practical investigation in which you:

- include a risk assessment to show how the investigation will be carried out safely;
- make a prediction and produce justification;
- describe and explain the reasoning behind any preliminary work carried out;
- identify relevant secondary sources of information used;
- plan how to use appropriate techniques to carry out a detailed practical investigation;
- list the equipment required;
- state the number and range of measurements to be undertaken;
- identify any variables that could affect the validity of any conclusions made;
- explain how variables will be controlled;
- show how you would present and display the data you could collect using appropriate methods;
- indicate how the data will be analysed;
- evaluate the investigation.

4.2.2 The Structure of the Cell

Molecular Biology is the study of the molecules and the chemical interactions that occur within cells. The cell is a complete and functioning biological unit that acts as a building block for all living things. In order to understand how the cell works, we need to look at some of the structures found within the cell and understand the role that each plays in the successful functioning of the cell.

You need to:

- produce a slide of a cellular tissue and describe the structures observed within the cell using a light microscope;
- describe the additional structures observed using an electron microscope;
- explain the functional differences between a light microscope and an electron microscope;
- explain the role of the cellular organelles found in both animal and plant cells.

4.2.3 Some Molecules Found Within the Cell

In order to fully understand cells, we not only need to understand the ultrastructure of a cell but also the role of some of the chemical molecules found within it. These molecules range from the simple water molecule to the more complex polymer of DNA that is found within the nucleus. Scientists also need to carry out chemical tests for the presence of these molecules when analysing the contents of cells.

You need to:

- understand the function and importance of water as a biological molecule;
- describe the process of osmosis and explain how cells maintain their correct water balance;
- understand the importance of carbon in biological molecules;
- understand the structure of carbohydrates to include the glycosidic bond, condensation and hydrolysis reactions;
- carry out tests for reducing sugar, non-reducing sugar and starch;
- understand the structure of lipids and phospholipids, to include the ester bond, saturated and unsaturated fats;
- describe the role of phospholipids in the structure of the cell membrane, to include the fluid mosaic model;
- carry out a test for lipids;
- understand the structure of proteins to include the peptide bond, alpha helix and beta pleated sheets, primary, secondary and tertiary structures and the formation of globular proteins;
- carry out a test for proteins;
- explain the role of enzymes within the cell;
- explain the structure and function of DNA.

4.2.4 Investigation of Cells and Cell Types, Measurement of Them and Counting Cell Numbers

An important skill is the ability to accurately measure the size of cells, count the numbers of cells on a microscope slide and calculate the number of cells in a given volume of liquid. Scientists who work in pathology laboratories in hospitals often need to know the relative numbers of red and white blood cells in samples of blood as this can provide valuable information for the diagnosis of certain diseases.

You need to:

- use an eyepiece graticule to determine the relative sizes of different cells or tissue structures;
- use a stage micrometer to determine actual dimensions of cells;
- use a haemocytometer to determine the number of cells in a specific volume of liquid;
- explain how and why the brewing industry and pathology laboratories use Coulter counters;
- explain how and why scientists in biomedical research and pathology laboratories study cells, cell counts and manifestations of cell changes.

4.2.5 Investigation of the Work of Molecular Biologists in Cellular Research

You need to:

- find out how cell counts can be used in the investigation of anaemia and leukaemia;
- find out how cervical smear tests are analysed in a hospital pathology laboratory for positive and negative results;
- describe the clinical symptoms of cystic fibrosis and Huntington's chorea, as examples of genetic disease, and their effect on the individual;
- explain the diagnostic tests, to include the use of monoclonal antibodies, that can be used to identify genetic diseases;
- discuss the moral and ethical implications of diagnostic testing for genetic disorders.

4.3 GUIDANCE FOR TEACHERS

4.3.1 Guidance on Delivery

This unit needs to draw on the scientific knowledge, skills and understanding provided by study of Units 1-3. It should also be possible to carry out the unit early in the course, allowing the development of basic biological skills in a context which builds on work done in GCSE Science or Applied Science.

Laboratory practical work, and the development of practical skills, is an integral part of the unit (it needs to constitute around 40-50% of the time allocated). The laboratory work can be completed at any time of the year, as the material required is not season-specific.

The principle aim of the unit is to give candidates a sufficient grounding in theoretical and practical cell biology to allow them to appraise critically the work and moral issues confronting them, and to review how these problems might be addressed by professional biologists and society as a whole.

Numerous opportunities for candidates to consider ethical issues will arise as they progress through the unit and in particular in Sub-section 4.2.5 (Investigation of the work of molecular biologists in cellular research). Examples of issues worth considering might include:

- the possibility of error arising during diagnostic testing;
- human-rights issues where genetic information might be used, for example, to block applications for employment, insurance or mortgage facilities;
- prenatal screening in order to detect genetic disorder and the subsequent decision whether or not to pursue a selective abortion;
- how serious a defect has to be before a selective abortion might be considered;
- the cost-effectiveness of screening.

4.3.2 Guidance on Assessment

As well as knowledge and understanding, candidates will be assessed on their ability to plan, observe, analyse and evaluate, and will need to be taught these skills if they are to achieve the higher grades.

AO1 and AO2 will be assessed by a **45** minute theory paper of **45** marks. These marks are weighted so that the paper is worth **50%** of this unit.

AO3 will be assessed by a pre-prepared plan for an investigation. Candidates will **not** be expected to carry out their plan. The nature of the investigation will be specified by OCR and should be presented to candidates **six** weeks before the external examination. Candidates will hand in the plan on a date specified by you which will be not later than the date of the examination. The marks for the plan will be weighted so that the plan is worth **50%** of this unit.

The plan will be marked by OCR using the following criteria:

Candidates:	**Marking criteria**	**Mark**
• include a risk assessment to show how the investigation will be carried out safely;	easily recognised safety procedures highlighted;	**1**
• make a prediction and produce justification;	prediction made; with justification;	**1** **1**
• describe and explain the reasoning behind any preliminary work carried out;	description; clear and in detail; reasons explained; clear and in detail;	**1** **1** **1** **1**
• identify relevant secondary sources of information used;	identified; relevance explained;	**1** **1**
• plan how to use appropriate techniques to carry out a detailed practical investigation;	basic skills and reasonable accuracy; sound skills and accuracy;	**1** **1**
• list the equipment required;	range of appropriate; full range of appropriate;	**1** **1**
• state the number of measurements to be undertaken;	appropriate number;	**1**
• state the range of measurements to be undertaken;	need recognised; appropriate range;	**1** **1**
• identify any variables that could affect the validity of any conclusions made and explain how variables will be controlled;	relevant variables are identified; controlled;	**1** **1**
• show how they would present and display the data they could collect using suitable methods;	suitable methods identified;	**1** **1**
• indicate how the data will be analysed;	simple data-handling; conclusions possible;	**1** **1**
• evaluate the investigation.	recognises sources of error; suggests methods for improving accuracy and/or validity.	**1** **1**
	Total marks available:	**24**
	Additional marks awarded on plan for use of scientific terminology:	**1**
	Total:	**25**

4.3.3 Resources

Organisations	Advisory Committee of Genetic Modification	(ACGM)
	Advisory Committee on Genetic Testing	(ACGT)
	Advisory Group on Scientific Advances in Genetics	(AGSAG)
	Cystic Fibrosis Foundation	(CFF)
	Gene Therapy Advisory Committee	(GTAC)
	Human Fertilisation and Embryology Authority	(HFEA)
	Human Genetics Advisory Commission	(HGAC)
	National Institute for Clinical Excellence	(NICE)
Publications	New Scientist	
	Scientific American	
Websites	www.cancerbacup.org.uk www.cff.org www.advisorybodies.doh.gov.uk/genetics/acgt www.advisorybodies.doh.gov.uk/genetics/gtac www.advisorybodies.doh.gov.uk/hgac/index.html www.hfea.gov.uk www.hse.gov.uk www.ost.gov.uk www.nice.org.uk	

5 Unit 5: Chemicals for a Purpose
[AS level, double award, optional, internally assessed]

5.1 ABOUT THIS UNIT

This AS level unit is an optional part of the double award only and is internally assessed.

The chemical industry is one of the UK's most successful large industries. Chemicals are manufactured for a range of uses, including pharmaceuticals (medicines), detergents, paints, fertilisers, fuels and petrochemicals, and specialist consumer goods.

Chemists working in the industry have many roles. They synthesise new chemical products, work with engineers to design and run chemical manufacturing processes, and analyse products for safety and quality. Many chemists are employed as consultants for sales and advertising.

In studying this unit, you will learn about the range of chemicals manufactured in the UK. You will learn about the chemistry behind making manufacturing-processes operate efficiently, and how the conditions they use are chosen. You will study the properties and actions of examples of chemical products used in consumer goods (such as detergents) and will prepare and analyse a sample of **one** product on a laboratory scale.

The work in this unit extends the knowledge and skills covered in GCSE Science and Applied Science.

There are strong links between this unit and Unit 2: *Analysis at work*, Unit 10: *Synthesising organic chemicals*, Unit 11: *Materials for a purpose* and AS units in GCE Chemistry.

The study of this unit is important if you want to progress on to degree courses in chemistry or chemical engineering, or into occupations using chemistry.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will provide evidence of your knowledge, understanding and investigation into chemicals for a purpose.

Your evidence will include:

- a description of **two** examples of inorganic and **two** examples of organic chemical products, discussing their uses, properties and chemical structure – your description will include more detail about **one** example of a product made from oil to show how its structure and chemistry relate directly to its use;
- a discussion of the **two** industrial processes that produce **two** different chemical products – at least **one** process will involve the use of a catalyst, whose action you will explain – you will evaluate each process by discussing its advantages and disadvantages, and by clearly explaining the importance of the products it produces;
- a sample and account of the preparation of a product that has been synthesised, purified and analysed for purity in the laboratory.

5.2 WHAT YOU NEED TO LEARN

You need to learn about:

- organics and inorganics;
- the chemistry of oil products;
- manufacturing processes;
- preparation and analysis of a chemical product.

5.2.1 Organics and Inorganics

The chemical industry produces both organic and inorganic compounds. These have different properties, and so are used in different ways. Chemists represent compounds using different types of formulae and research the properties of compounds to work out how they can be used.

You need to learn about the range of chemicals produced by the chemical industry.

You need to:

- discuss the difference in properties between ionic and covalent compounds;
- find and use data about properties, such as solubility, melting points, boiling points and state, to classify compounds as ionic or covalent;
- evaluate the use of a compound in terms of its properties;
- write formulae for the following inorganic compounds used and made in industry:
  – common acids and alkalis (including ammonia);
  – carbonates, chlorides, hydroxides and sulphates of sodium, potassium, calcium, magnesium, aluminium, iron, copper and zinc;
  – oxides of the metals listed above and those of carbon and sulphur;

- draw and recognise structural formulae of the following organic compounds:
  – hydrocarbons – simple alkanes and alkenes, and benzene;
  – alcohols;
  – carboxylic acids and esters;
- know the range of uses of some of the compounds that you study.

5.2.2 The Chemistry of Oil Products

The way that chemical products are used depends on their properties and reactions. Chemicals from oil are called petrochemicals. The UK is an oil-producing country, using oil from the North Sea and elsewhere as a raw material for making huge amounts of the chemicals we use everyday, including plastics, synthetic fibres and detergents.

In learning about oil products, you need to:

- give examples and uses of some chemical products from petrochemicals, e.g. esters, polyesters, addition polymers, detergents;
- describe the differences between soap and detergents in terms of the raw materials used to make them, and the action of each when they are used;
- explain the action of a detergent (an anionic surfactant) in terms of hydrophobic and hydrophilic regions of the molecule;
- research and discuss why detergent products, such as washing powder, have other additives – to include bleaches, fluorescents, phosphates and enzymes;
- describe the reaction that happens during addition polymerisation and outline how it is carried out on an industrial scale, e.g. polyethene, polystyrene, PTFE;
- discuss the chemistry of the following addition polymers in terms of their formulae, structure, properties and uses:
  – polyethene;
  – polystyrene;
  – PVC;
  – PTFE.

5.2.3 Manufacturing Processes

Some chemicals are produced on a very large scale. These processes need to run as cheaply and efficiently as possible, and also need to follow environmental considerations. Chemists design processes to use as little energy as possible. One way of lowering energy demand is to use catalysts. Catalysts are used in the manufacture of fertilisers, plastics, fuels and many other materials.

You need to research and study some large-scale chemical processes.

You need to:

- explain how catalysts work;
- describe the following processes that use catalysts:
  – cracking;
  – reforming (isomerisation) of crude oil fractions;
  – addition polymerisation;
- explain that different catalysts produce different products in addition polymerisation, e.g. LDPE and HDPE;
- evaluate the importance of these processes in terms of the usefulness of the products they produce;
- discuss how the catalysts increase efficiency and lower energy costs;
- know the difference between homogeneous and heterogeneous catalysts and outline the advantages and disadvantages of each;
- research and evaluate the conditions of chemical processes by considering the advantages and disadvantages of a process for making a chemical product, e.g. energy costs, waste products, availability and sustainability of raw materials.

5.2.4 Preparation and Analysis of a Chemical Product

Chemists working to develop new products prepare initial, small samples of chemicals for research and testing. You need to prepare a sample of a chemical on a laboratory scale and carry out some tests to determine its purity.

You need to:

- research and use an appropriate technique to carry out a laboratory preparation, e.g. refluxing;
- make a full risk assessment to cover the procedures and substances involved;
- use ratio, proportion and percentages to work out amounts of substances;
- use the chemical equation for a reaction to work out a theoretical yield;
- adapt your method to maximise the yield of your product;
- purify your product, e.g. recrystallisation or distillation;
- analyse the percentage yield and evaluate the process that you have used;
- research and use appropriate techniques to purify and check the purity of the product you have made.

5.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 5: Chemicals for a purpose
What you need to do:
You need to provide evidence of your knowledge, understanding and investigation into chemicals for a purpose [**50** marks]. This evidence needs to include**:** **AO1:** a description of **two** examples of **inorganic** and **two** examples of **organic** chemical products, discussing their uses, properties and chemical structure – your description needs to include more detail about **one** example of a product made from oil to show how its structure and chemistry relate directly to its use [**21**]; **AO2:** a discussion of the **two** industrial processes that produce **two** different chemical products – at least **one** process needs to involve the use of a catalyst, whose action you need to explain – you need to evaluate each process by discussing its advantages and disadvantages, and by clearly explaining the importance of the products it produces [**10**]; **AO3:** a sample and account of the preparation of a product that has been synthesised, purified and analysed for purity in the laboratory [**19**].
How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will give **four** examples of chemical compounds (**two** inorganic and **two** organic) giving their formulae; **[0 1]**	you will give **four** examples of chemical compounds (**two** inorganic and **two** organic), appropriate formulae are shown, e.g. full structural and you have presented data systematically to show the properties of the compounds, e.g. using charts, tables and graphs; **[2 3]**	you will represent the **four** examples (**two** inorganic and **two** organic) using full formulae and give detailed data about properties and uses, presenting them systematically using a wide range of presentation techniques, e.g. tables, pie charts and graphs. **[4 5]**	
	You will present clearly the uses and properties of the compounds; **[0 1]**	you have attempted to link the properties of the compounds to their uses; **[2 3]**	a full discussion will show how properties depend on structure and how uses depend on properties for each compound. **[4 5]**	
	You will research the chemistry of **one** of the examples, e.g. a polymer or detergent; **[0 1 2 3 4 5]**	you will research and give a more detailed account of the chemistry of **one** of the examples, e.g. a polymer or detergent, showing the main, relevant reactions and some use made of appropriate scientific terminology; **[6 7 8]**	you will fully research and give an account of the chemistry of **one** of the examples, e.g. a polymer or detergent, with full detail of structures of the substances involved; the reactions involved will be fully explained with additional researched detail throughout and good use made of appropriate scientific terminology. **[9 10 11]**	**/21**

Unit 5: Chemicals for a purpose (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	You will give an outline of **two** industrial chemical processes showing the conditions, raw materials and products; the usefulness of the products will be identified; **[0 1]**	you will give a more detailed description of **two** processes, including equations where appropriate; **[2 3]**	you will produce a fully researched, very detailed account of **two** processes, explaining all reactions fully. **[4 5]**	
	You will include a description of the role of the catalyst and identify some advantages and disadvantages of each process; **[0 1]**	you will discuss the role of the catalyst more fully and include a discussion about the advantages and disadvantages of the processes; **[2 3]**	you will give a full account of the chemistry of catalysis and the evaluation will show a sophisticated understanding of the potential social, economic and environmental impacts of the processes. **[4 5]**	**/10**
AO3	You will research and present a workable method with a safe risk assessment; **[0 1 2]**	you will research a more detailed method showing details of all apparatus and quantities used and include a workable risk assessment; **[3 4]**	you will research and produce a very detailed method and give a full description of each stage of the preparation, purification and analysis of the product and include a full, detailed risk assessment which shows selectivity in the information presented. **[5 6]**	
	You will present the method and results coherently using tables and diagrams; **[0 1 2 3]**	you will record and present observations systematically with some processing of data; **[4 5]**	you will record, present and process accurately all measurements systematically using a range of methods, e.g. prose, numbered lists, tables and graphs. **[6 7]**	
	You will show an awareness that the yield can be increased by changing the conditions; **[0 1 2]**	you will make workable suggestions about increasing the yield; **[3 4]**	you will evaluate systematically the method of the preparation. **[5 6]**	**/19**
			Total mark awarded:	**/50**

5.4 GUIDANCE FOR TEACHERS

5.4.1 Guidance on Delivery

This unit needs to draw on the scientific knowledge, skills and understanding provided by study of Unit 1: *Science at work*, Unit 2*: Analysis at work* and Unit 3: *Monitoring the activity of the human body*. The unit revisits some previous learning about ionic and covalent bonding and structure that candidates have met in Key Stage 4 Science or GCSE Applied Science. For some candidates, these areas will need revisiting and reinforcing, before they meet the new ideas in this unit.

The principal aim of this unit is for candidates to understand the extent and importance of the chemical industry in producing chemicals to make industrial and consumer goods. They need to think about the roles for chemists in the industry, including chemical engineers. Candidates, wherever possible, need to refer to information from everyday sources, e.g. labels, advertisements, magazine articles and websites, to find examples of chemical products to illustrate their work.

The importance of the work of the synthetic chemist and quality-control chemist is a key part of the chemical industry. Candidates will be carrying out a laboratory synthesis, where they will need to think about issues relating to the nature of a laboratory chemist's work.

Throughout the unit, candidates need to be encouraged to carry out their own research into the processes that they are studying, and think about issues such as the importance of the products, the sustainability of the processes used and the concerns about the use of energy.

Organics and Inorganics

This allows candidates to build on their skills, knowledge and understanding from GCSE Science and Applied Science, with specific regard to their work on formulae, equations and bonding.

Most GCE Chemistry textbooks contain sections that can be used in the teaching of structural formulae. Practical work can be carried out to compare ionic and covalent compounds. Research into data about properties of each can compare, for example, melting points, appearance, and uses.

To follow a vocational approach, candidates can analyse labels from, for example, cosmetics, medicines, fertilisers and washing powders, to find examples of organic and inorganic products. They need to look up data for a range of the compounds they study using either standard GCE data books or on-line data sources (see Sub-section 5.4.3 (Resources)). Candidates may process this data using graphs, spreadsheets etc. Below are mentioned some software packages, e.g. ISIS/DRAW, which can be used to draw structural formulae and be imported into word-processed documents. References, such as *The Essential Chemical Industry*, provide information on the main products of the UK industry.

The chemistry of oil products

This section builds on work at KS4 or GCSE Applied Science, relating to polymers, enzymes and chemicals from salt, and also links directly with the recognition of structural formulae in Sub-section 5.2.1 (Organics and inorganics).

Candidates need to become familiar with the structural formulae of the main organic products from oil. They need to recognise the formulae of all the compounds stated in Sub-section 5.2.1 (Organics and inorganics) and also esters, polyesters, polymers and detergents (the Chemfinder website is useful for this – see Sub-section 5.4.3 (Resources)).

A study of detergents needs to include some practical and investigative work, for example:

- measurement of the amount of soap and detergent needed to make a permanent lather;
- the action of both soap and detergent with hard and soft water;
- the comparison of advertisers' claims and packet labels for washing powders, liquids and tablets, with the aim of working out the function of each ingredient, for example:
  – bleaches oxidise stain molecules and remove their colour, but can cause coloured clothes to fade too;
  – sodium carbonate or phosphates are water softeners;
  – fluorescents cause white clothes to 'glow';
  – anionic surfactants are another name for the large anion detergent molecules;
  – enzymes are biological catalysts that catalyse the breakdown of organic molecules, such as proteins and fats, in stains – they operate in narrow optimum temperature ranges;
- looking at the instructions on washing powder relating to temperatures and wash cycles, and working out which ingredient is designed to work at which temperature, e.g. enzymes work best at lower temperatures, bleaches clean best at higher but will remove colour from clothes.

Candidates need to understand that chemical consumer products are usually a mixture of compounds, often both organic and inorganic, each with different properties, e.g. each additive listed in washing powder has a different purpose. (Candidates may like to consider ‘colour’ washing powders – why these products do not contain any bleach.)

Polymers need to be represented via structural formulae, as both monomers and polymers. Examples need to be limited to poly(ethene) type polymerisations, with a change in the side group to produce polymers such as PTFE and poly(phenylethene) (polystryene). In the study of polymers, candidates need to link the structure of the polymer to its properties and uses, e.g. how the presence of large groups or side groups stop chains moving and cause rigidity, brittleness and higher melting points.

Candidates can carry out some investigative work by:

- researching the structural formulae of some polymers;
- finding out about their properties and linking this to their structure.

Candidates need to discuss the properties of polymers such as melting point, flexibility and strength by using ideas about the structure and layout of the chains.

Manufacturing processes

This section builds on work at GCSE Science or Applied Science. Candidates need to be familiar with the idea that oil is extracted and separated into useful fractions by fractional distillation. There are videos available (see below) to recap these ideas.

Candidates need to understand that the fractions from crude oil undergo a series of chemical reactions and processing in the refinery to produce useful products and to ensure that supply meets demand for the lighter oil fractions. They need to appreciate the need for this, in terms of the economic profitability of the process, and the environmental desirability of the maximum use being made of the crude oil resource with the minimum waste produced.

The study of petrol is a useful context for studying reforming. Candidates can research the changes in the composition of petrol since the banning of lead compounds, and the role of reforming in increasing the octane rating of petrol-based fuels. They need to recognise reforming reactions by looking at the structures of the reactants and products.

Catalysts need to be discussed in terms of increasing rates of reaction and lowering the energy demand of processes. Important areas to discuss include:

- examples of catalysts linked to processes;
- the role of lowering activation energy (this can be represented graphically);
- a model of the surface action of heterogeneous catalysts;
- the difficulties caused by catalyst poisoning of heterogeneous catalysts and the importance of catalyst regeneration;
- examples of the use of homogenous catalysts, e.g. acid catalysts used in esterification (this links to the preparation of a product, see below);

- the process difficulties of separating a homogeneous catalyst from the mixture of products;
- the long-term economic benefit of reduced process cost vs high initial investment to buy the catalyst.

Practical work to illustrate catalysis could be carried out, e.g. testing the effectiveness of different metal oxides in catalysing the break down of hydrogen peroxide.

Candidates need to look at specific catalysts used in addition polymerisation, e.g. how the discovery and use of Zeigler catalysts revolutionised the polyethene industry.

Candidates need to evaluate chemical processes by looking at simple flow charts and discussing the broader implications of the process, for example:

- whether the process uses non-renewable raw materials;
- whether it is possible to use other, renewable, raw materials;
- the energy that is used;
- how the process is adapted to reduce energy demand;
- the waste products that are produced and whether they are environmentally damaging;
- what health and safety issues there are for people working on the process;
- the by-products that are made and whether they can be used;
- the importance of the products and for what they are used.

Examples of processes that can be used for teaching purposes include the membrane cell for the electrolysis of brine, the Haber process for the manufacture of ammonia and the Contact process for the manufacture of sulphuric acid. Candidates need to realise that the idea of the chemical industry as being a producer of both water- and air-pollutants is outdated, and that chemical technology is at the forefront of the 'search for solutions' in terms of environmental impact of manufacturing processes. When considering processes involving petrochemicals, candidates need to be aware of the conflicting demand for oil for immediate use as a fuel and for long-term use as a chemical feedstock.

Preparing and analysing a chemical product

Candidates who have followed the GCSE Applied Science course will have experience of calculating percentage yields. Many candidates will find the mathematics challenging and will need support.

Candidates need to prepare a sample of a product. They need to discuss and consider issues of how their method can be adapted to maximise the yield they produce. They need to use an equation for the reaction to suggest suitable quantities to use, and make decisions about which reactant needs to be in excess to maximise yield. Their preparation needs to be carried out under safe conditions according to a risk assessment that they produce themselves.

Candidates need to use GCE techniques, e.g. accurate measuring of quantities using accurate balances, pipettes or burettes where appropriate. Solid products need to be purified by recrystallisation, liquids by distillation.

The final product needs to be tested for purity using a melting-point or boiling-point test or chromatography.

Candidates need to use data from their initial weighing of reactants and the final mass of their product to show their percentage yield. They need to suggest how the yield could be improved.

Candidates need to discuss their work as an analogy of the work of synthetic chemists, who produce new molecules for testing as drugs and cosmetics. Such samples need to be of the highest purity. They also need to appreciate the role of quality control chemists who test samples of compounds and products before they are released for sale.

Suggestions for suitable products to prepare include:

- esters of ethanoic, propanoic or butanoic acids;
- 1-bromobutane from butan-1-ol.

Most standard GCE textbooks give details of suitable preparations that candidates can use as a basis for their work, and give guidance to candidates about the techniques needed.

5.4.2 Guidance on Assessment

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 5.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at AS level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below clarifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	1	• **Four** examples of chemical compounds (**two** inorganic and **two** organic), the formulae, uses and properties of the compounds are presented clearly; • basic summary outline giving more information about **one** example; • the summary includes relevant material that the candidate has covered in the lessons, but may lack depth and detail or may include irrelevant material;
	2	• **four** examples of chemical compounds (**two** inorganic and **two** organic) are given and detailed, and appropriate formulae are shown, e.g. full structural; • a sound and detailed discussion of the uses of the compounds is given, e.g. using charts, tables or graphs; • some attempt has been made to discuss the properties of **one** of the compounds and make links to its uses; • the chemistry behind the use of the compound is presented in outline;
	3	• full names and formulae are given for all examples (**two** inorganic and **two** organic); • some additional information is presented, sourced from independent research; • a wide range of presentation techniques have been used to present the uses, e.g. tables, pie charts, graphs; • a full discussion links properties to structure and uses for **one** of the compounds; • a fully-researched account of the chemistry of **one** of the examples is given, e.g. a polymer or detergent, to link its structure at a molecular level to its use; • the discussion is of a suitable depth, with evidence of detailed research and understanding of the reactions involved.

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	1	• **Two** industrial chemical processes are outlined at a basic level, e.g. showing the conditions, raw materials and products; • the discussion includes a list of some of the uses of the products and a mention of a catalyst; • some advantages and/or disadvantages of each process are identified;
	2	• a sound description of **two** processes is given, with additional depth and detail including, for example, equations or flow charts where appropriate; • the role of the catalyst is discussed more fully; • a more balanced, detailed discussion about the advantages and disadvantages of the processes is included; • covers relevant bullets from Section 5.2 in relation to the package; • there is evidence of logical presentation and structure to the work;
	3	• a fully researched, very detailed account of **two** processes is given, explaining all reactions fully, using a range of detailed techniques, e.g. equations, structural formulae, charts, flow diagrams; • a full account of the chemistry of catalysis is given, e.g. identifying the nature of the catalyst (hetero or homogeneous); • the evaluation shows a sophisticated understanding of the potential social, economic and environmental impacts of the processes.
AO3	1	• A workable method has been researched and presented with a safe risk assessment; • the method and results are presented but may lack detail, e.g. quantities, measurement techniques and apparatus used may not be fully explained; • awareness is shown that the yield can be increased by changing the conditions;
	2	• a more detailed method has been researched, showing details of all apparatus and quantities used; • the method will be able to be followed fully by another candidate; • a workable risk assessment is included, but this may contain irrelevant information; • observations have been recorded and presented systematically; • the work includes a calculation leading to a percentage yield; • workable suggestions about increasing the yield have been suggested;
	3	• a very detailed method has been researched with full description of each stage of the preparation, purification and analysis of the product; • the method is very clearly presented using, for example, diagrams, numbered steps, tables or a flow chart; • a full, detailed risk assessment is included which shows selectivity in the information presented; • all measurements are recorded and presented systematically using a range of methods, e.g. prose, numbered lists, tables, graphs; • any anomalous observations are noticed and commented on; • the data has been processed appropriately to determine a percentage yield and the method of the preparation has been systematically evaluated and suggestions for improvements have been made.

5.4.3 Resources

<table>
<tr><td>CD-ROM</td><td colspan="3">A free CD-ROM, 'The Science Behind Medicines', that includes a guide to drawing structural formulae is available from GlaxoSmithKline resources@edist.co.uk, www.gsk.com.</td></tr>
<tr><td>Organisations</td><td colspan="3">Association for Science Education
College Lane
Hatfield, Herts
AL10 9AA
Tel: 01707 283000
www.ase.org.uk;

Chemical Industry Education Centre
York University
York
YO10 5DD
Tel: 01904 432523
www.uyseg.org/ciec_home.htm.</td></tr>
<tr><td rowspan="4">Publications</td><td colspan="3">GlaxoSmithKline
www.gsk.com/education;</td></tr>
<tr><td>The Essential Chemical Industry</td><td>Chemical Industry Education Centre</td><td>185 342 577 X</td></tr>
<tr><td>Water</td><td>Unilever Educational Booklet</td><td></td></tr>
<tr><td colspan="3">– both available from ASE booksales (see above).</td></tr>
<tr><td rowspan="2">Textbooks</td><td>Salters Advanced Chemistry: Chemical Ideas</td><td>Heinemann</td><td>043 563 120 9</td></tr>
<tr><td>Salters Advanced Chemistry: Chemical Storylines</td><td>Heinemann</td><td>043 563 119 5</td></tr>
<tr><td>Websites</td><td colspan="3">Esso Classroom Modules on Oil:
www.esso.co.uk;

GlaxoSmithKline:
www.gsk.com;

Oil information:
www.schoolscience.co.uk.

Structural formulae drawing packages (free downloads):
http://www.acdlabs.com/download/;
http://www.mdl.com/download/idraw.html/;
http://www.psrc.usm.edu/macrog/index.htm;
http://www.uyseg.org/catalysis/pages/cat_frames.htm;

Websites for looking up data:
http://chemfinder.cambridgesoft.com/;
http://www.chemsoc.org/viselements;
http://www.webelements.com.</td></tr>
</table>

6 Unit 6: Forensic Science
[AS level, double award, optional, internally assessed]

6.1 ABOUT THIS UNIT

This AS level unit is an optional part of the double award only and is internally assessed.

Forensic science is any science that is used in courts of law. It can therefore cover almost any area of science.

The basic principle of forensic science, ‘that every contact leaves a trace’, was identified by one of its pioneers, Edmond Locard. By studying this unit, you will learn how this evidence is collected and the basic science underpinning the analysis of the main types of forensic evidence that may be presented in court. You will carry out simple forensic analyses, acquiring knowledge of more complex procedures, and report the results. You will evaluate the reliability of different types of forensic evidence in securing a conviction.

You need to report on a forensic case study, in which you will evaluate the quality of the types of evidence obtained and the strengths and weaknesses of the analytical methods used.

This unit extends the knowledge and skills covered in GCSE Science and GCSE Applied Science. There are strong links between this unit and units in GCE Chemistry. This unit complements Unit 1: *Science at work*, Unit 3: *Monitoring the activities of the human body* and Unit 16: *Working waves*. There are also strong links with Unit 4: *Cells and molecules*. Because of their multi-disciplinary approach, forensic investigations also lend themselves to synoptic assessment and so are suitable for use in Unit 8: *Investigating the scientist’s work*. This unit will help to prepare you for higher education courses in forensic science.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will conduct an investigation into forensic science. Your evidence will include:

- a knowledge and understanding of the need to preserve and record the crime scene, and the chemical, biological and physical techniques used to collect and visualise forensic evidence safely, including ethical considerations;
- a report (based on a forensic case study) on evidence and proof, including work which demonstrates the use of calculations to support forensic measurements or observations;
- at least **one** forensic analysis in **each** of the following areas:
  – visual/microscopical;
  – biological;
  – chemical;
  – physical.

6.2 WHAT YOU NEED TO LEARN

You need to learn about:

- recording and collecting evidence;
- methods of analysing evidence:
  – visual and microscopical methods;
  – biological and biochemical methods;
  – chemical methods;
  – physical methods;
- evidence and proof.

6.2.1 Recording and Collection of Evidence

Forensic science begins at the scene of crime. If the investigator does not recognise evidence, and record it in place at the crime scene or preserve it for later analysis in the laboratory, no amount of sophisticated laboratory equipment can resurrect the situation and make the evidence or findings admissible in court.

You need to:

- describe and explain the need to preserve and control the crime scene;
- describe and explain the need to record the crime scene using:
  – sketches;
  – video;
  – photography;
  – digital imaging;
  – thermography.

The search for evidence at the scene of the crime needs to be systematic and thorough. Evidence can be large objects or on a microscopic scale. The presence of some evidence, such as latent fingerprints, blood or hairs, can only be revealed by techniques used at the scene of crime or by analysis in the laboratory. In many instances, the modern forensic scientist has a range of options for the visualisation of evidence and selects the best method for the situation.

All evidence needs to be handled so that changes are prevented from taking place, and packaged separately.

You need to:

- describe chemical techniques (solvent extraction) for the safe collection of evidence, and the situations in which these techniques are used (for accelerants, drugs and toxins in tissue samples, explosives, and inks from forged documents);
- describe biological techniques (taking blood samples, breath samples, tissue samples, urine samples, swabs from the mouth, body or personal items) for the safe collection of evidence and the situations in which these techniques are used (DNA analysis, alcohol from suspected drink-drivers, drugs and toxins in suspects and at post-mortem);
- describe physical techniques (adhesive tape, forceps, plaster casts, vacuuming) for the safe collection of evidence and the situations in which these techniques are used (collecting hair samples, fibres, footprints, toolmarks, tyreprints);
- explain how the precautions taken during collection prevent contamination of evidence;
- discuss the ethics of retaining samples and data (DNA, fingerprints) from suspects and those convicted of crime and describe the current legal framework;
- discuss the need for an ethical code for forensic scientists.

6.2.2 Methods of Analysis of Evidence

The methods of analysis used by the forensic scientist must be based on established scientific principles if they are to be admissible in court. These analytical techniques cover a number of scientific disciplines and employ a wide range of techniques.

Visual and microscopical methods

You need to:

- use visual methods to match fingerprints, footprints, toolmarks, tyreprints;
- describe the use of dental records in identification;
- describe how microcrystalline tests are used to identify drugs;
- use a microscope to examine evidence (identify natural and man-made fibres, hair structure, the surface structure of pollen grains).

Biological and biochemical methods

You need to:

- explain how insects can be used as biological indicators of time of death and place of death;
- describe the techniques used to identify blood groups (immunological tests) and compare DNA samples (electrophoresis);
- explain why and describe how immunological techniques are used to identify minute traces of drugs in body fluids and body tissues.

Chemical methods

You need to:

- use chemical tests in the identification of organic and inorganic substances;
- describe how chemical tests can be used to identify common explosives and drugs;
- use chromatographic methods to separate mixtures of dyes or inks;
- describe the use of infrared spectroscopy to identify organic substances and materials such as:
  – fibres;
  – explosives;
  – drugs;
  – poisons;
- explain the use of standards, published values of relative retention times and spectra in drawing conclusions.

Physical methods

You need to:

- describe how test firings can identify the weapon used in a crime;
- use measurements and calculations of refractive index to compare samples of glass;
- use density-gradient methods for comparing samples of soil.

6.2.3 Evidence and Proof

From the analyses carried out, the role of the forensic scientist is to provide information previously unknown, or to corroborate information available. The end product of almost any forensic investigation consists of a forensic report. This information may be used by police to trace an offender, or to corroborate other evidence. It may be used by the prosecution, defence, the judge and ultimately the jury, in a trial. The quality of evidence is paramount. It is dependent on the type of evidence itself, and the level of standards employed by the forensic scientist.

You need to produce a report based on a forensic case study to:

- explain why forensic science professionals collect evidence;
- explain how forensic testing is made objective;
- describe the chain of evidence that may lead to a conviction;
- discuss the scientific strengths and limitations of different types of evidence and analytical techniques in assessing the probability of guilt;
- discuss the need to review evidence in the light of new scientific techniques to overturn miscarriages of justice or establish guilt beyond reasonable doubt.

6.3 ASSESSMENT EVIDENCE GRID

Unit 6: Forensic science

What you need to do:

You need to produce evidence of your investigation into forensic science [**50** marks].

This evidence needs to include**:**

AO1: a knowledge and understanding of the need to preserve and record the crime scene, and the chemical, biological and physical techniques used to collect and visualise forensic evidence safely, including ethical considerations [**21**];

AO2: a report on a forensic case study on evidence and proof, including evidence of work which demonstrates the use of calculations to support forensic measurements or observations [**10**];

AO3: at least **one** forensic analysis in **each** of the following areas:
– visual/microscopical,
– biological,
– chemical,
– physical [**19**].

How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will demonstrate a basic knowledge of the need to record and preserve the crime scene, giving some of the techniques used; **[0 1 2]**	you will demonstrate knowledge and understanding of the need to record and preserve the crime scene, describing a range of techniques used; **[3 4]**	you will demonstrate a thorough knowledge and understanding of the need to record and preserve the crime scene with a detailed description and explanation of a wide range of techniques used. **[5]**	
	Your work will show some information on how forensic scientists collect and visualise evidence safely using: chemical techniques; **[0 1]** biological techniques; **[0 1]** physical techniques; **[0 1]**	your work will show research and information on ways in which forensic scientists collect and visualise evidence, safely and appropriately, using: chemical techniques; **[2]** biological techniques; **[2]** physical techniques; **[2]** generally, you will use appropriate scientific terms and conventions correctly;	you will produce an in-depth research report showing understanding of a range of ways in which forensic scientists collect and visualise evidence, safely and appropriately, using: chemical techniques; **[3 4]** biological techniques; **[3 4]** physical techniques; **[3 4]** you will understand the science behind these techniques and use appropriate scientific terms and conventions correctly.	
	Your work will show a basic knowledge of ethical issues involved in retaining samples or data; **[0 1]**	your work will show a range of information on ethical issues related to forensic science; **[2 3]**	your work will show a range of relevant information on ethical issues in forensic science and an understanding of the need for an ethical code. **[4]**	**/21**

Unit 6: Forensic science (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	Your report, based on a case study, will contain some information on evidence and proof including information on the strengths and limitations of some types of forensic evidence; **[0 1 2]**	your report, based on a case study, will contain detailed information on evidence and proof which includes: – the ways in which forensic scientists ensure that the quality of evidence collected and analysed is objective; – strengths and limitations of the analytical techniques used and some interpretation of the probability of guilt; **[3 4]**	your report, based on a case study, will contain researched and relevant detailed information on evidence and proof which includes: – the ways in which forensic scientists ensure that the quality of evidence collected and analysed is objective; – detail on limitations; – strengths and weaknesses of the analytical techniques used; – an understanding of the probability of guilt and of a need to review evidence. **[5 6]**	
	You will complete *straightforward* calculations on forensic data and you will sometimes obtain the correct solutions; **[0 1]**	you will complete *straightforward* calculations on forensic data and you will obtain the correct solutions; **[2 3]**	you will complete more *complex* calculations and you will obtain the correct solutions to an appropriate degree of accuracy. **[4]**	**/10**
AO3	You will safely carry out **one** forensic analysis in **each** of the **four** areas: – visual and microscopical; – biological and biochemical; – chemical; – physical; **[0 1 2 3 4]**	you will carry out at least **one** forensic analysis in **each** of the **four** areas, safely and with some skill; you will use a range of techniques and equipment, repeat some measurements and work with an appropriate degree of accuracy; **[5 6]**	you will carry out at least **one** forensic analysis, in **each** of the **four** areas, safely, skillfully, using different techniques; you will explain why you used the range of techniques and equipment and repeat measurements where appropriate; you will work with an appropriate degree of accuracy throughout. **[7 8]**	
	You will make and record at least **one** set of forensic observations or measurements in each area and display the data obtained; **[0 1 2]**	you will make and record at least **one** set of appropriate forensic observations or measurements in each area, using some precision in your measurements, and display the data accurately in a range of ways; **[3]**	you will make and record at least **one** set of relevant forensic observations and measurements in each area, using the appropriate precision in your measurements, and you will display the data accurately in a range of ways. **[4 5]**	
	You will attempt to process and interpret some results in each of the **four** areas; **[0 1 2]**	you will process and interpret your results in each of the **four** areas; **[3 4]**	you will process and interpret your results in each of the **four** areas in detail, discussing their significance. **[5 6]**	**/19**
			Total mark awarded:	**/50**

6.4 GUIDANCE FOR TEACHERS

6.4.1 Guidance on Delivery

This unit focuses on some of the applications of forensic science that are most likely to be of interest to candidates. Sufficient time needs to be allowed for these topics to be covered in as much depth as is appropriate at this level whilst giving a stimulating learning experience.

The emphasis of the unit is on the practical techniques used by the forensic scientist. Most of the assessed practical elements of the unit require only simple apparatus or easily obtainable chemical reagents. There are opportunities, however, to carry out more sophisticated analyses. Although there are no assessed practical elements in Sub-section 6.2.1 (Recording and collection of evidence), it is hoped that, time permitting, candidates will be given the opportunity to carry out some of these techniques to facilitate their understanding of the science involved. These, along with the practical assessment (AO3), will give opportunities to reinforce the need for quality and objectivity in forensic investigations.

The success of this unit will depend on the availability of up-to-date information and resources. There are numerous websites devoted to forensic science, including one for the Forensic Science Service (www.forensic.gov.uk) which is a good starting point. Where centres anticipate that candidates will find difficulty in locating appropriate sources, case-study material may be substituted.

Recording and collection of evidence

An overview of the reasons for preserving and recording the crime scene needs to be discussed, and then candidates need to research the topic in detail. Modern methods, e.g. thermography, need to be discussed in addition to other methods, e.g. conventional photography.

Candidates need to research the wide range of techniques used to collect and visualise evidence and understand some of the science behind the methods; once again, it is essential that contemporary literature be consulted to review modern techniques. Many techniques are available and the modern forensic scientist chooses those best suited to the situation. It is hoped that candidates will be given the opportunity to try out some of the techniques. They need to be aware of at least **one** of each of the chemical, biological and physical techniques given in Sub-section 6.2.1 (Recording and collection of evidence). The wide variety of fingerprinting techniques available, for both hard and porous surfaces (see *Saferstein*, 2001), should give candidates an early opportunity to evaluate different forensic methods before producing their report in Sub-section 6.2.3 (Evidence and proof). The implementation of precautions to prevent contamination and, as a consequence, the production of a report that is admissible in court, and measures to ensure the safety of the forensic scientist, need to be highlighted.

Candidates need to be aware of the need for forensic scientists to behave ethically: not to offer opinions or conclusions which are untrue or are not supported by accepted scientific data, or to misrepresent their authority or expertise. Candidates need to be aware of, and be able to discuss, the value to the police of retaining samples and data from suspects and those convicted of crimes, the ethical considerations (particularly where there have been no convictions), the current legal framework, and the value and importance of privacy.

Analysis of evidence

Again, the multidisciplinary approach needs to be highlighted. This sub-section needs to constitute the greater part of the unit. Candidates need to carry out at least **one** forensic analysis using each of the following areas:

- visual and microscopical;
- biological;
- chemical;
- physical.

There is a wide range of activities from which to choose, but it must be ensured that these are sufficiently complex to allow the collection and analysis of numerical data. These activities might constitute parts of a crime-scene scenario, which would need careful planning.

The implications of the conclusions drawn from the information and data produced need to be considered. In order to draw conclusions from data, the need to use standards, published chemical data and spectra, and comparisons with databases, should be emphasised. Again, candidates need to consider the forensic implications of the data collected before producing their evaluation in their report in Sub-section 6.2.3 (Evidence and proof).

Evidence and proof

Candidates need to focus on a case study (real or fictitious) and discuss the strengths and weaknesses of the evidence involved. Higher-level candidates should be citing scientific reasons for the high or low level of reliability of the evidence in terms of ‘proof’. These candidates need to be discussing aspects such as points of comparison in fingerprints and test sites, and sex and coding areas in DNA analyses. They may also consider the probability that the evidence has come from a suspect rather than someone else, e.g. consider that a full DNA analysis gives results that are accurate to one in a billion: in a country with a population of 60 million, a match could be considered ‘conclusive’ proof. For higher-level candidates, there is an opportunity to introduce data on gene frequencies and carry out some calculations of allele frequency from data on the occurrence of phenotypes (Hardy-Weinberg equation).

The work of the forensic scientist in assisting in the conviction or acquittal of a suspect depends on quality evidence, and candidates need to research the various ways in which this is ensured. The limitations of types of evidence should be researched and discussed in detail. Candidates also need to discuss the need to review evidence when new scientific techniques are developed. They could examine miscarriages of justice, or cases where contemporary forensic evidence has established guilt. Suitable cases for research and discussion include Mary Druhan, Mark Cleary, Peter Fell, Terry Allen, Omar Raddad, Paul Blackburn, Sheila Bowler, Gary Mills and Tony Poole, John Alexander Dickman, Robert William Hoolhouse, the 'Birmingham Six', the 'Bridgewater Four', Derek William Bentley, the 'Guildford Four', James Hanratty, Judith Minna Ward, Stefan Ivan Kiszko and Timothy John Evans.

6.4.2 Guidance on Assessment

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 6.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at AS level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• At this level, candidates describe in basic terms why the crime scene has to be preserved and recorded before disturbance; • they describe, in basic terms, how a limited number of types of forensic evidence are searched for, then collected safely, using chemical, biological and physical techniques – at least **one** technique from each of chemical, biological and chemical techniques needs to be described; • they give reasons for careful collection of evidence limited to the principles of avoiding contamination and for the safety of the forensic scientist, but give no details; • some basic information on the ethics of retaining samples and data needs to be included;
	2	• at this level, candidates show that some research has been carried out to describe why the crime scene has to be preserved and the principal ways in which this is carried out; • they describe how types of forensic evidence are searched for, indicating that the search is thorough and systematic and give a basic description of the approach; • candidates describe the collection of a range of different types of forensic evidence, using a variety of chemical, biological and physical techniques, giving information on the situations in which these techniques are used; • they give reasons for careful collection of evidence, suggesting how contamination is avoided using the various methods; they describe safety measures taken by the forensic scientist and how risks can be minimised; • their work needs to show information on a range of ethical issues related to suspects and those convicted and to be aware of the current legal framework;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	3	• at this level, candidates describe and explain in detail why, and how, the crime scene is preserved, e.g. first of all defining the crime scene area, then the exclusion of other people, barricading or roping off the area, protection from the elements, positioning of guards; • they explain the need for recording before disturbance and their description of the methods used include modern techniques and where appropriate, the science behind them; • they describe how a variety of different types of forensic evidence are searched for, defining search patterns, if appropriate, and techniques; the candidates then describe how a range of different types of evidence is collected, using chemical, biological and physical techniques and discussing alternative techniques for collecting similar types of evidence; • they give reasons for careful collection of evidence, illustrating how different types of evidence may be subject to different types of contamination and how measures are taken to prevent this; a description of safety measures includes how these prevent risk from a variety of hazards; • their work needs to show an understanding of ethical issues and include relevant points from the current legal framework.
AO2	1	• At this level, candidates complete a report based on some of the bullet points in Sub-section 6.2.3 (Evidence and proof); • candidates can use an actual case study (see Section 6.4 for some suggested examples) or a fictitious one; • candidates outline the need for the collection of quality evidence and define the basic principles involved in standardising methods of analysis; • they describe the chain of evidence that may lead to a conviction; • they state the strengths and limitations of some types of forensic evidence; • candidates include work showing *straightforward* calculations (see Appendix B for examples) which use data from candidates' own practical work or taken from case-study material;
	2	• at this level, candidates complete a report based on the bullet points in Sub-section 6.2.3 (Evidence and proof); • candidates use an actual case study (see Section 6.4 for some suggested examples) or a fictitious one; • candidates outline the need to collect evidence and the procedures for the collection of quality evidence by listing the agencies involved and stating the principles involved in standardising methods of analysis; • they describe the chain of evidence that may lead to a conviction; • they state the strengths and limitations of a range of different types of forensic evidence and carry out some interpretation; • candidates include work showing *straightforward* calculations (see Appendix B for examples) which use a range of data from candidates' own practical work or that taken from case-study material – solutions will be correct;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	**3**	• at this level, candidates complete a report based on the bullet points in Sub-section 6.2.3 (Evidence and proof); • candidates use an actual case study (see Section 6.4 for some suggested examples) or a fictitious one; • candidates describe the involvement of all the various agencies for the collection of quality evidence and explain the processes involved in standardising methods of analysis – they state the limitations, strengths and weaknesses of a wide range of types of forensic evidence, illustrate these with examples for each type and quantify these where appropriate; they show evidence of interpretation in assessing the probability of guilt; • they fully describe the chain of evidence that may lead to a conviction; • candidates give evidence of the need to review in the light of new scientific development; • candidates include work showing *complex* calculations (see Appendix B for examples) which use a range of data from candidates' own practical work or that taken from case-study material – solutions will be correct.
AO3	**1**	• Candidates use a risk assessment to show safe working where appropriate; • they take at least **one** set of forensic measurements from each area of forensic analysis – see Sub-section 6.2.2 (Methods of analysis of evidence); • they record observations and measurements and the data are displayed appropriately, with help; • candidates attempt to interpret the results and relate them to the forensic investigation;
	2	• candidates carry out risk assessments consistent with COSHH guidelines before each relevant activity to show safe working; • they take at least **one** set of forensic measurements from each area of forensic analysis – see Sub-section 6.2.2 (Methods of analysis of evidence); • they work with an appropriate degree of accuracy, using a range of techniques; • they record relevant observations and measurements from the above experiments and the data are displayed accurately, without help; • they display results accurately in a range of ways; • candidates process results, and draw basic conclusions interpreting the results and relating them to the forensic analyses;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	**3**	• candidates take measurements and make observations using the most appropriate techniques and equipment for each type of evidence in Sub-section 6.2.2 (Methods of analysis of evidence); • they repeat measurements, explaining the need to repeat; • they work with an appropriate degree of accuracy; • they record relevant observations and measurements from the above experiments and the data are displayed accurately, without help; • they display results accurately in a range of ways; • candidates draw conclusions interpreting the results and relate them to the forensic investigation.

6.4.3 Resources

Organisations	The Environment Agency; The Forensic Science Service; The Laboratory of the Government Chemist.			
Textbooks	Jackson ARW & Jackson JM	*Forensic Science*	Pearson Education	013 043 251 2
	Nickell J & Fischer JF	*Crime Science*	The University Press of Kentucky 1998	081 312 091 8
	Owen D	*Hidden Evidence*	Quintet Publishing 2001	186 155 365 X
	Platt R	*Crime Scene: The Ultimate Guide to Forensic Science*	Dorling Kindersley 2003	075 134 576 8
	Saferstein R	*Criminalistics*	Prentice-Hall 2001	013 013 827 4
	White P (ed)	*Crime scene to court*	RSC 1998	085 404 539 2
Websites	Contamination and explosives; http://www.fsni.gov.uk/contamtxt.html Crime scene investigator – for collection and visualisation of evidence; www.crime-scene-investigator.net/ Drugs; http://www.druglibrary.org/schaffer/index.HTM http://www.interpol.int/Public/Drugs/synthetic/default.asp Drugs in sport; http://www.biomedcentral.com/1471-8219/1/3 Environment Agency; http://www.environment-agency.gov.uk			

Websites	Ethics in forensic science: http://users.bigpond.net.au/anzfss/ethics.htm FBI's handbook of forensic sciences; http://www.fbi.gov/hq/lab/handbook/intro.htm Fire related case study; http://www.ific.co.uk/code/SampleReport.htm Fire scene investigator, including mass spectrometry; http://www.kore.co.uk/appnote_tcat_fire.htm Firearms; http://www.firearmsid.com/ Forensic odontology; http://www.bafo.org.uk Forensic Science Service – has a comprehensive reading list; http://forensic.gov.uk/forensic Forensic Science weblinks; http://www.tncrimlaw.com/forensic/ George Washington University weblinks; http://www.gwu.edu/~forensic/listofli.htm Laboratory of the Government Chemist; http://www.lgc.co.uk/ Metropolitan Police Service site; http://www.met.police.uk/index National Center for Forensic Science; http://ncfs.ucf.edu/ University of Central Lancashire; http://www.uclan.ac.uk/facs/science/forensic/index.htm UWE's site – Information on forensic science analyses; http://www.uwe.ac.uk/fas/courses/chem/forensic/FSframeintro.htm

7 Unit 7: The Physics of Sport

[AS level, double award, optional, internally assessed]

7.1 ABOUT THIS UNIT

This AS level unit is an optional part of the double award only and is internally assessed.

A sporting event is an experiment to determine the best player or team. It is a complicated experiment, because there are so many variables, but on the day, the result may be determined by some simple measurements.

The popularity of, and participation in, sport is world-wide and is a multi-billion pound business, with manufacturers spending huge sums on product development and promotion, and successful performers gaining fame and fortune.

Sport provides employment for many people across the world – not only in performance and manufacturing but also in a wide range of ancillary services, such as provision of facilities, medicine, catering, publishing, transport and so on.

The range of sports is enormous and encompasses the events of the summer and winter Olympics, professional team games, motor sports, aviation, rock climbing, angling etc.

Where appropriate, you should consider ethical issues linked to the content of this unit, e.g. expenditure on materials and developments/spin off for other applications, consumption of raw materials, use of drugs/special diets to enhance performance, improvement of health and fitness of general population.

Competitive players want to monitor and improve their own performance and their equipment. It is often helpful to know why and how things happen.

The unit builds on the content of GCSE Science and Applied Science, especially the work on forces, motion, light and waves. It is supported by Unit 2: *Analysis at work* and Unit 3: *Monitoring the activity of the human body* and complements much of Unit 11: *Materials for a purpose* and Unit 16: *Working waves*.

This unit could be studied simply out of interest, to provide balance in your AS course, or to prepare for higher education courses which include aspects of sport or physics.

This unit is assessed through your portfolio work. The mark on that assessment will be your mark for the unit. You will produce a series of **six** short guidance leaflets for the coaches at a sport and recreation centre to help them answer questions of a technical nature from their trainees. Your evidence will include:

- A '*Measurement in Sport*' leaflet which will include the units, devices and techniques used for making measurements of **five** different quantities in specified sports of your choice;
- A '*Seeing in Sport*' leaflet which will include the structure of the eye and how it forms an image, related to **one** chosen sport where good vision is of critical importance;
- A '*Movement in Sport*' leaflet which will include an account of how chemical energy is most efficiently converted into useful mechanical work using the muscles, bones and joints of **one** or more limbs and related to **one** chosen sport where efficient movement is of critical importance;
- A '*Choice of Ball Material*' leaflet which will include the required material properties and how these are achieved in **one** specified type of ball;
- An '*Equipment in Sport*' leaflet which will include the required material properties, and how these are achieved, in **one** or more other chosen item of sports equipment;
- A '*Technique in Sport*' leaflet which will include **one** example related to a specified sport of your choice of either collisions, trajectories of moving objects or lift, e.g. in aerofoils.

One of the leaflets '*Movement in Sport*' or '*Technique in Sport*' will include examples of relevant calculations.

Your evidence will also demonstrate that you have obtained information by experimental investigation relating to **one** or more of your leaflets.

7.2 WHAT YOU NEED TO LEARN

You need to learn about:

- measurement;
- physics of the body;
- physics of equipment and techniques.

7.2.1 Measurement

Most sports events have an element of competition. Large amounts of glory, personal pride and money may depend upon the result. It is important to make accurate measurements to determine who was fastest, highest, strongest, etc.

During training and preparation for an event, sportsmen and women may wish to monitor the performance of their body and their equipment.

Measurements are made by comparing objects or events with internationally-agreed standards.

You need to:

- know the SI units of:
  – mass;
  – length;
  – time;
  – temperature;
  – pressure;
  – force;
  – weight;
  and their multiples and submultiples;
- know the practical units used for measurement in sport, such as:
  – mm Hg;
  – °C;
  – calories;
  and how they relate to the SI units;
- carry out calculations and conversions using SI and other units;
- know about the range of devices and techniques for making measurements in sport and explain the need for calibration and the limitation of these devices:
  – manual clockwork and electronic clocks/stopwatches;
  – mechanical and optical timing gates;
  – rules and tape measures;
  – manometers and pressure cells;
  – mercury/glass thermometers, thermistors;
  – clip-on pulse monitors;
  – radar;
  – data logging;
- carry out and record measurements using sports equipment or laboratory equivalent;
- use formulae and equations to solve problems involving force, mass, acceleration, momentum, work, energy and power;
- use vectors to solve problems involving velocities or forces.

7.2.2 Physics of the Body

The eyes provide much of the information used by sportsmen and women during their performance. You need to examine the physical principles involved in the eye. The musculo-skeletal system functions as a series of connected levers actuated by muscles under the control of the central nervous system (CNS). You need to investigate the mechanical principles involved. The use of energy for movement will be considered.

You need to:

- know the basic anatomy of the eye:
  – cornea;
  – iris;
  – cilliary muscles;
  – lens;
  – aqueous and vitreous humour;
  – retina;
  – rods and cones;
  – optic nerve;
- describe the formation of a real image with a + lens and relate this to the eye;
- describe the optical function of each of the parts of the eye listed above;
- describe the effects of colour filters on white/day/flood light and explain how the use of coloured contact/spectacle lenses may help sports players, e.g. tennis, aviation;
- know the principle of conservation of energy;
- know that muscles are not very efficient at converting chemical energy to mechanical work done;
- apply the principle of moments to bone/muscle joints, calculate in/output forces, mechanical advantage, velocity ratio, and show how the angle between the bone and the muscle affects the forces involved;
- explain why exercise produces heat and its implications in endurance events such as marathon running.

7.2.3 Physics of Equipment and Techniques

Performance in many sports has been dramatically improved by the use of 'new materials'. New materials are expensive to develop and their first use is often in high cost/high reward applications such as defence, aerospace, medicine, Formula 1 motor sport, professional golf and tennis. You need to examine the physical properties that are useful in sport materials and how they affect performance.

Many sports techniques may be analysed by applying basic physical principles.

You need to:

- know the principles of conservation of energy and momentum;
- know what is meant by the coefficient of restitution;
- know the meaning of terms used to describe the physical properties of materials:
  – strength;
  – elasticity;
  – stiffness;
  – density;
  – toughness;
  – brittleness;
- describe the typical properties of:
  – metals;
  – ceramics;
  – polymers;
  – 'old' composites such as wood and leather;
- explain what is meant by a composite material;
- research the use of new materials in a range of sporting applications and show why a particular material was used for a particular job and explain the advantage to the player;
- design and carry out a safe experiment to determine the coefficient of restitution for a ball of your choice.

Many sports events involve the interchange of kinetic energy, gravitational potential energy and elastic potential energy. You need to calculate or make reasonable estimates of these quantities.

You need to:

- calculate the energy and momentum involved in diverse examples of sports;
- apply conservation of energy and momentum to simple sporting examples such as the collision of snooker balls, rugby players, bats and balls;
- explain the effects of spin on the trajectory and bounce of a ball;
- explain how sails and wings produce forces for motion and lift;
- show that rotating objects have both kinetic energy and momentum, and explain how a change in shape may lead to a change in rate of rotation and apply this to various sporting examples.

7.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 7: The physics of sport

What you need to do:

You need to produce a series of **six** short guidance leaflets for the coaches at a sport and recreation centre to help them answer questions of a technical nature from their trainees:

- A *'Measurement in Sport'* leaflet which will include the units, devices and techniques used for making measurements of **five** different quantities in specified sports of your choice;
- A '*Seeing in Sport'* leaflet which will include the structure of the eye and how it forms an image, related to **one** chosen sport where good vision is of critical importance;
- A '*Movement in Sport'* leaflet which will include an account of how chemical energy is most efficiently converted into useful mechanical work using the muscles, bones and joints of **one** or more limbs and related to **one** chosen sport where efficient movement is of critical importance;
- A '*Choice of Ball Material'* leaflet which will include the required material properties and how these are achieved in **one** specified type of ball;
- An '*Equipment in Sport'* leaflet which will include the required material properties and how these are achieved in **one** or more other chosen item of sports equipment;
- A '*Technique in Sport'* leaflet which will include **one** example related to a specified sport of your choice of either collisions, trajectories of moving objects or lift, e.g. in aerofoils.

Please note: **One** of the leaflets *'Movement in Sport'* or *'Technique in Sport'* needs to include examples of relevant calculations.

You also need to produce evidence that you have obtained information by experimental investigation relating to **one** or more of your leaflets [**50** marks].

How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will demonstrate some knowledge and understanding of the facts, phenomena and principles involved in the unit in your: • *'Measurement in Sport'* leaflet **[0 1]** • *'Seeing in Sport'* leaflet **[0 1]** • *'Movement in Sport'* leaflet **[0 1]** • *'Choice of Ball Material'* leaflet **[0 1]** • *'Equipment in Sport'* leaflet **[0 1]** • *'Technique in Sport'* leaflet **[0 1]**	you will demonstrate an extensive knowledge and understanding of the facts, phenomena and principles in your leaflets; there may be minor omissions but there are no serious scientific errors in your: • *'Measurement in Sport'* leaflet **[2]** • *'Seeing in Sport'* leaflet **[2]** • *'Movement in Sport'* leaflet **[2 3]** • *'Choice of Ball Material'* leaflet **[2]** • *'Equipment in Sport'* leaflet **[2]** • *'Technique in Sport'* leaflet **[2 3]**	you will demonstrate comprehensive and detailed knowledge and understanding of the facts, phenomena and principles in your: • *'Measurement in Sport'* leaflet **[3]** • *'Seeing in Sport'* leaflet **[3]** • *'Movement in Sport'* leaflet **[4]** • *'Choice of Ball Material'* leaflet **[3]** • *'Equipment in Sport'* leaflet **[3]** • *'Technique in Sport'* leaflet **[4 5]**	**/21**

Unit 7: The physics of sport (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	You will show that you sometimes select the relevant principles relating to the selections and that you have some success in using them in the explanation in your: • *'Choice of Ball Material'* leaflet **[0 1]** • *'Equipment in Sport'* leaflet **[0 1]**	you will show that you usually identify the underlying principles relating to the selections; although there may be minor errors and omissions, your explanations will be clear and accurate in your: • *'Choice of Ball Material'* leaflet **[2]** • *'Equipment in Sport'* leaflet **[2]**	you will show that you accurately identify the underlying principles relating to the selections and you will correctly use the principles to give a clear, accurate and thorough explanation in your: • *'Choice of Ball Material'* leaflet **[3]** • *'Equipment in Sport'* leaflet **[3]**	
	You will show that you can perform basic calculations correctly but you rarely apply mathematical techniques in an appropriate way in your: • *'Movement in Sport'* or *'Technique in Sport'* leaflet **[0 1]**	you will show that your use of mathematics is generally accurate and appropriate in your: • *'Movement in Sport'* or *'Technique in Sport'* leaflet **[2 3]**	you will show that you use mathematical techniques confidently, accurately and appropriately and where relevant to enhance the explanations in your: • *'Movement in Sport'* or *'Technique in Sport'* leaflet **[4]**	**/10**
AO3	You will show that you can plan a simple experiment and conduct it safely; **[0 1 2]**	you will show that you can plan an experiment and conduct it safely; you produce and follow a risk assessment which covers the majority of safety issues; **[3 4]**	you will show that you can plan and conduct an experiment safely in accordance with your risk assessment which is comprehensive and realistic. **[5 6]**	
	You will show that you have used a range of equipment and conduct the investigation safely to obtain some valid data; **[0 1 2]**	you will show that you have used a range of equipment and techniques and conduct the investigation safely to obtain adequate valid data and repeat measurements; you record data in a suitable form and usually to an appropriate degree of precision; **[3 4]**	you will show that you have used a wide range of techniques and equipment and conduct the investigation safely to obtain ample valid data and repeat measurements; you record data clearly and to an appropriate level of precision. **[5 6]**	
	You will give some interpretation of the results, and relate these to the investigation; **[0 1 2 3]**	you will interpret the results and draw basic conclusions relating to the investigation; **[4 5]**	you will interpret the results in detail and draw conclusions, discussing their significance to the investigation. **[6 7]**	**/19**
			Total mark awarded:	**/50**

7.4 GUIDANCE FOR TEACHERS

7.4.1 Guidance on Delivery

This unit focuses on some of the applications from Unit 11: *Materials for a purpose*. This unit allows for extensive coverage of such applications within the context of the vocational area of sport.

The emphasis of the unit is to develop an understanding of how physical factors of science influence the effect and performance of sport. Candidates need to consider how the technology behind sporting equipment has enabled the performance of sportsmen and women to be improved. Candidates need to refer to information from everyday sources such as advertisements, magazine articles and websites.

Throughout the unit, candidates need to be encouraged to carry out their own research into how the physics of materials affects sporting equipment and subsequent sporting performance.

Measurement

An overview and discussion of the reasons why accurate measurements in the sporting world are of such importance needs to be undertaken. This section builds on work at Key Stage 4 and GCSE Applied Science in relating the scientific and physical units used.

Candidates need to become familiar with SI units and submultiples. Candidates need to use and convert these units in context with sporting measurements, e.g. weight- or power-lifting and the use of kilograms (kg) and pounds (lbs), time in relation to seconds, hundredths and thousandths of a second.

Such understanding of SI units can be taught through isolated exercises involving conversions and calculations or through experimental methods and techniques.

Candidates need to research and study the range of devices and techniques that allow measurement in sport to be made. These can be researched and investigated through experimental work. Candidates themselves could engage with sports or training equipment such as treadmills, exercise bikes, rowing machines, running, swimming and cycling. Candidates can record and monitor timings, changes in body temperature, peak flow – lung capacity, pulse and heart rate. Data logging equipment, such as that from *Phillip Harris,* can be used to monitor such changes, and data developed, manipulated and presented in different formats. Devices need to be calibrated as part of experimental procedures, evidence that can then be used to assess the limitations of devices and comparisons can be made, e.g. manual clock versus electronic stop-clock.

Physics of the body

A variety of assessment activities can be used to measure achievement of the outcomes in this section. These need to involve candidates in a practical analysis, where possible, and need to be supported by scientific analysis, highlighting the relevant biological and physical principles. This needs to be supported by relevant external visits to facilities where biomechanical analysis takes place. Coaches and guest speakers will support the delivery and add relevance to underpinning knowledge.

One approach to this section is to overlap relevant text from GCE Physics and Human Biology. Candidates need to be familiar with the central nervous system from the relevant GCE Biology text. A diagram/model will help candidates to gain a better understanding of the anatomy of the eye. For knowledge of real images, the use of ray diagrams can aid the understanding of this area.

Candidates can research new vision technology to understand how contact lenses and spectacles can help sports players in areas such as tennis, snooker and aviation. Candidates can investigate wavelength changes through experimental work to determine how coloured filters affect white light.

The principle of moments can be taught instructively and calculations used to support this. To optimise movement in sport and exercise, the coach or instructor needs to be aware of how the force generated by muscle groups across a joint can be used to develop a range of movement in other joints and muscle-groups.

Physics equipment and techniques

Candidates need to research relevant/related articles from newspapers, magazines, journals and websites to appreciate how the performance in many sporting areas has been improved by the use of new materials such as composites.

Candidates need to learn through discussion to enable them to appreciate that the change in ‘physical properties’ of materials has improved performance in many sporting areas, such as professional tennis, golf, skiing, rowing, and motor racing. By improving the physical properties of a material, the energy and momentum of performance can be changed and candidates need to be clearly taught about the principles of ‘conservation of energy and momentum’ through instructive and experimental delivery.

GCE Physics texts will provide further explanations on rotating objects – circular motion having both kinetic energy and momentum, and how a change in shape may lead to a change in rotation when applied to various sporting examples, e.g. discus, hammer and badminton. **One** such experiment can be followed through the SATIS module.

Candidates need to show a clear understanding of physical properties terminology to enable them to differentiate between strength, elasticity, toughness, brittleness, stiffness and density. These properties need to be considered carefully when designing new sporting equipment. A small change in density of a material can have a significant effect on the performance of equipment. Candidates also need to be made aware that there is a great deal of dependency on each property in relation to others and compensation is often needed with physical properties when designing performance materials. Candidates need to refer to a glossary on physical properties similar to that used in Unit 11: *Materials for a purpose* and to identify, select and process information. It would be preferable to introduce the properties as they arise in discussions of materials types, perhaps also encouraging candidates to build up their own list of definitions.

One approach to teaching about a class of materials is to start with a set of **ten** or more samples that are in the teaching environment or are brought in from outside. These will include types of metals, ceramics, polymers and old composites and new, e.g. glass-reinforced plastic. Candidates can then work in groups to discuss what properties the samples have that make them suitable for their given purpose. Some of the items may well include sporting equipment, e.g. cricket bat, tennis racket or fishing rod.

The study of the effects of spin on the trajectory and bounce of a ball along with forces and motion of sails can be followed through GCE Physics and Sports Science texts.

7.4.2 Guidance on Assessment

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 7.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at AS level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
	Mark Band	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• Candidates produce **six** leaflets outlining the facts, phenomena and principles; • the summaries include relevant material that they have researched;
	2	• candidates demonstrate a sound and detailed understanding of the facts, phenomena and principles; • this may include analysed scientific data, but may have few minor omissions but scientific data is precise;
	3	• candidates give a full and comprehensive demonstration of knowledge and understanding of facts, phenomena and principles; • candidates show detailed evidence of these.
AO2	**1**	• Candidates select appropriate materials for each of the chosen applications; • a clear explanation of each technique is required; • candidates perform basic calculations to support some mathematical input;
	2	• candidates identify clearly the underlying principles relating to choice of materials for each of the applications with only minor omissions or errors; • candidates show appropriate use of mathematics to support their work;
	3	• candidates identify clearly and accurately the underlying principles relating to choice of materials for each of the applications; • a detailed explanation of the principles is required; • candidates show confident and accurate use of mathematical techniques – these are appropriate and relevant to enhancing detailed explanations.
AO3	**1**	• Candidates present a simple experimental plan that shows awareness of safety; • the experiment shows the use of a range of equipment in obtaining valid data; • investigative work has been carried out safely – interpretation of results has been undertaken and related to investigation;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	2	• candidates use a range of techniques and equipment; • investigation conducted safely to obtain adequate and valid data; • repeat measurements undertaken as part of the investigation; • recorded data is presented in a suitable format with an appropriate degree of precision; • interpretation of results is undertaken and basic conclusions relating to the investigation are drawn;
	3	• candidates use a wide range of techniques and equipment; • investigation conducted safely to obtain adequate and ample data; • repeat measurements undertaken as part of the investigation; • clearly recorded data to an appropriate level of precision; • undertake detailed interpretation of results and draw conclusions; • discuss conclusions' significance to the investigation.

7.4.3 Resources

Publications	Advanced GNVQ Unit 2: Investigating materials and their uses, Page 66-122 Heinemann GNVQ Advanced Assignments, Nuffield Science in Practice, Unit 2: Investigating materials and their uses, Assignment 7: Spectacle lenses p 61-72 SATIS 14-16 Unit 209: Information on contact lenses Assignment 9: Modifying materials p 79-87 SATIS 16-19 Science and technology in society Units 76-100 1992 Unit 99: Making a racket Unit 100: Racket games – the physics of rackets 086 357 163 8
Textbooks	Beashel P & Taylor J — *Sport Examined* — Nelson Brimicombe M — *Physics in Focus,* Chapters 3, 5 and 27 — Nelson — 1990 — 017 448 1748 Hawkey R — *Sport Science* — Hodder — 1991 Leybold H — *Physics Catalogue of Experiments* Chapters 7,8,9,and 34 Parker K & Parry M — *Physics of Sport* (*Supported Learning in Physics Projects)* — Heinemann — 043 568 845 6 Wirhed R — *Athletic Ability and the Anatomy of Motion* — Mosby-Wolfe — 1997

Websites	Altis: Links to tennis science, basic physics of rowing http://altis.ac.uk/browse/cabi/8cfb10d3dd0ae49a87320653cbfa587e.html Australian Academy of Science: Measurement in sport – the long and the short of it http://www.science.org.au/nova/033/033key.htm Exploratorium: Sport Science – Baseball, skateboard, surfing, cycling, hockey http://www.exploratorium.edu/sports/ Links http://www.teach-nology.com/teachers/subject_matter/physical_ed/physics/ Science of Motor Racing http://www.science.ie/scopetv/content/ The physics of sports: Swimming, baseball and softball, ice hockey and figure skating, basketball, soccer, track, cycling, golf, auto racing, American football, tennis, gymnastics http://home.nc.rr.com/enloephysics/sports.htm Winter Olympics, Sport and Science, Physics and Biomechanics The Physics of Luge The Science of Jumping and Rotating http://btc.montana.edu/olympics/physbio/default.htm

8 Unit 8: Investigating the Scientist's Work
[A2 level, mandatory, internally assessed]

8.1 ABOUT THIS UNIT

This A2 level unit is mandatory and is internally assessed.

The production of new and improved products is dependent on innovative technology and research. Research advances knowledge and technology and provides trained scientists to meet the needs of industry. Scientists are not only involved in scientific work but they also need to be able to communicate, plan and have good organisational skills. It is essential that the outcomes of any research or analytical work are accurately recorded and clearly presented.

This unit provides an opportunity to work as a research scientist, and to use the knowledge and skills that you have developed in previous work to complete an extended investigation into a topic which you can research and study in depth. It will give you the opportunity to increase your practical competence and organisational skills and allow you to increase your confidence to work both independently and with your colleagues.

This unit extends the work covered in the AS units and gives an opportunity for synoptic assessment. It draws together the skills and knowledge from all parts of the mandatory units. There are strong links involving planning opportunities within Unit 4: *Cells and molecules*, and involving techniques within Unit 9: *Sampling, testing and processing.* This unit also offers the chance to build on knowledge and further investigative work from other units, both AS and A2. It can also complement A2 units in GCE Chemistry, Biology, Physics and Psychology.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will produce an information pack, which can be used and understood by a group of scientific research technicians. Your evidence will include:

- a detailed and workable plan for **one** scientific vocational investigation, to include aims and objectives, full details of experimental work, and constraints under which you will need to work, with documented evidence of research;
- a record of the data collected and how it was processed and interpreted;
- evidence to show how the plan was implemented safely and an evaluative scientific report on the outcomes of the investigation suitable for the technicians to understand and use.

8.2 WHAT YOU NEED TO LEARN

You need to learn about:

- planning an investigation;
- carrying out the investigation;
- processing and presenting data from the investigation;
- evaluating the investigation;
- presenting the outcomes of the investigation.

8.2.1 Planning an Investigation

An essential skill of a working scientist is to plan and organise the work they do. Using time effectively and keeping to deadlines are important in daily work schedules. In this unit, you will aim to work as a research scientist, and will complete an investigation which will allow you to study in depth a project that brings together the skills and knowledge you have gained from previous units. Your investigation, which needs to be related to a vocational context, needs to be carefully planned. Your plan needs to cover the whole investigation, not just the experimental work. In the workplace, teamwork forms an essential part in the efficient running of an organisation. To reflect the real work situation, teamwork can contribute towards part of your investigation, but you need to include your own individual evidence.

For the plan, you need to:

- carry out suitable research on the chosen topic;
- decide on the aim of the investigation;
- set realistic and achievable tasks (objectives);
- organise both the time availability and the use of specialist facilities;
- identify and use suitable secondary sources of information to select the relevant material;
- make suitable checks for the validity of the information chosen;
- select appropriate techniques and equipment to obtain the primary data;
- identify any constraints and their effect on what you can do;
- research and use the relevant health and safety regulations;
- consider any ethical implications.

8.2.2 Carrying Out the Investigation

You will have the opportunity, in this part of the unit, to use your organisational and practical skills. This part of the investigation involves implementing your plan. You need to follow the necessary procedures correctly and safely in order to gather sufficient primary data to allow the objectives to be achieved. You need to work to the deadlines you have set and, as in a work situation, make appropriate changes or modifications to your work if you are not achieving the required outcomes. You need to show you can work independently and call on colleagues if and when required. Accuracy in recording results is an important part of investigative work. You need to record all relevant observations and measurements as you complete your experimental work.

You need to know how to:

- carry out risk assessments and comply with health and safety regulations;
- order the required equipment to carry out the experimental procedures;
- if necessary, carry out trials to check that specific techniques or procedures will provide the data required;
- use the techniques and procedures chosen to obtain primary data (either quantitative or qualitative) accurately and reliably;
- work to deadlines set and make any changes as appropriate;
- check accuracy and reliability of data throughout the project, making any changes as required;
- record accurately the data you collect in an appropriate format (any quantitative data needs to be recorded to the required precision);
- identify the need to repeat any work or collect additional data where appropriate;
- use an appropriate sampling method to obtain a representative sample.

8.2.3 Processing and Presentation of Data from the Investigation

One of the skills of a good scientist is the ability to present the results and outcomes from experimental or research work in a clear and concise way. This work needs to be suitably presented so that it can be interpreted correctly.

The data you have gathered from your investigative work needs to be processed by carrying out calculations and plotting graphs, and then presented in a suitable format. You need to be aware of the variety of ways this can be done so it is suitable for the audience for which it is intended.

You need to know how to:

- group data to make analysis easier;
- select and use appropriate methods to process data;
- use standard methods to carry out calculations and graphical methods to display any qualitative data;
- deal with any anomalous data;
- present results in suitable and effective ways.

8.2.4 Evaluation of the Investigation

At the beginning of your investigation, you set both aims and objectives. You now need to evaluate the results and any data you have collected and come to valid conclusions. It is important in all scientific work that the outcomes recorded are accurate and reflect what has been carried out. The outcomes are not always as expected and therefore you need to comment on whether the methods you used were suitable, or maybe give recommendations on what could be carried out in the future if others continued working on similar topics.

You need to know how to:

- interpret the results and identify any sources of error;
- draw conclusions which are valid in relation to the data collected and to the purpose of the investigation;
- evaluate the methods used and if appropriate make recommendations for improvements to the investigation.

8.2.5 Presentation of the Outcomes of the Investigation

An essential skill for scientists is the ability to share their work with others. Those involved can range from other scientists with good scientific knowledge to interested members of the public. A final part of the scientist's work is to produce a report, which evaluates to what extent the aim of the investigation has been achieved.

You need to know how to:

- produce a clear and accurate report of the outcomes of the investigation which could be used and understood by research technicians (this report could be a written report, presentation poster, video or any other appropriate medium);
- set out the report in a way that is logical, well structured, concise and clear;
- use scientific terminology accurately.

8.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 8: Investigating the scientist's work				
What you need to do:				
You need to produce an information pack, which can be used and understood by a group of scientific research technicians [**50** marks]. This evidence needs to include**:** **AO1:** a detailed and workable plan for **one** scientific vocational investigation, to include aims and objectives, full details of experimental work, and constraints under which you will need to work, with documented evidence of research [**10**]; **AO2:** a record of the data collected and how it was processed and interpreted [**14**]; **AO3:** evidence to show how the plan was implemented safely and an evaluative scientific report on the outcomes of the investigation suitable for the technicians to understand and use [**26**].				
How you will be assessed:				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO1	You will produce a workable and clearly presented plan for **one** investigation linked to a vocational context; the plan shows a basic knowledge of the scientific principles and experimental techniques involved; **[0 1 2]**	you will produce an achievable and logically presented plan, for **one** investigation with direct vocational involvement which shows a sound knowledge and understanding of the aims and objectives set; **[3]**	you will produce a comprehensive, realistic, achievable and logically presented plan for **one** suitable investigation which demonstrates thorough knowledge and understanding of the aims and objectives. **[4 5]**	
	You will show evidence of selected research about suitable experimental work and health and safety, identifying information on deadlines you will need to be aware of; **[0 1 2]**	you will show evidence of a wide range of relevant research, selected from a number of sources with suitable validation, identifying constraints you will have to work under and how they can be overcome; **[3]**	you will show evidence of thorough research and suitable selection of information from a wide range of sources, identifying and discussing constraints, their effect and suitable contingency plans. **[4 5]**	**/10**
AO2	You will record the results of the investigation and present them in a suitable format; **[0 1]**	you will produce a description and explanation of the results presented in a suitable format; **[2 3]**	you will record and present the results of the investigation in a suitable manner and provide a detailed explanation. **[4]**	
	You will show limited processing and interpretation of the data collected with a suitable link to the vocational context set; **[0 1 2]**	you will show suitable processing and interpretation of the data collected, relating to the objectives of the investigation; **[3]**	you will show evidence that the appropriate method of processing has been selected and used and any anomalous data identified and evaluated; a critical analysis of the results relating to the objectives of the investigation. **[4 5]**	
	You will carry out a number of completed straightforward calculations; **[0 1 2]**	you will carry out a number of complex calculations completed with partial success; **[3]**	you will carry out a number of complex calculations to completion, obtaining the correct solutions to the appropriate degree of accuracy. **[4 5]**	**/14**

Unit 8: Investigating the scientist's work (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO3	You will provide evidence that the experimental procedures or trials in the investigation have been safely and correctly carried out and repeated where necessary using risk assessments; **[0 1 2]**	you will show evidence that a range of experimental techniques and procedures has been safely and skilfully completed, using suitably detailed risk assessments, within the constraints of the plan; you will demonstrate that an appropriate degree of accuracy has been used; **[3 4]**	you will show evidence that a wide range of experimental techniques and procedures has been safely, skilfully, accurately and independently completed, using risk assessments which you have produced. **[5 6]**	
	You will produce a record which shows that the plan has been followed and monitored; **[0 1 2]**	you will record any modifications or changes needed to be made, providing reasons for the changes; **[3]**	you will carry out and provide explanations of any strategies used to overcome any deficiencies or constraints of the plan. **[4 5]**	
	You will produce a clear and accurate report of the outcomes of the investigation, using basic scientific terminology correctly, which can be understood by research technicians; **[0 1 2]**	you will produce a logical and accurate report of the outcomes of the investigation, using scientific terminology correctly, which can be understood and used by research technicians; there is evidence to show understanding of the scientific concepts involved in the investigation; **[3 4 5]**	you will produce a logical and well-structured report of the outcomes of the investigation using all the appropriate scientific terminology, suitable for use by scientific technicians; this will show a high level of scientific knowledge and understanding relevant to the investigation and its applied implications. **[6 7]**	
	You will interpret the data; **[0 1]**	you will assess the reliability of the data and how well the investigation achieved its aims; **[2 3]**	you will discuss the reliability of the investigation with a detailed scientific discussion of how the investigation achieved its aims and objectives. **[4]**	
	You will produce a basic evaluation of the investigation; **[0 1]**	you will produce an evaluation of the investigation; **[2 3]**	you will produce a critical evaluation of the investigation, incorporating suitable amendments where appropriate. **[4]**	**/26**
			Total mark awarded:	**/50**

8.4 GUIDANCE FOR TEACHERS

8.4.1 Guidance on Delivery

The intention is that this unit will provide candidates with time to work on projects that reflect the activities of scientists in the workplace. It has been designed to allow candidates scope to draw on knowledge, understanding and skills gained from other units, as well as knowledge which will be gained specifically for this investigation. The investigation needs to, as far as possible, replicate a real working situation and be subject to constraints of deadlines, support and resources. The topic chosen needs to have some vocational/real life context.

Planning an investigation

Sub-section 8.2.1 (Planning an investigation) provides opportunities for candidates to determine their own aims and objectives, although they need to agree these before beginning the investigation, (**one** overall topic could be set for a group if staff are not confident in candidates working on different investigations). Research needs to include accessing secondary sources (paper-based, electronic and human) and making decisions about what is relevant and what needs to be disregarded. The investigation may be devised in liaison with industry, universities or institutions such as hospitals or other service providers if the appropriate contacts can be found. In this instance, plans need to be made to fit in with the organisation concerned.

Candidates need to be aware of:

- the necessary scientific knowledge, theories, concepts and ideas;
- the time available, including access to laboratories and computer facilities;
- resources including chemicals, apparatus, support materials;
- health and safety requirements;
- travel costs, risk assessments etc. if required;
- any ethical issues which may need to be considered, e.g. guidance on testing.

Carrying out the investigation

In the workplace, scientists need to work reliably, accurately and with precision. The practical work that candidates carry out needs to be at A2 standard and give them the opportunity to work accurately and to the appropriate precision, e.g. when choosing the appropriate instrument/piece of apparatus. The investigation needs to be targeted at this level and allow candidates to learn some new techniques, as well as using ones covered in previous units. Candidates may work within a team, but where this happens, the work of other members of the group needs to be fully acknowledged. Candidates, however, need to show individual results and conclusions. Any teamwork needs to be acknowledged in the plan.

Processing and presenting data

Techniques for processing data include arithmetic, statistics, use of equations, use of spreadsheets, graphs and gradients. Formats for recording data include text, charts, tables, diagrams, bar charts, histograms and graphs. Candidates need to have practice in processing data before they use the techniques in their investigation.

Presenting the outcomes of the investigation

The completion of this work gives candidates the opportunity to present the outcomes of their investigation in a variety of ways: a written report, a verbal presentation with evidence of what was said, e.g. a PowerPoint presentation, suitable leaflets/booklet.

The complete evidence for this unit is an information pack, which includes all the evidence to cover all assessment objectives.

Suggested ideas for investigations

- Investigation into the properties of polymers (physical and chemical)
- Fermentation
- Enzyme activity
- Physics of moving objects
- Vitamin C and iron in foods
- Investigations involving: smokers, peak flow, cardiac recovery, exercise
- Environmental investigations

8.4.2 Guidance on Assessment

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 8.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• The plan includes evidence that candidates have demonstrated some knowledge and understanding of science, recognised and recalled facts and have included some scientific terminology and practical techniques; • they have selected, organised and presented the information for the plan from information that has been provided or acquired through their own research; • details for the plan include information as shown in Sub-section 8.2.1 (Planning an investigation) – some omissions are acceptable at this level;
	2	• candidates' work has few omissions or inaccuracies though some areas may not be as extensively covered as others; • the plan includes evidence that candidates have recognised and recalled facts, terminology and practical techniques; • they have selected, organised and presented the information for the plan from information that has been acquired through their own research; • details for the plan includes information as shown in Sub-section 8.2.1 (Planning an investigation) – some detailed information is needed on some bullet points listed;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	3	• candidates' work demonstrates that they have used their knowledge and understanding from other units in the specification with no omissions; • the plan includes evidence that candidates have recognised and recalled facts, principles, concepts and practical techniques and used scientifically terminology accurately; • they have selected, organised and presented relevant information for the plan from information that has been acquired through their own research; • details for the plan include information as shown in Sub-section 8.2.1 (Planning an investigation) – detailed and logical information is needed on all bullet points listed.
AO2	1	• Candidates' evidence gives limited processing and interpretation of the data collected in the investigation with some link to a vocational input; • the data processed and presented includes evidence that candidates have completed some descriptive work, some explanation and carried out *straightforward* calculations (see Appendix B), sometimes obtaining the correct solutions; • a record of the data collected and how it was processed which includes the details as shown in Sub-section 8.2.3 (Processing and presentation of data from the investigation);
	2	• candidates' evidence gives suitable processing and interpretation of the data collected in the investigation with a link to the vocational context; • the data processed and presented includes evidence that candidates have completed descriptive work, explanation and carried out some *complex* calculations (see Appendix B) with partial success; • a record of the data collected and how it was processed which includes the details as shown in Sub-section 8.2.3 (Processing and presentation of data from the investigation);
	3	• candidates' evidence indicates that the appropriate method of processing has been selected and applied to the data collected in the investigation; • the outcomes have been linked to the vocational context chosen; • the data processed and presented includes evidence that candidates have described, interpreted and evaluated and carried out some *complex* calculations (see Appendix B), obtaining the correct solutions to an appropriate degree of accuracy; • a record of the data collected and how it was processed which includes the details as shown in Sub-section 8.2.3 (Processing and presentation of data from the investigation);

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	1	• Candidates produce evidence which indicates that they have carried out practical tasks safely, using risk assessments, with the results suitably recorded; evidence of how the plan for the investigation was safely implemented and followed; • this includes a record of coverage of most of the bullet points in Sub-section 8.2.2 (Carrying out the investigation); • candidates produce a clear and accurate report providing some interpretation of results with a basic evaluation (this report can be a written report, presentation poster, video or any other appropriate medium) suitably presented for the given audience; • evidence shows that basic scientific terminology has been used correctly; • candidates at this level are expected to show basic coverage of the requirements of Sub-sections 8.2.4 (Evaluation of the investigation) and 8.2.5 (Presentation of the outcomes of the investigation) – some omissions are acceptable;
	2	• candidates produce evidence which indicates that they have carried out all practical tasks safely and skilfully using suitably detailed risk assessments; • experimental work demonstrating a range of techniques has been used with the appropriate degree of accuracy, if appropriate, and all relevant results recorded; • their investigation has been well planned and followed with a suitable record which incorporated amendments where appropriate; • candidates produce a logical and accurate report providing interpretation of results with a good evaluation (this report can be a written report, presentation poster, video or any other appropriate medium) suitably presented for the given audience; • evidence shows that scientific terminology has been used correctly and understood; • candidates at this level are expected to show coverage of all the requirements of Sub-sections 8.2.4 (Evaluation of the investigation) and 8.2.5 (Presentation of the outcomes of the investigation) – limited detail in some areas is acceptable;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	**3**	• candidates produce evidence which indicates that they have carried out all practical tasks safely and skilfully, using risk assessments which they have produced; • experimental work demonstrating a range of techniques has been used with the appropriate degree of accuracy and the results recorded with appropriate precision; • their investigation has been independently planned and followed with suitable critical evaluation, incorporating amendments where appropriate; • candidates produce a logical and well structured report providing detailed interpretation of the outcomes with a basic evaluation (this report can be a written report, presentation poster, video or any other appropriate medium) suitably presented for the given audience; • evidence that fluent scientific terminology has been used and understood correctly; • candidates at this level are expected to show detailed coverage of all the requirements of Sub-sections 8.2.4 (Evaluation of the investigation) and 8.2.5 (Presentation of the outcomes of the investigation) – with no omissions.

8.4.3 Resources

Organisations	It is suggested that if centres wish to link the investigations to an organisation they use: – breweries; – fitness centres; – health centres; – local University Science Departments; – opticians. *Some local industries have facilities for candidates to work on-site (need to check risk assessments/health and safety guidelines).*
Textbooks	*GNVQ Science Advanced* Heinemann 043 563 2531 *Nuffield Science in Practice* Gadd K & Holman J (eds) *Advanced Science* Nelson 017 448 2353 *(Both books are based on old specifications, but content is still useful).* *Suggest for practical information – use of any GCE Chemistry/Biology Physics Practical textbook will contain ideas for practical work.* Good references to ethical issues can be found in SATIS units: *What is Science?* 086 357 158 1 *What is Technology?* 086 357 159 X *How Does Society Decide?* 086 357 160 3

Websites	Department of Trade and Industry: 151 Buckingham Palace Road, London SW1W 9SS www.dti.gov.uk Health and Safety at Work: www.vts.rdn.ac.uk – gives information on a range of health and safety sites and how to use the Internet effectively; (free tutorial created by subject specialists from Universities and professional organisations) Health and Safety for TWITS: www.rboocock.freeserve.co.uk – good basic work on laws and regulations Natural Environment Research Council: Polaris House, North Star Ave., Wiltshire SN2 1EU www.nerc.ac.uk Office for National Statistics: 1 Drummond Gate, London SW1V 2QQ www.statistics.gov.uk Royal Society of Chemistry: Burlington House, Piccadilly, London W1V 0BN www.rsc.org.uk UK Cleaning Products Industry Association: 1st Floor Suite, Century House, High Street, Tattenhall CH3 9RJ www.ukcpi.org University of York Education, Chemical Industry Education Centre: www.ciec.org.uk

9 Unit 9: Sampling, Testing and Processing
[A2 level, externally assessed]

9.1 ABOUT THIS UNIT

This A2 level unit is an optional part of the single award and a mandatory part of the double award and is externally assessed.

Two important areas in which scientists work are in the analysis and identification of naturally occurring materials and in the development of beneficial new products from these materials. By studying this unit you will understand how scientists use their knowledge to develop techniques for sampling and testing these materials.

There are many areas in which analytical scientists work. They may work in environmental organisations, in hospital laboratories or be involved in assessing the suitability of novel ceramic materials. Processing includes the making of new medicinal products, modifying polymers for new purposes or new methods for recycling scarce metals.

This unit complements Unit 1: *Science at work*, Unit 2: *Analysis at work* and Unit 3: *Monitoring the activity of the human body,* and requires greater detail about the needs for sampling, testing and processing across several different areas of activity. It also supports investigative work in Unit 8: *Investigating the scientist's work*.

This unit draws together skills developed in both the AS and A2 units already studied and gives opportunities for synoptic assessment.

There are links in this unit to a number of NVQ framework areas involving Construction, Engineering, Manufacturing and Health and Social Care.

This unit will help you prepare for a higher education course as well for employment in a science-based industry.

This unit is assessed through an external assessment. The mark on that assessment will be your mark for the unit.

9.2 WHAT YOU NEED TO LEARN

You need to learn about:

- identifying the requirements of sampling;
- obtaining representative samples and correct storage;
- following a standard testing procedure or devising a suitable test;
- evaluating test results;
- processing in the laboratory;
- identifying or devising a suitable process;
- carrying out small-scale processing;
- evaluating the process.

9.2.1 Identification of the Requirements of Sampling

When samples are to be collected in a scientific way, a number of questions need to be considered:

- What is the purpose of collection?

Once you have answered this, then the nature of the sample needs to be taken into account.

- Is the source homogeneous or does its composition appear to vary?
- Are the samples affected by storage and, if so, how long should they be kept before they are tested?
- Should more than **one** sample be collected, and from where?
- In collecting samples, are you aware of possible dangers caused by weather changes or other environmental hazards?
- Once collected, which method of testing should you choose to obtain the best results?
- Is a modification of this method necessary?

You need to:

- decide where, when and how often to take samples;
- decide how many samples to select;
- collect samples with regard to any possible hazards and to assess any risks present;
- comment on the health and safety implications of your sampling;
- select the most appropriate size of sample to take;
- choose the most appropriate way of storing the samples before testing them;
- know what to do if your sampling method does not work.

9.2.2 Obtaining Representative Samples and Correct Storage

Samples can be collected by following standard procedures or by modifying them according to circumstances. Sometimes an appropriate procedure does not exist and you need to use your scientific knowledge to devise the most suitable method of collection.

Once the samples have been obtained, they need to be stored in such a way that the samples do not alter on standing. This is particularly important when storing food samples but chemical samples too may alter under some conditions of temperature, humidity or light.

You need to know how to:

- use an appropriate sampling method to obtain a representative sample;
- be certain that the correct conditions for sampling are observed;
- prepare and use the correct equipment for sampling;
- control the conditions when collecting so that the samples are of the optimum quality;
- store the samples under the correct conditions;
- record details of the samples selected;
- clean sampling equipment and dispose of materials in a correct way;
- ensure that safe operating procedures are followed.

9.2.3 Following a Standard Testing Procedure or Devising a Suitable Test

Once the samples have been obtained, you need to know which properties of the material are to be determined during the test.

This might be finding the percentage of a metal in an ore, or the electrical conductivity of an alloy or the purity of a drug being manufactured in a process. The samples then need to be prepared for sampling. This could involve crushing and making a solution for chemical analysis, or sectioning a sample for microscope work.

Once the sample is prepared, it needs to be tested, either by using or adapting a standard testing procedure, or by devising a completely new method.

You need to:

- recognise the properties to be determined;
- select, adapt or devise a suitable method of testing;
- prepare the samples for testing;
- prepare the testing equipment for use;
- ensure that you are aware of any potential hazards that may occur during testing;
- follow the testing method in the correct order, modifying it as necessary;
- record any modifications to the normal testing method;
- accurately record the results of a test;
- clean the testing equipment and dispose of materials correctly.

9.2.4 Evaluation of the Test Results

The data obtained from the tests then need to be interpreted and the results evaluated. This can be done by calculation or by a graphical method or by presenting the results in a diagrammatic form.

You need to know how to:

- present your results in the clearest way;
- process your results by the use of appropriate calculations;
- identify any unexpected results and decide what action to take;
- evaluate the accuracy, validity and reliability of the test results;
- report the significance and implications of the test results.

9.2.5 Processing in the Laboratory

New processes are tried out in the laboratory before deciding whether to proceed up to larger-scale manufacture using a pilot plant. Small-scale processing is also used to prepare small quantities of very pure materials as reference standards in analysis.

You need to:

- describe techniques and procedures used to process materials and products in the laboratory;
- explain the meaning of simple scientific terms used in sampling, testing and processing.

9.2.6 Identifying or Devising a Suitable Process

The product that you are making needs to satisfy certain criteria such as quantity, purity and cost, as well as health and safety considerations during and after manufacture.

The method that you choose will have to be appropriate to these criteria. You may find that a suitable method is already available or you may need to modify an existing method or even devise a new method.

You need to:

- understand the purpose of small-scale processing;
- find a suitable standard processing method;
- adapt your method if the method does not work as expected;
- devise a suitable processing method if one is not available;
- identify any hazards and assess the risks of your method.

9.2.7 Carrying out Small-Scale Processing

An important part of laboratory work is to be confident when using the materials and equipment. You may need to gain additional skills in the use of more specialised equipment.

To carry out small-scale processing in an effective way, you need a grasp of the underlying scientific ideas, as well as good manipulative skills and a careful attention to detail.

You need to:

- obtain the necessary equipment and materials;
- prepare your equipment for use;
- assemble the equipment;
- produce small quantities;
- assess your product against the specification required;
- alter your procedure if any problems arise;
- clean your equipment after use and dispose of unwanted materials correctly;
- follow the health and safety guidelines for your processing method.

9.2.8 Evaluation of the Process

An important part of any procedure is its evaluation. You need to evaluate the process against the starting objectives.

You need to:

- see if your product fits the required specification;
- see if your process fits the requirements;
- decide if further development of your processing method is required;
- make recommendations for production on a larger scale.

9.3 GUIDANCE FOR TEACHERS

9.3.1 Guidance on Delivery

There are many opportunities to gather evidence for help in this unit while candidates are working on other units. For example:

- Unit 2: *Analysis at work* – physiological measurements related to the human circulatory and respiratory systems;
- Unit 10: *Synthesising organic chemicals* – the preparation of organic compounds in the laboratory and the scaling up of these reactions.

Samples for analysis can be taken from a range of situations, e.g. samples could be collected from the environment (rock samples, rivers and living organisms).

Another source of samples might be from a production-line of a local company as well as samples made during processes being carried out in your centre's laboratory.

Candidates need to be aware of the need for maintaining sample integrity and need to consider problems of contamination and of decomposition on standing.

Details of standard methods of sampling and testing can be obtained from a number of sources, e.g. from local companies or from hospital laboratories. Details are also obtainable electronically and from the *British Standards Institute* as well as from books and journals. Some methods are necessarily complicated and you may need to interpret them and modify them as required.

Testing procedures will produce data that can be handled in a variety of ways, from simple calculations, particularly those involving percentages, to graphs and other diagrammatic representations.

Candidates need to have some experience of small-scale processing in the laboratory.

The purpose of small-scale processing in industry includes the need to:

- produce small quantities of substances which can be used as reference standards;
- produce small quantities of a product for which there is a specialist need;
- test the viability of a process *before* large-scale production.

Examples of suitable small-scale processing might include the:

- manufacture of a material, e.g., an alloy, ceramic or chemical compound;
- production of a printed circuit-board;
- modification of an existing compound or material to fit a new requirement, e.g. in polymers and composites;
- recycling and recovery of materials, e.g. metals, solvents, paper, polymers;
- formulation of a product by combining together different components, e.g. cosmetics, compound fertilisers, washing materials.

There are many possibilities in other units for investigations in this area.

The external assessment for this unit will explore this topic from a wider vocational perspective.

9.3.2 Guidance on Assessment

This unit is assessed through pre-released case study material and a 1½ hour question paper with **90** marks which assesses AO1 (**45-55** %) and AO2 (**45-55** %).

There are **three** questions of short-answer style whilst some question part(s) will give candidates the opportunity to present their response by means of continuous prose.

Two of the questions will be based on the pre-released case study material, which will be circulated to centres prior to the examination.

This unit requires little specific-subject matter to be learned and assessed. Questions will be set on the applications of other units with regard to sampling, testing and processing.

9.3.3 Resources

Centres should consult the resource material given in other units and use this in conjunction with specific references to techniques of sampling, testing and processing in the publications outlined below.

Organisations and Websites	The British Standards Institute: www.bsi.org.uk The Institute of Biology: www.iob.org The Institute of Physics: www.iop.org The Royal Society of Chemistry: www.rsc.org			
Publications	British Pharmacopoeia Chemistry and Industry Chemistry Review New Scientist			
Textbooks	Jeffery GH *et al*	*Vogel's Textbook of Quantitative Chemical Analysis*	Longman 1989	058 244 693 7
	Radojevic M & Bashkin V	*Practical Environmental Analysis*	The Royal Society of Chemistry 1999	085 404 594 5

Information gained during visits to local organisations for Unit 1: *Science at work* will help to show the relevance of this unit.

10 Unit 10 Synthesising Organic Chemicals
[A2 level, optional, internally assessed]

10.1 ABOUT THIS UNIT

This A2 level unit is optional and is internally assessed.

Many chemists work as part of a team involved in the creation and development of new and increasingly sophisticated compounds. Most of the compounds made today are organic and impact considerably on our lives. Pharmaceuticals, dyes, plastics and explosives all play an important role in today's society, and chemists are always striving to improve or create new substances in order to bring us greater social and economic benefits.

The work of the chemist may vary, from the synthetic chemist striving to discover novel molecules which can benefit our quality of life, to the analytical chemist investigating the purity of products, and finally to the process development chemist who will scale up the synthesis and assess its viability.

This unit builds on Unit 2: *Analysis at work*, Unit 3: *Monitoring the activity of the human body* and Unit 5: *Chemicals for a purpose*. It can also complement A2 units in GCE Chemistry and Biology. There are also links to the NVQs in Laboratory Operations and Process Operations.

This unit will help you prepare for higher education courses in chemistry or other science courses with a chemical component. It will also provide you with some of the skills needed for working in a chemical or science-based industry.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will investigate synthesising organic chemicals. Your evidence will include:

- a report or leaflet which demonstrates an understanding of organic chemistry by the correct identification and naming of functional groups, the importance of different types of isomerism and different types of reactions involving organic molecules;
- an investigation of therapeutic drugs including their usage and mode of action in the body;
- research on a process used to manufacture an organic compound – you will show an understanding of the factors to be considered by a manufacturer when scaling up a small-scale process in terms of health and safety, plant design, costs and the use of automation with evidence of appropriate calculations;
- production of **two** preparations of organic compounds you have made and purified in the laboratory – **one** of which will be an anti-inflammatory drug – a report for each sample detailing their preparation, method of purification, percentage yield and evaluation.

10.2 WHAT YOU NEED TO LEARN

You need to learn about:

- organic compounds and functional groups;
- types of chemical reaction;
- manufacture and purification of organic compounds;
- determination of yield and purity;
- therapeutic drugs and medicines;
- industrial manufacture of chemical compounds.

10.2.1 Organic Compounds and Functional Groups

Chemical synthesis forms the foundations on which the chemical and pharmaceutical industries are built. Carbon has the unique ability to form strong chemical bonds between not only carbon atoms but also many other elements such as oxygen, hydrogen, chlorine and nitrogen. Before any synthesis is undertaken, the synthetic chemist needs to take into account **two** factors – the identity of functional groups within molecules and molecular shape. Both factors are central to the understanding of reaction pathways.

You need to:

- explain why carbon forms such a huge range of compounds;
- describe organic compounds as chain, branched chain or ring;
- distinguish between aliphatic and aromatic compounds;
- recognise the following types of aliphatic compound and their functional groups:
  – alkene, >C=C<;
  – alcohol, -OH;
  – carbonyl, >C=O;
  – carboxylic acid, -COOH;
  – amine, -NH2;
  – amide, -CONHR;
  – ester, -COOR;
- recognise the following types of aromatic compounds and their functional groups:
  – benzene;
  – phenols;
  – phenylamines;
  – carboxylic acids;
- name organic compounds containing the functional groups listed above;
- draw structural and displayed formulae for compounds containing the functional groups listed above and describe their 3D shape;
- identify which bonds can rotate in a molecule and describe the effect this has on its 3D shape;

- explain and give examples of structural and stereo isomerism;
- locate information about the solubility, melting points and boiling points of organic compounds.

10.2.2 Types of Chemical Reaction

Each functional group has its own characteristic set of reactions. These reactions enable the synthetic chemist to plan a synthesis that is both efficient and safe.

You need to:

- recognise and give examples, by using the functional groups given in Sub-section 10.2.1 (Organic compounds and functional groups), of the following types of reaction:
  – substitution;
  – addition;
  – redox;
  – esterification;
  – hydrolysis;
  – polymerisation;
  – diazotisation;
- write balanced chemical equations for the reactions listed above;
- identify reagents and conditions needed for the above reactions.

10.2.3 Manufacture and Purification of Organic Compounds

The preparation of a compound is usually first tried in the laboratory on a small scale. Several methods of preparation may be tried and the yields compared; the products then need to be analysed to determine purity. Methods often have to be adapted to combine the best features of a number of routes and the best purification methods.

You need to:

- carry out risk assessments and handle substances and laboratory equipment safely;
- select and assemble, where necessary, the equipment required for carrying out reactions, including heating, cooling, mixing and purifying reaction mixtures;
- follow standard procedures to prepare and purify organic compounds;
- modify standard procedures to improve a preparation;
- separate mixtures using a variety of methods such as precipitation, crystallisation, filtration, distillation and solvent extraction;
- purify products by distillation and recrystallisation;
- determine actual yield of a preparation.

10.2.4 Determination of Yield and Purity

Chemists need to be able to assess the viability of a particular preparation; part of this process involves calculating percentage yield, to determine how much of the reactants have been converted to products. Analysis of the product is then necessary to determine the success of the purification process. Finally, chemists often have to research published data with which to compare their results.

You need to:

- calculate theoretical yield and actual yield for a preparation;
- write balanced chemical equations for your preparations;
- calculate quantities of reactants needed to produce a given quantity of product;
- scale a preparation up or down;
- measure melting points and boiling points accurately;
- follow standard procedures to analyse the purity and/or composition of a preparation;
- compare your experimental data with published data.

10.2.5 Therapeutic Drugs and Medicines

Drugs and medicines form an important area of organic synthesis, as they impact on our well-being. Their manufacture and sales contribute significantly to our economy. Therapeutic drugs, alongside improvements in health and hygiene, have played significant roles in the prolonging of life-expectancy.

You need to:

- find out about the different types of drugs and their applications, including antibiotics, antiviral, analgesic, antihistamine, anti-hypertension, anti-inflammatory, anaesthetic;
- find out about the principles of drug action in terms of the chemical structure of a drug and receptor sites in the body;
- find out about how a drug gets into the body and its site of action;
- prepare a sample of an anti-inflammatory drug and asses its purity using a standard procedure.

10.2.6 Industrial Manufacture of Chemical Compounds

After a new compound has successfully been created in the laboratory, the next stage is to scale up the process to pilot plant and finally industrial production. This process involves chemists working as part of a diverse team of specialists investigating all aspects of the manufacturing and market requirements for a product.

You need to find out about:

- the factors that need to be considered when scaling up a small-scale preparation to a manufacturing process;
- how manufacturing processes are monitored and controlled to ensure safe and economic control;
- the health and safety regulations that impact on the manufacturing process;
- the difference between batch and continuous processes and what judgements have to be made in deciding which is the most appropriate route;
- the use of automation in laboratory operations and in monitoring reaction conditions;
- the direct and indirect costs of production and how the selling price of the product is determined;
- issues which impact on society.

10.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 10: Synthesising organic chemicals

What you need to do:

You need to produce evidence of your investigation into synthesising organic chemicals [**50** marks].

This evidence needs to include**:**

AO1: a report or leaflet which demonstrates an understanding of organic chemistry by the correct identification and naming of functional groups, the importance of different types of isomerism and different types of reactions involving organic molecules; an investigation of therapeutic drugs, their usage and mode of action in the body [**10**];

AO2: research on a process used to manufacture an organic compound; you need to show an understanding of the factors to be considered by a manufacturer when scaling up a small-scale process in terms of health and safety, plant design, costs and the use of automation; evidence of appropriate calculations [**14**];

AO3: production of **two** preparations of organic compounds you have made and purified in the laboratory, **one** of which will be an anti-inflammatory drug; a report for each sample detailing their preparation, method of purification, percentage yield and evaluation [**26**].

How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will demonstrate a basic knowledge and understanding of the classifications of organic compounds, identification of functional groups and isomerism; **[0 1]**	you will demonstrate a knowledge and understanding of the classifications of organic compounds, identification of all listed functional groups and the importance of isomerism; **[2]**	you will demonstrate thorough knowledge and understanding of the classifications of organic compounds, identification of functional groups within molecules and the importance of isomerism linked to specific examples. **[3]**	
	You will show understanding of some reaction types, using appropriate nomenclature and examples, and in some cases relating them to specific functional groups; **[0 1]**	you will show understanding of many of the reaction types given in the unit specification, using appropriate nomenclature and examples, and in most cases relating them to specific functional groups; **[2]**	you will show understanding and explain all the reaction types given in the specification, using appropriate nomenclature and examples, and relating them to specific functional groups. **[3]**	
	You will investigate some different drug types and show a basic knowledge and understanding of the principles of drug action, using some scientific terminology and conventions correctly; **[0 1]**	you will investigate a variety of different drug types and show knowledge and understanding of the principles of drug action, giving clear, well-explained examples in each case, using scientific terminology and conventions correctly; **[2 3]**	you will investigate a wide range of drug types and show a thorough knowledge and understanding of the principles of drug action, giving detailed examples, the therapeutic effect explained and the usage of such drugs evaluated, using scientific terminology and conventions correctly throughout. **[4]**	**/10**

Unit 10: Synthesising organic chemicals (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	You will produce information on a process used to manufacture an organic compound, and the factors to be considered, selecting some appropriate sources and presenting information clearly; **[0 1 2]**	you will show researched evidence into a process used to manufacture an organic compound, and the range of factors to be considered, selecting a range of appropriate sources, interpreting and presenting information clearly; **[3]**	you will show thorough research into a process used to manufacture an organic compound, and the factors to be considered, using a wide range of appropriate sources, evaluating and justifying the information, presenting it clearly, concisely and coherently. **[4 5]**	
	You will find and use information about some of the costs and benefits to individuals, companies and society associated with the manufacture of an organic compound; **[0 1 2]**	you will find out about and explain the costs and benefits to individuals, companies and society associated with the manufacture of an organic compound; **[3]**	you will interpret, explain and evaluate the costs and benefits to individuals, companies and society associated with the manufacture of an organic compound, in a clear and concise way. **[4 5]**	
	You will demonstrate correctly, straightforward calculations related to your research and preparations but with some assistance; **[0 1]**	you will demonstrate correctly, complex calculations related to your research preparations with little assistance; **[2 3]**	you will demonstrate, correctly and independently, complex calculations related to your research and preparations. **[4]**	**/14**
AO3	You will show valid risk assessments for your work; **[0 1]**	you will use COSHH data to produce valid risk assessments, with some assistance; **[2]**	you will use COSHH data to produce a valid risk assessment independently. **[3]**	
	You will have safely carried out **two** preparations, **one** of which is an anti-inflammatory drug; **[0 1 2 3]**	you will have planned, and safely completed, **two** preparations, **one** of which is an anti-inflammatory drug, using a range of techniques; **[4 5]**	You will have independently planned, and skillfully and safely completed, **two** preparations, **one** of which is an anti-inflammatory drug, using a wide range of techniques justifying reasons for the use of such techniques. **[6 7 8]**	
	You will make and record some observations and measurements related to both preparations, and display information clearly; **[0 1]**	you will make and record, in a suitable format, observations from both preparations; record some results to an appropriate level of precision and display information accurately; **[2]**	you will make and record, in a suitable format, appropriate observations from both preparations; record all results to an appropriate level of precision and display all information logically and accurately. **[3]**	
	You will provide evidence of some processing of the results; **[0 1 2]**	you will provide adequate processing of the results from both preparations; **[3 4]**	you will provide correct processing of all the results from both preparations. **[5 6]**	
	You will draw some conclusions related to both preparations; **[0 1 2]**	you will draw conclusions with explanations related to the outcomes of both preparations; **[3 4]**	you will be able to draw detailed conclusions, explaining and evaluating your results for both preparations and suggesting alternative techniques where appropriate. **[5 6]**	**/26**
			Total mark awarded:	**/50**

10.4 GUIDANCE FOR TEACHERS

10.4.1 Guidance on Delivery

This unit draws on the scientific knowledge, skills and understanding provided by the study of Unit 1: *Science at work*, Unit 2: *Analysis at work* and Unit 3: *Monitoring the activity of the human body*. It also develops the organic component of Unit 5: *Chemicals for a purpose*.

It is important that candidates become familiar with and confident in using standard chemical substances and laboratory equipment. Correct nomenclature and terminology need to be embodied within the delivery, whilst the underpinning chemical principles need to be introduced gradually as the unit progresses, using practical sessions to support the theory wherever possible.

Practical work is an integral part of the unit and the skills required for the preparation and analysis of the organic compounds can be developed through a practical based approach to the underpinning theory. This allows candidates with all learning styles the opportunity to understand the basic chemistry requirements for the unit.

The principal aim of the unit is to give candidates a sufficient grounding in theoretical and practical organic chemistry to allow them to appreciate the work and contribution made by the organic chemist to modern day living and realise the diversity of their work.

Organic compounds and functional groups

This allows candidates to build on their skills, knowledge and understanding from GCSE science and from the AS units within this qualification.

Candidates need to know about functional groups and how they are named, and 3D shapes of organic molecules and their properties. They need to understand that single covalent bonds are free to rotate (unless hindered by bulky functional groups) but multiple bonds are not. The effect of intermolecular forces on the properties of organic molecules need to be emphasised and candidates need to use paper and electronic sources of information to find out about their properties. Candidates need to know about both stereo-isomerism and structural isomerism and the effect they have on the properties of a compound. In particular, stereo-isomerism needs to be related to drug activity in the body.

The use of molecular models (both Molymod models and electronic models) needs to be used to demonstrate 3D shape and isomerism.

Types of chemical reaction

Candidates need to classify reactions as:

- substitution, e.g. Friedel-Crafts reactions;
- addition, e.g. hydrogenation reactions;
- redox (oxidation and reduction), e.g. the oxidation of primary alcohols to carboxylic acids;
- esterification, e.g. the preparation of Germolene and aspirin;
- hydrolysis, reaction with water, e.g. hydrolysis of amides and esters;
- polymerisation, addition and condensation, e.g. preparation of nylon;
- diazotisation, preparation of azo dyes – this is best done as a demonstration due to the toxic nature of the chemicals involved.

They need to be able to write balanced chemical equations for the reactions they use in the synthesis.

Making and purifying organic compounds

Candidates need to be familiar with the correct usage of the following processes and apparatus:

- containing and transferring chemicals, for example:
  – beakers;
  – conical flasks;
  – test tubes;
  – boiling tubes;
  – spatulas;
  – dropping pipettes;
  – delivery tubes;
  – quick fit apparatus;
- measuring and monitoring:
  – volume, e.g. graduated beaker, measuring cylinder, burette, one-line and graduated pipettes;
  – mass, e.g. top-pan balance;
  – temperature, e.g. thermometer, thermocouple;
  – time, e.g. stop-clock;
- heating, for example:
  – reflux;
  – Bunsen burner;
  – electric heating mantle;
  – water bath;
  – oil bath;
  – electric hot-plate;
  – heat-proof mats;
  – tongs;
  – test-tube holders;

- cooling, e.g. ice baths, condensers and water baths;
- mixing, e.g. stirring rod and magnetic stirrers;
- separating and purifying:
  – solvent extraction;
  – filtration, e.g. atmospheric and reduced pressure;
  – evaporation;
  – distillation;
  – recrystallisation;
- determining purity:
  – melting and boiling points;
  – titration;
  – chromatography;
  – *spectroscopic methods are **not** required*.

All work should be carried out only when a valid risk assessment has been made and candidates need to pay due regard to the risk assessment.

Determining yield and purity

Candidates should be familiar with purifying products and assessing purity using the methods described. They then need to process their data to calculate percentage yield of a preparation. In addition, they need to perform calculations to determine the quantities of reactants needed to produce a theoretical amount of product for reactions other than those carried out. Candidates need to locate relevant published data from a variety of sources, compare their experimental data and draw conclusions.

Therapeutic drugs and medicines

Hospitals and local pharmacists may be able to provide candidates with expert advice. This may be in the form of a visit to a local hospital and/or a visiting speaker. Not all drugs have complex structures, less complex ones such as aspirin, paracetamol and ibuprofen can be used to illustrate molecular shape. Candidates can also build molecular models of these compounds, prepare them and purify them in the laboratory. The Royal Society of Chemistry produces several publications outlining the history of such drugs, methods of preparation and ways of determining purity. General anaesthetics, such as ether and nitrous oxide, also have simple structures and would provide straightforward examples to study. CD-ROM simulations can be used to show the shapes of more complex molecules.

Industrial manufacture of chemical compounds

The development of a new compound from its production in the laboratory through to full-scale manufacture would provide an excellent case study. This allows for the requirements of the specification to be met by considering the factors to be taken into account when scaling up a process, an evaluation of the use of batch and continuous processes, the role of automation in both manufacturing and testing, health and safety implications and the costs associated with the process. The report could focus on a pharmaceutical product already studied, or make use of any local manufacturing facilities. An industrial visit or speaker would provide a great deal of useful information. Candidates need to be aware of how sampling and testing operations are carried out on an industrial scale as opposed to the school laboratory.

10.4.2 Guidance on Assessment

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 10.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• Candidates produce a report or a leaflet which shows knowledge and understanding of Sub-section 10.2.1 (Organic compounds and functional groups) and Sub-section 10.2.2 (Types of chemical reaction) – some omissions are acceptable at this level but candidates aim to cover the majority of the information listed by the bullet points; • some evidence of how material has been selected and linked to the work on therapeutic drugs etc. is shown; • candidates carry out some investigative work into the use and mode of action of at least **one** therapeutic drug – examples of the information to be covered to be taken from Sub-section 10.2.5 (Therapeutic drugs and medicines);
	2	• candidates produce a report or a leaflet which shows a detailed knowledge and understanding of Sub-section 10.2.1 (Organic compounds and functional groups) and Sub-section 10.2.2 (Types of chemical reaction) – candidates cover the majority of the information listed by the bullet points and are able to identify functional groups within a variety of organic molecules including therapeutic drugs; the importance of isomerism in shape and selective action and reactions is also included and candidates also show evidence of the importance of the functional groups in determining the type of reactions; • detailed evidence of how material has been selected and linked to the research work on therapeutic drugs etc. is shown; • candidates carry out their own investigative work into the use and mode of action of a number of therapeutic drugs – examples of the information to be covered to be taken from Sub-section 10.2.5 (Therapeutic drugs and medicines);
	3	• candidates produce a report or a leaflet which shows thorough knowledge and understanding of Sub-section 10.2.1 (Organic compounds and functional groups) and Sub-section 10.2.2 (Types of chemical reaction) – candidates cover fully all the information listed by the bullet points and are able to identify, independently, functional groups within a variety of organic molecules including therapeutic drugs, the importance of isomerism in shape and selective action and are able to recognise different types of reactions; candidates also show evidence that they know the importance of the functional groups in determining the type of reactions; • detailed evidence of how material has been selected and linked to the research work on therapeutic drugs etc. is shown; • candidates carry out their own detailed investigative work into the use and mode of action of a wide range of therapeutic drugs and show a thorough knowledge and understanding of the principles of drug action – examples of the information to be covered to be taken from Sub-section 10.2.5 (Therapeutic drugs and medicines).

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	1	• Candidates select an appropriate organic compound that is manufactured on a large scale and focus on coverage of the requirements in Sub-section 10.2.6 (Industrial manufacture of chemical compounds) – information on the reaction type and functional groups involved is included and all bullet points are considered, although some omissions are allowed; • evidence of sources used and how information was selected is included – work is clearly presented; • calculation work can include work on % yields and, if possible, costs involved in manufacture/production of organic compounds – if difficulties are encountered in obtaining this information, case study work can be used (see also Appendix B);
	2	• candidates select an appropriate organic compound that is manufactured on a large scale and focus on detailed coverage of the requirements in Sub-section 10.2.6 (Industrial manufacture of chemical compounds) – all bullet points are considered and some are discussed and explained in considerable detail; • evidence of a range of sources used and why information was selected should be included – work is clearly and logically selected and presented; • calculation work can include work on % yields and, if possible, costs involved in manufacture/production of organic compounds – if difficulties are encountered in obtaining this information, case study work can be used; the appropriate degree of accuracy should be used and work is correct;
	3	• candidates select an appropriate organic compound that is manufactured on a large scale and apply scientific facts and understanding in order to cover all of the requirements in Sub-section 10.2.6 (Industrial manufacture of chemical compounds) – all bullet points are considered and are discussed and explained in considerable detail; • evidence of a range of sources used and why information was selected is included – work should be clearly and logically selected and presented; • calculation work includes detailed work on % yields and costs involved in manufacture/production of organic compounds – if difficulties are encountered in obtaining this information, case study work can be used; the appropriate degree of accuracy is used and all work is correct – evidence of more complex calculations is shown.

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	**1**	• Candidates demonstrate that they have used risk assessments when carrying out both preparations and evidence is supplied that they have prepared the samples and used a range of techniques and equipment – **one** of the preparations is an anti-inflammatory drug but the other can be any suitable product chosen from Sub-section 10.2.2 (Types of chemical reaction); details needed are based on information listed in Sub-section 10.2.3 (Manufacture and purification of organic compounds); • some record has been made of relevant observations or measurements and some processing of results has been completed; • some guidance can be given at this level to conclusions and interpretation of work covered by the preparative work;
	2	• candidates demonstrate that they have used COSHH data to produce risk assessments and have safely completed both preparations – some guidance can be given to the production of the risk assessments; • evidence is supplied that they have done some planning in order to prepare the samples and used a range of techniques and equipment – **one** of the preparations is an anti-inflammatory drug but the other can be any suitable product chosen from Sub-section 10.2.2 (Types of chemical reaction); details needed are based on information listed in Sub-section 10.2.3 (Manufacture and purification of organic compounds); • records have been made, in a suitable format, of relevant observations or measurements and some processing of results has been completed – work shows the appropriate level of precision and accuracy; • candidates show evidence of interpretation of their preparative work and draw some relevant conclusions;
	3	• candidates demonstrate that they have used COSHH data independently to produce risk assessments and have safely completed both preparations; • evidence is supplied that they have planned and skilfully prepared the samples and used a range of techniques and equipment with suitable justification for the use of the techniques – **one** of the preparations is an anti-inflammatory drug but the other can be any suitable product chosen from Sub-section 10.2.2 (Types of chemical reaction); details needed are based on information listed in Sub-section 10.2.3 (Manufacture and purification of organic compounds); • records have been made, in a suitable format, of relevant observations or measurements and there is correct processing of all results – all work shows the appropriate level of precision and accuracy; • candidates show evidence of detailed interpretation of their preparative work with relevant conclusions and suitable explanations and evaluation where appropriate.

10.4.3 Resources

Local hospitals and pharmacists can provide information about drugs and their mode of action. There are also many science books containing information about drugs.

If possible, arrange visits to appropriate chemical plants or visiting speakers.

<table>
<tr><td>Publications</td><td>Royal Society of Chemistry publications are an invaluable source of background information and preparative routes for organic compounds.
Examples include:
• Alchemy? Chemistry and industrial processes for schools and colleges. (CD- ROM);
• Analysts: Analytical science in action. (Video).
• Aspirin: a curriculum resource for post-16 chemistry courses;
• Industrial chemistry case studies;
• Paracetamol;
• Medicinal chemistry;
• The age of the molecule;
• Which compound? Which route?
The Chemical Industry Education Centre, University of York produces a range of useful materials.
SATIS 16-19 published by the Association for Science Education – it is advisable to access www.ase.org.uk as this gives information about these publications and is regularly updated:
Martin Green The Pharmaceutical Business APBI ISBN PHA BUS
What is Science 086 357 1581
What is technology 086 357 159X
How Does Society Decide 086 357 1603
Data books including the Rubber Book give vast amounts of physical data.</td></tr>
<tr><td>Textbooks</td><td>Many advanced level chemistry books include sections on nomenclature and functional groups. There is also a variety of practical chemistry books that can be used to develop practical skills and provide preparative methods.
Recommended is:
Heaton A ed. An Introduction to Industrial Chemistry Kluwer 1995
The Essential Chemical Industry University of York 835 432 577X e-mail:ciec@york.ac.uk
Industrial Chemistry Case Studies RSC 085 404 9258</td></tr>
</table>

Websites	Post-16 resources for science including manufacturing and biotechnology: www.abpischools.org.uk Educational resources, including free post-16 resources: www.gsk.com The Royal Society of Chemistry homepage, providing links to other relevant sites: www.rsc.org – excellent list of books/publications available access books for students www.rsc.org/is/books/books_students.htm Chemical industries education centre website offering many learning resources and useful links: www.york.ac.uk/org/ciec

11 Unit 11: Materials for a Purpose
[A2 level, optional, internally assessed]

11.1 ABOUT THIS UNIT

This A2 level unit is optional and is internally assessed.

Manufacturers selecting a material for a new product need to match the physical properties of the chosen material to the requirements of the application. In addition, they need to match cost to budget and consider environmental, and health and safety issues.

In this unit, you will learn to select an appropriate material from available data and to support your choice with well-reasoned argument. You will develop an understanding of key properties of some of the main classes of materials and how to relate those properties to the specification.

During the study of this unit, you will undertake practical work to measure some of the physical properties you learn about.

There are strong links between this unit and units in GCE Physics.

This unit will help you to prepare for higher education courses in applied science, especially those requiring an introduction to materials science. It builds on Unit 5: *Chemicals for a purpose* and it complements aspects of Unit 7: *The physics of sport*, but study of Unit 7 is **not** a prerequisite for this unit.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will select materials for **two** specified purposes and demonstrate underlying knowledge about types and properties of materials. Your evidence will include:

- a poster and accompanying leaflet outlining the structures of polymers, metals, ceramics or glasses, and composite materials;
- **two** case studies describing, in detail, your selection from published data of different preferred materials for stated purposes, calculations of tensile stress and strain, the Young modulus and toughness from a graph of force against extension and details of sample dimensions;
- your reports on:
  - (i) an experiment to measure how the extension of a sample varies with tension;
  - (ii) your design and testing of an impact-testing machine and an assessment of its effectiveness compared with the recognised industrial standards,
  - (iii) tests to show the effect of your work-hardening, annealing and tempering treatments;
  - (iv) the results of your experiments to measure electrical and thermal conductivities and specific heat capacity.

11.2 WHAT YOU NEED TO LEARN

You need to learn about:

- types of materials;
- physical properties;
- identification of objectives and constraints;
- selection.

11.2.1 Types of Materials

The properties of materials are related to their structure. This, in turn, depends on the type of atoms bonded together, the type of bonding and the conditions under which they have been made. You need to know, and be able to differentiate between, the structures of the following classes of materials, with particular reference to the aspects identified:

- polymers – addition and condensation polymers, thermoplastics and thermosetting materials, cross-lining, plasticisers and fillers;
- metals – crystal structures of pure metals and alloys, dislocations, work-hardening, heat treatment;
- ceramics and glasses – soda glass, borosilicate and lead glasses, toughening and sintering;
- composite materials – reinforced concrete, glass-fibre and carbon-fibre reinforcing.

You need to carry out the following treatments and test their effectiveness:

- work-hardening;
- annealing;
- tempering.

11.2.2 Physical Properties

The way in which a material stretches when under tension tells us a lot about it. In school or college experiments, you can measure the extension of a wire mounted vertically on a wall when weights are hung from it. The equivalent industrial testing machine is called a tensometer. Modern methods of measuring the hardness of a material measure its ability to withstand indentation. Industrial testing machines include Vickers, Brinell, and Rockwell. To help you to understand what these tests involve, you need to, individually or in a group, devise and test your own impact-testing machine.

You need to:

- carry out an experiment to measure how the extension of a sample varies with tension;
- design and test an impact-testing machine and compare it with the recognised industrial standards;
- measure the thermal conductivity of a good conductor;
- measure the electrical conductivity of a sample of resistance wire;
- measure the specific heat capacity of a metal sample.

From a graph of the tensile force and extension of a sample, you need to:

- calculate tensile stress and strain;
- obtain values of the Young modulus and tensile strength and comment on its ductility;
- relate toughness to the area under the graph;
- suggest, where appropriate, how the material might have been treated to change its properties.

You also need to understand and be able to apply the following properties:

- density;
- hardness, including Vickers, Brinell, Rockwell and Mohs' scales;
- elastic modulus (you need to define the Young modulus and recognise the shear, bulk and torsional moduli);
- fracture strength σ_f (for the purposes of this course, this may be considered to be the same as ultimate tensile strength σ_u);
- toughness;
- ductility and brittleness;
- electrical conductivity and resistivity;
- thermal conductivity;
- specific heat capacity;
- resistance to corrosion;
- thermal expansivity.

11.2.3 Identification of Objectives and Constraints

The first step in selecting a material for a purpose is to identify the *essential* and *desirable* selection criteria. You need to:

- identify the objectives and constraints imposed by a given application;
- distinguish between objectives and constraints.

In addition to the properties or the material itself, designers take into account other 'external' factors. You need to discuss the following in the context of identifying objectives and constraints:

- price;
- demand;
- environmental considerations;
- production costs;
- government regulations;
- quantity required;
- quality required.

11.2.4 Selection

An engineer then has to identify and select the materials that meet the project's objectives and constraints. From this shortlist, some will fulfil the objectives better than others. This narrows the choice down further. There may still remain more than **one** material to choose from, particularly if there is more than **one** objective.

You need to select an appropriate material, for a given application, from a given range of data. You need to:

- identify a list of materials that meet your constraints;
- select those materials from your list which best meet your objectives;
- make a reasoned choice between the options which meet your constraints, where more than **one** option meets your objectives;
- select a suitable material from a given range and justify your choice.

You also need to select an appropriate material for a given application, for which data is not provided, where the properties are commonly known, e.g. copper is a good conductor, glass is transparent and ceramics are strong.

Practical work is not expected in this part of the unit.

11.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 11: Materials for a purpose				
What you need to do:				

You need to produce evidence of selection of materials for **two** specified purposes and of underlying knowledge of types and properties of materials [**50** marks].

This evidence needs to include:

AO1: a poster and accompanying leaflet outlining the structures of polymers, metals, ceramics or glasses, and composite materials [**10**];

AO2: **two** case studies describing, in detail, your selection from published data of different preferred materials for stated purposes; calculations of tensile stress and strain, the Young modulus and toughness from a graph of force against extension and details of sample dimensions [**14**];

AO3: your reports on
(i) an experiment to measure how the extension of a sample varies with tension;
(ii) your design and testing of an impact testing machine and an assessment of its effectiveness compared with the recognised industrial standards;
(iii) tests to show the effect of your work-hardening, annealing and tempering treatments;
(iv) the results of your experiments to measure electrical and thermal conductivities and specific heat capacity [**26**].

How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will produce an outline of the structures of at least **one** example of each of polymers and metals; **[0 1]**	you will produce a description, with diagrams, of the structures of at least **two** examples of each of polymers and metals; physical properties are stated; **[2 3]**	you will produce a description, with diagrams, of the structures of more than **two** examples of each of polymers and metals, relating their structures to physical properties. **[4 5]**	
	You will produce an outline of the structures of at least **one** example of each of ceramics or glasses and composite materials; **[0 1]**	you will produce a description, with diagrams, of the structures of at least **two** examples of each of ceramics or glasses and composite materials, physical properties are stated; **[2 3]**	you will produce a description, with diagrams, of the structures of more than **two** examples of each of ceramics or glasses and composite materials, relating their structures to physical properties. **[4 5]**	**/10**
AO2	You will produce a first case study clearly stating the purpose, suggesting, from published data, at least **two** alternative materials and identifying the selected material with some reason given for the choice; **[0 1]**	you will produce a first case study clearly stating the objectives and constraints imposed by the purpose, suggesting, from published data, at least **three** possible alternative materials and identifying the selected material with criteria given for the choice; **[2 3]**	you will produce a first case study clearly stating the objectives and constraints imposed by the purpose, suggesting, from published data, at least **three** possible alternative materials, identifying the selected material and fully justifying the choice. **[4 5]**	
	You will produce a second case study clearly stating the purpose, suggesting, from published data, at least **two** alternative materials and identifying the selected material with some reason given for the choice; **[0 1]**	you will produce a second case study clearly stating the objectives and constraints imposed by the purpose, including the required properties, suggesting, from published data, at least **three** possible alternative materials and identifying the selected material with criteria given for the choice; **[2 3]**	you will produce a second case study clearly stating the objectives and constraints imposed by the purpose, including the required properties, suggesting, from published data, at least **three** possible alternative materials, identifying the selected material and fully justifying the choice. **[4 5]**	
	You will produce calculations, with some assistance, of tensile stress and strain, the Young modulus and toughness from a graph of force against extension and length and cross-sectional area of sample; **[0 1 2]**	you will produce calculations from given equations of tensile stress and strain, the Young modulus and toughness from a graph of force against extension and length and cross-sectional diameter of sample; **[3]**	you will produce calculations, unaided, of tensile stress and strain, the Young modulus and toughness from a graph of force against extension and length and cross-sectional diameter of sample. **[4]**	**/14**

Unit 11: Materials for a purpose (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO3	You will produce a report on an experiment to measure how the extension of a sample varies with tension, including plan and safety precautions, a table showing **one** set of results, and graph; **[0 1 2 3 4]**	you will produce a report on an experiment to measure how the extensions of **two** different samples vary with tension, including your unaided plan and risk assessment, a table showing repeat sets of results, graph and calculation of gradient; **[5 6]**	you will produce a report on an experiment to measure how the extensions of **two** different samples vary with tension, including your unaided plan and risk assessment, a table showing repeat sets of results, graph and calculation of Young modulus and comments on why your samples differ. **[7 8]**	
	You will produce a report on your design and testing of an impact testing machine, including plan and safety precautions, a description and diagram of your method, and sample results; you use basic scientific terminology correctly; **[0 1 2 3 4]**	you will produce a report on your design and testing of an impact testing machine, including unaided plan and safety precautions, a description and diagram of your method, sample results and a comparison with the recognised industrial standards; your report is clear and logical and uses basic scientific terminology correctly; **[5 6]**	you will produce a report on your design and testing of an impact testing machine, including unaided plan and safety precautions, a description and diagram of your method, improvements from initial prototype, sample results, and an assessment of its effectiveness compared with the recognised industrial standards; your report is logical and well-structured and uses correct scientific terminology throughout. **[7 8]**	
	You will produce a report on tests you have carried out on samples you have work-hardened, annealed and tempered and control samples; **[0 1]**	you will produce a report on tests you have carried out on samples you have work-hardened, annealed and tempered and control samples, including a comparison of the treated and untreated samples; **[2 3]**	you will produce a report on tests you have carried out on samples you have work-hardened, annealed and tempered and control samples, including an evaluation of whether the treatments have produced the expected result. **[4 5]**	
	You will produce a single set of results from each of your experiments to measure the thermal conductivity of a good conductor, the electrical conductivity of a sample of resistance wire and the specific heat capacity of a metal sample, and calculated values of thermal conductivity, electrical conductivity and specific heat capacity; **[0 1]**	you will produce a full set of results including repeat readings from each of your experiments to measure the thermal conductivity of a good conductor, the electrical conductivity of a sample of resistance wire and the specific heat capacity of a metal sample, and calculated values of thermal conductivity, electrical conductivity and specific heat capacity and estimated uncertainty of thermal conductivity; **[2 3]**	you will produce a full set of results including repeat readings from each of your experiments to measure the thermal conductivity of a good conductor, the electrical conductivity of a sample of resistance wire and the specific heat capacity of a metal sample, and calculated values of thermal conductivity, electrical conductivity and specific heat capacity, and estimated uncertainty of thermal conductivity and evaluation of your result compared to 'book' value. **[4 5]**	**/26**
			Total mark awarded:	**/50**

11.4 GUIDANCE FOR TEACHERS

11.4.1 Guidance on Delivery

This unit is about materials selection. In order to make informed choices between alternatives, it is necessary for candidates to learn something about the main classes of materials, their structure, and their properties. A large proportion of the delivery time of the unit will necessarily be taken up in covering these aspects. In order to keep the goal of materials selection in view, examples of applications to which materials are suited and applications requiring particular properties need to be stressed throughout.

The practical elements of the unit are important because they will help candidates to appreciate the very tangible nature of the concepts they are learning. Those who go on to follow courses in material engineering will encounter the full range of material testing available. Within this unit it is only possible to deal with a few examples in detail. Candidates, however, need to be aware that testing methods exist for all the properties they encounter in the unit.

Types of materials

One approach to teaching about a class of materials is to start with a set of, say, **ten** or **twelve** samples of polymers. These need to, as far as possible, be actual manufactured items, e.g. a piece of plastic guttering and a plastic bag, rather than samples from a kit. Candidates can then work in groups to discuss what properties the samples have which make them suitable for that purpose. Next, the materials can be identified and labelled. This can then lead on to what the names and descriptions mean and what processes the material has undergone in manufacture.

In rounding off the study of each class of materials, candidates can be invited to seek out, and, where possible, bring in to class, other examples of applications of the class of materials, and to identify them.

Physical properties

The glossary on the following page identifies the range of properties which candidates will be expected to use. It would be difficult to maintain candidates' enthusiasm by simply working through the list week by week. It would be preferable to introduce the properties as they arise in discussions of materials types, perhaps also encouraging candidates to build up their own list of definitions.

Another option is to give candidates the opportunity to measure as many of the properties as possible. It is likely that this option will be limited by the time available. A visit to the engineering department of a local manufacturer, college or university may provide an opportunity for candidates to see real materials testing in action.

Density: Mass per unit volume (kg m^{-3}).
Tensile stress: Tensile force/cross sectional area (N m^{-2}).
Tensile strain: Change in length/original length (no units).
Elastic modulus: Slope of the linear part of the stress-strain curve.
Young modulus, E: Tensile stress/tensile strain (N m^{-2}).

Candidates also need to recognise that the Young modulus can be applied for compression. They may also encounter the shear, bulk and torsional moduli but are not expected to define these.

Toughness: The ability of a material to absorb energy and deform plastically without fracturing. The tougher the material, the more difficult it is for cracks to grow in it.

Candidates need to find the toughness from the area under a force-extension graph. (See Bolton, p16). Knowledge of impact tests such as Charpy and Izod is not expected.

Ductile materials: stretch more, e.g. 20% mild steel, than brittle materials, e.g. 1% cast iron, when under tension.

Hardness: is a crude measure of strength. It is measured by pressing a pointed diamond or hardened steel ball into the material surface.

For Brinell and Vickers tests,
hardness = force/area of indentation (MPa.)
The Rockwell scale is based on the depth rather than the area of indentation.
Mohs' scale assessed the ability of **one** material to scratch another.

Ultimate tensile strength, σ_u: Stress at which the material, loaded under tension, breaks (MPa.).

Candidates may also meet the term fracture strength σ_f, but will **not** be expected to distinguish between σ_u and σ_f.

Electrical conductivity, σ / Resistivity, ρ: Siemen per unit length (S m^{-1}) / Ohm per unit length ($\Omega^{-1}m^{-1}$)

Reciprocal of resistivity: $\sigma = \frac{1}{\rho} = \frac{L}{RA}$

where: L is the length of a sample;
A is its cross-sectional area and
R is its resistance.

Thermal conductivity: $\lambda = \frac{\text{rate of flow of heat}}{\text{temperature gradient}}$ $Wm^{-1}k^{-1}$

where: temperature gradient = $\frac{\text{change in temperature}}{\text{unit length along the direction of flow of heat.}}$

Resistance to corrosion

Thermal expansivity: Candidates will only be expected to be familiar with the linear expansivity or coefficient of linear expansion.

$\alpha = \frac{\text{change in length}}{\text{original length x change in temperature}}$ K^{-1}

Specific heat capacity, c = $\frac{\text{heat gained (or lost)}}{\text{mass x change in temperature}}$ $J\ kg^{-1}\ K^{-1}$

Identifying objectives and constraints

A constraint is a feature of design that needs to be met at a specified level. An objective is a feature for which the best possible value is sought.

Ashby (1999) gives an example to illustrate the difference between the two:
For a racing bicycle, mass needs to be minimised – this is an *objective*; cost must not exceed a particular budget – this is a *constraint*.
A requirement for a shopping bicycle is that cost needs to be minimised – this is an *objective*; mass must not exceed a certain limit – this is a *constraint*.

Selection

Candidates need to learn to adopt a structured approach to materials selection. This is best reinforced by the study of case histories.

Having identified what properties are essential or desirable, candidates are expected to select using data set out in tables such as those in Sub-section 11.4.4 (Selection). These are given as examples and candidates are expected to find and use additional data.

11.4.2 Guidance on Assessment

Regular, early and constructive feedback to candidates on their performance is essential and crucial. Help with planning and structuring their portfolio work in a logical manner throughout the course will lead to better understanding of their work and is likely to achieve higher marks.

Giving candidates deadlines for the completion of the various sections of their work and encouraging them to adhere to them, is also essential if candidates are not going to rush to complete and possibly finish up with marks below their potential.

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 11.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• Candidates demonstrate that they understand the differences in the structures of the different classes of materials listed;
	2	• candidates demonstrate that they understand the differences in the structures and properties of the different classes of materials listed;
	3	• candidates demonstrate that they can relate the differences in the properties of the different classes of materials listed to their structures.
AO2	**1**	• Candidates outline the purpose of an application and select a reasonable material to fulfil this; • candidates carry out the required calculations with some assistance;
	2	• candidates identify fully the purpose of an application, suggest a number of alternatives and make a reasoned choice between them to fulfil the requirement; • candidates carry out the required calculations given the appropriate equations;
	3	• candidates identify fully the purpose of an application, suggest a number of alternatives and fully justify their choice between them to fulfil the requirement; • candidates carry out the required calculations unaided.
AO3	**1**	• Candidates are able to carry out each of the experiments safely with some guidance, obtaining at least **one** set of results in each case; • candidates demonstrate that they have some knowledge of the effect of work-hardening, annealing and tempering on the physical properties of **one** metal;
	2	• candidates are able to carry out each of the experiments safely, obtaining full sets of results in each case and carrying out appropriate analysis of the results; • candidates demonstrate that they know the effect of work-hardening, annealing and tempering on the physical properties of **one** metal;
	3	• candidates are able to carry out each of the experiments safely, obtaining full sets of results in each case and carrying out appropriate analysis of the results; they are able to evaluate their experiments and draw meaningful conclusions from them; • candidates demonstrate that they can explain the effect of work-hardening, annealing and tempering on the physical properties of **one** metal.

11.4.3 Resources

CD		*Exploring Materials Education Pack*	Science Museum 1998	190 074 7103
Equipment	Young modulus apparatus, XPS 070 010, Scientific and Chemical £105 + wires; Young modulus apparatus, c. £80 or c. £320, Phillip Harris; Young modulus apparatus, XBV-711-V Griffin, c. £105; Hardness of metals apparatus Phillip Harris, c. £20 + hand microscope c. £12.			
Textbooks	Ashby M	*Material Selection in Mechanical Design*, 2nd ed.	Butterworth Heinemann	075 064 579X
	(Useful teacher's resource, but well beyond the level expected of candidates for this unit);			
	Bolton W	*Materials for Engineering* 2nd ed.	Newnes	2000
	Higgins AH	*Materials for the engineering technician*	Butterworth Heinemann	034 067 654X
	Newey C & Wever G (eds.)	*Materials Principles and Practice*	Open University	075 060 3909
Websites	www.materials.ac.uk/resources			

12 Unit 12: Electrons in Action
[A2 level, optional, internally assessed]

12.1 ABOUT THIS UNIT

This A2 level unit is optional and is internally assessed.

All around us, people are using personal stereos, mobile phones and computers. These instruments would not function without batteries as a source of electrical energy. There is a huge demand for portable sources of electricity. Scientists have already designed storage batteries that provide a reliable source of electricity, and research into developing environmentally-friendly and more efficient cells is ongoing. Physical chemists and technologists investigate electrochemical reactions under different conditions as a first step in development or improvement.

An understanding of the principles of electrochemistry is necessary to carry out safe and economic industrial processes, such as the extraction and purification of important metals.

There are links to Unit 2: *Analysis at work*, Unit 3: *Monitoring the activity of the human body* and Unit 5: *Chemicals for a purpose*. There are also links between this unit and AS and A2 units in GCE Chemistry and Physics.

This unit will help you to prepare for higher education courses in chemistry, or applied science courses with a chemical or physics element. It will also provide you with some skills needed for working in a science-based industry.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will conduct an investigation into the principles and applications of electrochemical changes. Your evidence will include:

- a presentation outlining the applications of stated electrochemical changes;
- a comparison of commercial cells: non-rechargeable, rechargeable and fuel, including construction, resources, uses, sustainability, efficiency, safety and environmental issues;
- practical investigations into:
  - (a) the factors which can change the potential difference of a cell and those which have no effect;
  - (b) the factors which affect the efficiency of a simple laboratory experiment in which an object is copper plated.

12.2 WHAT YOU NEED TO LEARN

You need to learn about:

- electrochemical charge;
- principles and applications of commercial cells;
- electrolysis and the extraction of metals;
- fuel cells.

12.2.1 Electrochemical Change

You need to:

- explain redox in terms of electron transfer;
- understand what is meant by oxidation number;
- recognise the particles that gain or lose electrons in a chemical reaction;
- recognise changes in oxidation number;
- write ionic half equations and combine them to give equations for redox reactions;
- explain redox equilibria.

12.2.2 Principles and Applications of Commercial Cells

Chemical reactions that proceed by the complete transfer of electrons are a potential source of electricity. Scientists need to understand how the movement of the electrons can be improved and harnessed to produce an electric current. By changing the variables in simple experiments and analysing the results, scientists can develop cells that are efficient, safe and useful.

You need to:

- explain the difference between a cell and a battery;
- explain the terms 'half-cell' and 'electrode potential';
- use metal/metal-ion half-cells to make an electrochemical cell;
- explain the purpose of the salt bridge;
- identify the half-ion reactions that are taking place in the cell;
- define potential and potential difference;
- measure the potential difference (pd) generated by some simple electrochemical cells;
- measure the effect of changes in concentration and temperature on the pd of voltaic cells;
- explain the terms current, EMF, terminal potential difference and internal resistance;
- explain the term 'standard hydrogen electrode' and describe how it is measured;

- use standard electrode potentials to calculate EMF of cells.
- explain why values of the calculated and experimental EMF may be different.

Conventional electrochemical cells are used in calculators, torches, personal stereos, computers and many other machines. There are many types advertised for sale and you will be able to investigate some of them.

You need to:

- describe examples of primary and secondary cells and explain how they work;
- explain the difference between a primary and secondary cell.

You need to carry out research on:

- the different types of batteries on the market and their uses;
- factors that need to be considered when choosing a battery;
- care and maintenance of batteries;
- the importance of recycling batteries.

12.2.3 Electrolysis and the Extraction of Metals

Electricity is a flow of electrons that can be used to perform work. In a voltaic cell a chemical reaction produces electricity. In an electrolytic cell an external source of electricity is used to produce a chemical reaction. Electrolytic cells are of considerable economic importance. Without them we would not be able to produce large amounts of important metals like aluminium and sodium.

You need to:

- explain electrolysis and the terms electrolytic cell, electrolyte, anode, cathode, anion and cation;
- write redox equations for reactions that occur during electrolysis;
- use the electrochemical series to predict the preferential discharge of ions at electrodes;
- understand that the concentration of an ion and the type of electrode can affect the preferential discharge of ions;
- define the coulomb;
- calculate and measure the amount of product deposited at an electrode during electrolysis under different conditions.

There is a constant need to produce useful materials from minerals present in the earth's crust. Thousand of tonnes of aluminium are produced annually in the U.K. and this could not have been achieved before the discovery of electricity. The use of some metals like copper and tin require a high degree of purity. Even though these metals can be extracted by other methods, electrolysis is used in their purification.

You need to:

- explain why some metals can only be extracted by electrolysis;
- set up a simple electrolytic cell to obtain pure copper;
- explain why there is a high demand for very pure copper.

You need to find out about the electrolytic production of at least **two** metals. You need to:

- give reasons for the choice of raw materials, electrolyte, electrodes;
- describe how energy costs are conserved;
- explain all chemical reactions that take place;
- describe how products and by-products are collected and stored;
- describe safety and environmental issues;
- produce calculations of the amount of electricity used for the annual production of a metal.

12.2.4 Fuel Cells.

The production of electricity using combustion of fuels is very inefficient as chemical energy is lost to the surroundings as heat energy. Research is being carried out into the development of fuel cells that convert chemical energy directly into electrical energy. By studying this section, you will find out how fuel cells work, the problems that scientists need to overcome and the benefits that fuel cells will bring to the community and environment.

You need to:

- describe a fuel cell and explain how it works;
- identify the difference between a fuel cell and a voltaic cell;
- explain the term ‘energy density’.

You need to find out about:

- different types of fuel cell;
- uses of fuel cells;
- the efficiency of fuel cells when compared to other types of cell;
- the availability and storage of suitable renewable fuels;
- safety and environmental issues.

You need to compare fuel cells to alternatives, including electric vehicles.

12.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 12: Electrons in action				
What you need to do:				
You need to produce evidence of your investigation into the principles and applications of electrochemical changes [**50** marks]. This evidence needs to include**:** **AO1:** a presentation outlining the applications of stated electrochemical changes [**10**]; **AO2:** a comparison of commercial cells: non-rechargeable, rechargeable and fuel, including construction, resources, uses, sustainability, efficiency, safety and environmental issues [**14**]; **AO3:** practical investigations into: (a) the factors which can change the potential difference of a cell and those which have no effect; (b) the factors which affect the efficiency of a simple laboratory experiment in which an object is copper plated [**26**].				
How you will be assessed:				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO1	You will investigate redox equilibria and demonstrate a basic knowledge and understanding of the principles underlying at least **two** of the applications of electrochemical changes, including correct scientific terminology and conventions; **[0 1]**	you will investigate redox equilibria and demonstrate a sound knowledge and understanding of the principles underlying the full range of applications of electrochemical changes identified in this unit; you will give clear explanations and will use appropriate scientific terms and conventions accurately; **[2 3]**	you will investigate redox equilibria and demonstrate a thorough knowledge and understanding of the principles underlying the full range of applications of electrochemical changes identified in this unit; you will give clear explanations and will use appropriate scientific terms and conventions accurately throughout. **[4 5]**	
	You will demonstrate research into the production of electricity and metals, using some appropriate examples, selecting information and presenting it clearly; **[0 1]**	you will demonstrate research into the production of electricity and metals, using a range of examples, selecting and interpreting information and presenting it clearly; **[2 3]**	you will demonstrate research into the production of electricity and metals, using the full range of examples given, selecting and interpreting information and presenting it clearly. **[4 5]**	**/10**
AO2	You will describe at least **one** example of each of **two** types of commercial cells, make some comparisons and give a limited interpretation of information; **[0 1 2 3 4]**	you will describe **three** different commercial cells, make comparisons, give a good explanation and interpretation of information; **[5 6]**	you will describe a wide range of cells, make all comparisons, give a full explanation and interpretation of information. **[7 8]**	
	You will carry out some straightforward calculations of EMF of cells and quantity of charge; you will obtain and use data to compare the efficiency of commercial cells; **[0 1 2]**	you will carry out calculations of EMF of cells, quantities of charge and mass of products; you will obtain and use data to compare the efficiency of commercial cells and obtain correct solutions; **[3 4]**	you will carry out complex calculations of EMF of cells, quantities of charge and mass of products; you will obtain and use data to compare the efficiency of commercial cells and obtain correct solutions to the appropriate degree of accuracy. **[5 6]**	**/14**

Unit 12: Electrons in action (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO3	Using risk assessments, you will carry out measurements of EMF of cells and mass of copper plate; you will change at least **one** of the conditions of each experiment to obtain **two** sets of results for measurement of EMF and **two** sets of results for the measurement of copper plate; **[0 1 2 3 4]**	you will produce risk assessments, consistent with COSHH guidelines; you will carry out measurements of EMF of cells and mass of copper plate; you will change conditions to obtain more than **two** sets of results for measurement of EMF and more than **two** sets of results for the measurement of copper plate; you will work with an appropriate degree of accuracy; **[5 6]**	you will produce your own detailed risk assessments, consistent with COSHH guidelines; you will carry out a wide range of measurements of EMF of cells and mass of copper plate; you will consider and change a range of conditions to obtain corresponding sets of results for measurement of EMF and for the measurement of copper plate – at least **one** set of results show no effect; you will explain any practical techniques that will improve results; you will work with an appropriate degree of accuracy. **[7 8]**	
	You will make and record relevant observations and measurements from the above experiments; you will display the data appropriately, with help; **[0 1 2 3]**	you will make and record relevant observations and measurements from the above experiments, using precision in your measurements; you will display the data obtained accurately in a range of ways; **[4 5 6]**	you will make and record relevant observations and measurements from the above experiments, using precision in your measurements; you will display the data obtained accurately in a range of ways. **[7 8 9]**	
	You will give some interpretation of the results; you will evaluate your procedures; **[0 1 2 3]**	you will interpret the results and draw basic conclusions; you will evaluate your procedures; **[4 5 6]**	you will interpret the results in detail and draw conclusions; you will evaluate your procedures and suggest alternatives. **[7 8 9]**	**/26**
			Total mark awarded:	**/50**

12.4 GUIDANCE FOR TEACHERS

12.4.1 Guidance on Delivery

This unit will provide candidates with an opportunity to extend their knowledge and understanding of oxidation, reduction and redox equilibria. It will also introduce them to some applications of electrochemical reactions and the importance of these reactions with regard to energy changes. Many candidates are interested in issues of pollution and saving the environment. They will be able to expand their experience in these fields as they study the topics in this unit.

It is important that candidates learn and use the correct nomenclature and terminology. This can be introduced gradually and practised as the course progresses. Simple practical experiments, demonstrations and problem-solving exercises can be used to help strengthen understanding and maintain interest.

Most of the practical elements of the unit require only simple electrical apparatus, standard laboratory apparatus, carbon electrodes, a range of metals and metallic salts. A supply of commercial and storage cells will also be required. Before starting an experiment, candidates need to be encouraged to:

- have aims and objectives for the experiment;
- be organised;
- have tables ready to record observations and measurements;
- note measurements accurately;
- note the degree of accuracy of the apparatus and instruments used;
- note any conditions and materials that may affect results;
- identify hazards and prepare a risk assessment.

Electrochemical change

There are many simple test-tube experiments using displacement reactions that can be used to revise oxidation and reduction. These examples can be used to introduce transfer of electrons and then oxidation number. They can also be used to practise writing ionic half equations. Candidates need to identify:

- particles which are oxidised or reduced;
- the change in oxidation number and hence the number of electrons transferred;
- particles which act as oxidising agents and those which act as reducing agents.

A simple metal/metal ion voltaic cell will demonstrate the transfer of electrons around an external circuit. There may be time for candidates to make a simple battery from coins and lemon juice.

Some candidates may need to study many examples before they fully understand what is meant by an equilibrium reaction. They need to understand that there is a potential for the reaction to take place in a forwards or backwards direction and that the direction will depend on the conditions and reagents. A demonstration of the reactions in which zinc is oxidized to zinc ions by copper, and the one in which zinc ions are reduced to zinc by magnesium is a simple introduction to the reversible reaction:

$Zn(s) \rightleftharpoons Zn^{2+}(aq) + 2e^-$

Principles and applications of commercial cells

The fact that an equilibrium reaction exists between a metal and its ions introduces the existence of a half-cell and electrode potential.

Candidates need to understand that:

- potential cannot be measured;
- only potential difference can be measured;
- the polarity of the electrode will be determined by the identity of the other cell;
- values of standard electrode potentials are related to the standard hydrogen electrode.

Practical technique is important. Candidates need to become familiar with what happens if:

- the salt bridge is removed;
- crocodile clips are covered by the solution;
- the voltmeter is connected incorrectly;
- a high-resistance voltmeter is connected;
- the concentration of solution in one half-cell is changed.

They need to be encouraged to think of other factors such as size/position of electrode, which may or may not affect results.

A good understanding of chemical equilibria and how conditions can change potential will enable candidates to understand the need for a standard electrode and will help them to carry out tasks successfully.

The electrochemistry of primary and secondary cells is explained fully in most GCE Chemistry textbooks. Candidates should not have difficulty in finding information on commercial and rechargeable cells – there are some very good websites. However, candidates need to be encouraged to be selective when recording and presenting data.

Candidates could be asked to list storage cells with which they are already familiar. A survey could be carried out on types of cells purchased by a group of people, such as the class, or family and friends. The survey could be developed to find out about the use of each type; hours of use per day; cost per hour; voltage; total energy output etc. Some of this information could be used to compare costs and efficiency. All points in Sub-section 12.2.2 need to be covered as this topic forms a large part of Task AO2.

Electrolysis and the extraction of metals

Most of the terminology should be familiar.

Candidates need to know that:

- electrons, from an external source, are used to produce a chemical change;
- ions need to be able to move through the electrolyte;
- positive ions move towards the negative electrode;
- when **two** different metal ions are present, the metal ions with the more positive potential are most likely to be discharged;
- the preferential discharge of an ion can be affected by its concentration;
- sometimes metal ions react with the electrodes (see extraction of sodium);
- the amount of product formed during electrolysis is determined by the amount of electricity passed around the circuit and the number of electrons involved in the reaction at the electrode;
- the unit of charge is the coulomb; coulombs = amps x seconds;
- **96 500** coulombs is the charge carried by **one** mole of electrons or **one** mole of singly charged ions.

Simple experiments to investigate copper plating should provide an opportunity for candidates to practise their technique, obtain results and carry out calculations. Candidates need to be encouraged to discuss ideas and to interpret results.

The industrial manufacture of metals such as Aluminium and Sodium covers most of the electrochemistry required and illustrates how simple experiments are developed to give a good rate of production while conserving energy and maintaining safety.

Many GCE Chemistry/Physics textbooks provide data on annual production and give examples on how to calculate the amount of electricity used.

Candidates need to:

- check that they have studied all points in the specification;
- select appropriate material;
- use their own words when writing coursework.

The practical experiment for producing pure copper forms the basis for the second strand of the task for AO3. It needs to be developed in order to meet all the criteria for a high mark. Some research into electroplating may be useful.

Fuel Cells

After studying the previous topics and realising the importance of recycling storage cells, the class could be asked to debate the question ‘Do we have an energy crisis?’ Candidates may have already discovered information about fuel cells when researching portable batteries and they will introduce the topic. It needs to be emphasised that hydrogen is not the only type of fuel used in these cells. Candidates need to research all points in Sub-section 12.2.4 so that they can fulfill all the criteria for AO2.

12.4.2 Guidance on Assessment

Candidates need to carry out research for this unit, they need to be taught how to find, select and record the relevant information and its source. Coursework needs to include diagrams, tables, charts, graphs and calculations that are accurate to the correct degree. Candidates need to interpret their findings and draw conclusions.

Regular, early and constructive feedback to candidates on their performance is essential and crucial. Help with planning and structuring their work in a logical manner throughout the course will lead to better understanding of their work and is likely to achieve higher marks.

Giving candidates deadlines for the completion of various sections of their work, and encouraging them to adhere to them, is also essential if candidates are not going to rush to complete and possibly finish up with marks below their potential.

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade*, which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 12.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the grid comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the grid).

The maximum mark for each strand is shown in the far right hand column of the grid and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed Mark.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered. The final mark for the candidate is out of a total of **50** and is found by totaling the marks for each AO strand.

The further guidance below amplifies the criteria in the Assessment Evidence Grid and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	1	• A presentation to demonstrate the applications of electrochemical changes, including clear, correctly labelled diagrams and correct terminology, evidence for the presentation can be in the form of a poster, leaflet, powerpoint; • portfolio demonstrates a basic understanding of redox reactions with appropriate examples; • some research has been done, but selection and presentation is limited;
	2	• the presentation demonstrates applications of electrochemical changes in the production of primary cells, secondary cells, fuel cells and extraction of metals; including clear, correctly labelled diagrams of each; • portfolio demonstrates a knowledge and understanding of most of the redox reactions involved; the conditions required with explanations; scientific terms and conventions have been used; • research into each application has been done and relevant information has been selected and presented clearly and logically in the candidate's own words with sources credited;
	3	• the presentation demonstrates applications of electrochemical changes in the production of primary cells, secondary cells, fuel cells and extraction of metals; including clear, correctly labelled diagrams of each; • the work demonstrates a thorough knowledge and understanding of all the redox reactions involved; the conditions required, with explanations; scientific terms and conventions have been used correctly; a wide range of research into each application has been done and relevant information has been selected; • the presentation is clear, logical, includes an evaluation and is expressed in the candidate's own words with sources credited.
AO2	1	• Examples of cells are described; there is only limited comparison and evaluation as outlined in the assessment grid; • the candidate has carried out straightforward calculations involving EMF of cells and quantity of charge; some data has been recorded to compare the efficiency of batteries and calculations of efficiency have been attempted;
	2	• examples of each type of cell are described in detail; valid comparisons and evaluations have been made as outlined in the assessment grid; • the candidate has carried out calculations involving EMF of cells; quantity of charge and mass of product; data has been recorded to compare the efficiency of batteries; calculations of efficiency have been made and the correct solutions obtained;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	3	• examples of each type of cell are described accurately and in detail; valid comparisons have been made and detailed evaluations presented, as outlined in the assessment grid; • the candidate has carried out calculations involving EMF of cells; quantity of charge and mass of product; data has been recorded to compare more than **one** aspect of efficiency of batteries; calculations of efficiency have been made and the correct solutions obtained to an appropriate degree of accuracy.
AO3	1	• The candidate has used a risk assessment in each activity; carried out the experiment using a satisfactory practical technique and appropriate apparatus; changed the conditions of each experiment to obtain sets of results for measurement of EMF and for the measurement of copper plate; • relevant observations and measurements from the above experiments have been recorded; the data has been displayed appropriately, with help; • the candidate has recorded units accurately; made calculations and attempted to interpret the results by considering practical technique and the principles of electrochemistry;
	2	• the candidate has carried out risk assessments consistent with COSHH guidelines before each activity; carried out the experiment using a good practical technique and the correct apparatus; • where appropriate, the candidate has repeated measurements and averages have been calculated; the candidate has worked with an appropriate degree of accuracy; • relevant observations and measurements from the above experiments have been recorded and the data has been displayed accurately, without help; results have been displayed accurately in a range of ways; • the candidate has recorded units accurately; made calculations; drawn basic conclusions; interpreted the results by considering practical technique and the principles of electrochemistry;
	3	• the candidate has carried out detailed risk assessments consistent with COSHH guidelines before each activity; • where appropriate, the candidate has repeated measurements and averages have been calculated; the candidate has worked with an appropriate degree of accuracy; • relevant observations and measurements from the above experiments have been recorded and the data has been displayed accurately, without help; results have been displayed accurately in a range of ways; • the candidate has recorded units accurately; made calculations; drawn conclusions; interpreted the results by considering practical technique and the principles of electrochemistry.

12.4.3 Resources

CD-ROM	Aluminium a Modern Metal, Aluminium Federation; and the accompanying student information booklet CD Magic of Metals, schools education pack, Dr Ray Oliver; Non-Ferrous Alliance 2004, available from the Aluminium Federation			
Textbooks	Independent Learning Project for Advanced Chemistry (ILPAC) 2nd Ed.			
		Book 4: s-Block Elements	John Murray	071 955 334 2
		Book 7: Equilibrium III Redox Reactions	John Murray	071 955 337 7
	Lister T & Renshaw J	*Understanding Chemistry for A Level*	Stanley Thornes	074 870 216 4
	University of Bath	*Science 16-19 Chemistry*	Nelson	017 448 236 1
	University of York Science Group	*Salters Advanced Chemistry: Storyline*	Heinemann	043 563 1063
		Chemistry in Context Laboratory Manual and Study Guide	Nelson	017 448 1640
Video	Electrochemistry ESSO Industrial Chemistry for Colleges and Schools RSC			
Websites	These sites have very useful information about electrochemical cells: http://www.howstuffworks.com/ http://www.fuelcells.org http://www.rbrc.org http://www.ausetute.com.au/ http://www.valence.com/BatteryEducation.asp			

13 Unit 13: The Mind and the Brain
[A2 level, optional, internally assessed]

13.1 ABOUT THIS UNIT

This A2 level unit is optional and is internally assessed.

How does the set of mental processes we collectively refer to as 'mind' emerge from activity in the brain? Attempts to answer this question are being spear-headed by neuroscientists, cognitive scientists, psychologists and philosophers. The challenge of explaining mind and consciousness has been fuelled by the remarkable advances made in our understanding of mind and brain during the 1990s, the 'Decade of the Brain'.

Neuroscience involves the scientific study of mind and brain. The breadth of subjects studied is vast and includes consciousness, addiction, mechanisms of cognition, stress and mental illness, to name but a few. A variety of methods and techniques are employed, which vary from psychological testing and behavioural observation, to brain imaging and brain surgery. Neuroscience is currently **one** of the most exciting and rapidly developing areas of scientific enquiry. It is a component of many degree courses, and is a subject in which findings from molecular biology are explored alongside issues in philosophy and psychological science.

This unit builds on Unit 1: *Science at work*, Unit 3: *Monitoring the activity of the human body*, Unit 4: *Cells and molecules* and Unit 8: *Investigating the scientist's work*. There are links between this unit and the A2 units in the OCR GCE Biology and Psychology specifications.

This unit will help to prepare you for higher education courses in medicine, neuroscience, applied biology, psychology and philosophy, and/or for other vocational qualifications in areas including the life sciences and healthcare.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will carry out a comprehensive exploration of research methods employed in the study of mind and brain. Your evidence will include:

- the production of **two** sets of fact sheets, designed to raise mental-health awareness, **one** set on stress and illness and the second set on research methods employed in the study of the healthy and the damaged brain;
- an evaluation of the scientific methods and techniques used in the study of mind and brain, together with a consideration of associated ethical issues and evidence of statistical research;
- the design and safe execution of a simple experiment to investigate **one** aspect of cognitive function and an investigative case study into memory loss.

13.2 WHAT YOU NEED TO LEARN

You need to learn about:

- the mind, stress and illness;
- exploring the healthy and the damaged brain;
- methods and ethical issues in brain research;
- everyday cognition.

13.2.1 The Mind, Stress and Illness

The belief that mind is involved in the development of physical illness can be traced back to the earliest days of medicine and the ancient Greeks. However, research has only recently provided reliable evidence to link mental state and behaviour with certain physical illnesses such as heart disease. Moreover, the evidence linking psychological factors and development of diseases such as cancer remains poor.

You need to:

- distinguish the general term 'stress' from specific emotional states such as anger;
- identify possible causes of stress;
- discuss the biological basis of the stress response, including the importance of hormones such as cortisol;
- explain physiological and pyschological measurement of stress;
- consider the implications of stress in relation to physical illness;
- discuss how intervention programmes may be employed to prevent disease progression and outcome;
- research statistics for the UK to prepare a fact sheet identifying the frequency of different categories of stress-related mental health problems.

13.2.2 Exploration of the Healthy and the Damaged Brain

The human brain comprises thousands of millions of nerve cells, or *neurons*, and their supporting cells. These cells work in synchrony with over a thousand neurochemicals and many thousands of genes to orchestrate cognition and behaviour.

You need to:

- describe how the structure and function of nerve cells varies in the brain;
- recount the passage of the nerve impulse along the neuron and the electrochemical events at the synapse, including the generation of post-synaptic potentials;
- provide examples of the receptor subtypes for dopamine and serotonin in the brain, and explain how Cocaine and Prozac work at the synaptic junction and produce their behavioural effects;

- describe the structure and functions of the following brain structures:
  – frontal lobes;
  – temporal lobes;
  – parietal lobes;
  – occipital lobes;
  – corpus callosum;
  – ventricles;
  – limbic system (including hypothalamus, hippocampus and amygdala);
  – basal ganglia;
  – brain stem;
- describe the behavioural- and cognitive-effects associated with damage to the frontal lobes using Phineas Gage as an example, and explain how the brain attempts to deal with damage to itself;
- explain how genes may exert their effects on behaviour via expression in the brain;
- discuss how Alzheimer's disease and Huntington's disease affect the brain and behaviour and understand the rationale for the pharmacological treatment of Alzheimer's disease;
- explain how foetal brain-cell grafts and stem-cell technology might be used in the treatment of neurodegenerative disease;
- discuss current theories of schizophrenia; the dopamine hypothesis and the role of brain circuits in producing auditory hallucinations, genetic contributions, environmental influences, and expound the pharmacological basis of antipsychotic medication.

13.2.3 Methods and Ethical Issues in Brain Research

A knowledge of the methods and techniques employed in modern brain research, along with their advantages and limitations, is crucial to understanding and evaluating findings.

Important ethical issues inevitably arise from investigations of the brain and mind. These issues relate, not just to the methods used to study and alter brain function, but to any new knowledge about the brain acquired by these methods. You need to consider some of the important ethical issues associated with brain research and its applications, which scientists and the public are now beginning to address.

You need to:

- describe invasive methods (brain stimulation, lesion production, stereotaxic surgery) of investigating brain function;
- describe non-invasive methods (repeated transcranial magnetic stimulation and brain imaging techniques such as fMRI and MEG, computational modelling) of investigating brain function;
- describe experimental techniques (foetal brain-tissue grafting, stem-cell research);

- describe genetic techniques in brain research (knock-out mouse models in memory research) and illustrate how these techniques can be combined with those such as fMRI above;
- discuss the ethics of brain investigation and the various techniques employed;
- consider the ethics of future technologies:
  – whether advances in medicine and biotechnology should be used to enhance cognitive and mental function;
  – whether brain scanning should be used as a screening tool or as a predictor of a tendency to behaviours such as aggression.

13.2.4 Everyday Cognition

How and why are we aware of events around us? How can we remember what we had for lunch yesterday and plan what we intend to do tomorrow? You will consider fundamental elements of cognition, applications to cognitive research and patient care, and some basic practical work.

You need to:

- discuss the neurobiological and molecular basis of memory, explaining the roles of synaptic plasticity and long-term potentiation in learning, along with the relative roles of cellular mechanisms such as gene activation;
- discuss elements involved in 'eye-witness testimony';
- carry out simple learning tests to compare different individuals' ability to recall events;
- discuss both biological and psychological mechanisms and implications of memory loss;
- describe the cognitive assessment and neuropsychological treatment of amnesia;
- discuss research carried out in the areas of memory loss in relation to either neurological deficit or head injury.

13.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 13: The mind and the brain
What you need to do:
You need to produce evidence of a comprehensive exploration of research methods employed in the study of mind and brain [**50** marks]. This evidence needs to include**:** **AO1:** the production of **two** sets of fact sheets designed to raise mental-health awareness, one set on stress and illness, and the second set on research methods employed in the study of the healthy and the damaged brain [**10**]; **AO2:** an evaluation of the scientific methods and techniques used in the study of mind and brain, together with a consideration of associated ethical issues and evidence of statistical research [**14**]; **AO3:** the design and safe execution of a simple experiment to investigate **one** aspect of cognitive function and an investigative study into memory loss [**26**].
How you will be assessed:

Assessment Objective	Mark Band 1	Mark Band 2	Mark Band 3	Mark Awarded
AO1	You will produce **one** fact sheet including selected information about stress and related illness that has been clearly presented; **[0 1 2]**	you will produce **one** detailed set of researched fact sheets including a clear definition of stress, its possible causes and its effects on health, with relevant information selected and clearly and logically presented; **[3]**	you will produce **one** set of detailed fact sheets, detailed work based on thorough research, including a clear definition of stress, its possible causes and its effects on health with reference to intervention programmes; you will provide evidence that relevant information has been selected from a variety of sources and is clearly and logically presented. **[4 5]**	
	You will produce **one** fact sheet including selected information about the study of the brain that has been clearly presented; **[0 1 2]**	you will produce **one** detailed set of researched fact sheets that have been clearly presented, based on the study of the brain; **[3]**	you will produce **one** set of detailed fact sheets, detailed work based on thorough research into both the healthy and the damaged brain, with evidence that relevant information has been selected from a variety of sources and is clearly and logically presented. **[4 5]**	**/10**
AO2	You will demonstrate a basic knowledge of the methods used in studying the brain and how they are used in an experimental or a clinical setting; **[0 1 2]**	you will demonstrate knowledge and understanding of the methods used in studying the brain and explain how they are used in both an experimental and a clinical setting; you will mostly use scientific terms accurately; **[3 4 5]**	you will demonstrate a thorough knowledge and understanding of the methods used in studying the brain; you will explain how such methods are used in both an experimental and a clinical setting, and how they are used in confirming hypotheses regarding normal brain function and in the diagnosis of brain diseases; you will use appropriate scientific terms accurately throughout. **[6]**	

Unit 13: The mind and the brain (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO2	You will carefully select information and present it clearly; you will acknowledge the ethical aspects of brain research; **[0 1 2]**	you will select carefully a wide range of information, giving reasons for your choice of resources; you will present information clearly and logically; you will discuss the moral and ethical implications of brain research; **[3]**	you will demonstrate an ability to identify the preferable methods for investigating a particular research question; you will evaluate information both for and against a method, presenting it clearly and logically; you will discuss comprehensively moral, ethical and conceptual considerations associated with the various methods employed in brain research; you will provide evidence of statistical research. **[4 5]**	
	You will prepare a fact sheet involving statistical evidence with basic calculations shown; **[0 1]**	you will complete a fact sheet detailing statistical evidence, including statistical-test calculations with some summary of results; **[2]**	you will present statistical evidence with appropriate complex statistical calculations with full explanation of the rationale behind the test and result gained. **[3]**	**/14**
AO3	You will carry out a simple experiment to evaluate a particular cognitive function following ethical guidelines; **[0 1 2]**	you will design and carry out a simple experiment to evaluate a particular cognitive function showing evidence of consideration of ethical guidelines; **[3]**	you will design and carry out an experiment to evaluate a particular cognitive function showing evidence of all relevant ethical guidelines and steps taken to reduce risk. **[4 5]**	
	You will plan and investigate a research problem and show that you have considered appropriate ethical issues; **[0 1 2]**	you will plan confidently and complete your research problem, identifying its advantages and limitations; you will provide evidence that you have considered ethical issues; **[3 4 5]**	you will plan thoroughly and complete your research problem; you demonstrate a clear understanding and justification of your work; you demonstrate consideration of ethical issues in your design. **[6]**	
	You will record data relating to your design and display the data; **[0 1 2]**	you will record precisely relevant data and display the scientific data accurately in a range of ways using tables and simple graphs; **[3 4 5]**	You will record precisely a detailed data set; you will display the scientific data accurately in a range of ways; you will collect sufficient data to complete simple statistics on the results. **[6]**	
	You will offer a basic interpretation of the results; **[0 1 2]**	you will interpret the results and draw basic conclusions, explaining your results clearly, making real-life application wherever appropriate; **[3]**	you will interpret the results in detail using secondary sources to support your findings and draw conclusions relating to your results. **[4 5]**	
	You will offer a basic evaluation of your work; **[0 1]**	you will provide examples of how your work could be improved upon; whether your chosen method is the most suitable, identifying advantages and limitations; **[2 3]**	you will provide practical and clinical analogies wherever appropriate and discuss how your experimental design could be modified using other existing methods and suggestions for further research. **[4]**	**/26**
			Total mark awarded:	**/50**

13.4 GUIDANCE FOR TEACHERS

13.4.1 Guidance on Delivery

The intention is that this unit will provide candidates with an introduction to how the brain works, the methods employed in investigating brain function and applications of this knowledge to a variety of academic and clinical areas. Neuroscience encompasses many disciplines and this unit introduces issues in philosophy, physiology, psychology and medicine relevant to the modern study of mind and brain. Many of these issues feature in the news and are the subject of popular science programmes, and candidates need to intelligently debate important topics.

Sub-section 13.2.1 (The mind, stress and illness) investigates the relationship between mind, stress and disease and explores the extent to which mind is linked to physical illness. Once candidates have learned about the stress responses, including the way in which the brain communicates with the immune system, they can debate whether stress is implicated in illnesses such as cancer and explore possible mechanisms. Recent developments have allowed us to explore the complex interaction between nervous and immune systems. Chemicals produced by immune cells stimulate parts of the brain; in turn, the immune system can be regulated by brain chemicals which also influence behaviour. Disruption of this mechanism has been implicated in both acute (short-term) and chronic (long-term) diseases. Candidates need to explore this, and other stress responses, and consider how illnesses such as heart disease and cancer develop and how psychological factors might input into these disorders.

Psychological factors such as stress and anxiety may also affect disease development indirectly by increasing the amount someone eats, smokes and drinks. Candidates need to learn how knowledge of biological mechanisms and psychological states and behaviours is integrated and applied in preventative-stress management and disease-intervention programmes.

Sub-section 13.2.2 (Exploration of the healthy and the damaged brain) concentrates on the basics of brain function and what happens when things go wrong. This provides the groundwork for later sub-sections of this unit and it is vital that candidates understand nerve-cell function and events at the synaptic junction, and that they grasp topics such as memory neurobiology and nervous-immune-system interaction.

Candidates need to study normal brain function and consider what happens when things go wrong, with a focus on frontal-lobe dysfunction. They also need to study examples of chemical systems in the brain, applying that knowledge to models of how **two** common drugs, Cocaine and Prozac, exert their effects on mind and brain.

Certain diseases and conditions have severe consequences for the brain, with profound and sometimes irreversible effects on cognition, mind and behaviour. Candidates need to explore the nature of Alzheimer's disease and Huntington's disease, both of which cause degeneration of brain tissue. They need to consider how these illnesses are currently treated and how they may be treated in the future. Schizophrenia, a profound disturbance of perception, mood and thought, also radically alters sense of self and mind. Candidates also need to learn about the various symptoms of schizophrenia, its likely causes and how the illness is treated.

Sub-section 13.2.3 (Methods and ethical issues in brain research) addresses methods and ethics in the study of mind and brain. Once clear on these scientific methods, candidates need to assess the successes of these technologies and look at the moral and ethical issues that they raise. This will prepare them for the assessed work that they need to complete. Candidates need to understand how to apply existing techniques to new questions and think creatively about new approaches. They need to study a variety of methods employed in neuroscience.

Candidates need to write a review of these methods, identifying strengths and weaknesses before studying a prepared account of an experimental protocol in neuroscience. They need to compose a critical evaluation of the methods employed and formulate an alternative experimental protocol with methods that they judge to be more appropriate, considering ethical issues in the process.

Sub-section 13.2.4 (Everyday cognition) addresses the problems in conceptualising mind and consciousness, and the relationship between consciousness and cognition in people with and without brain damage. Determining the nature of consciousness, and understanding how subjective experiences of mind arise from the activity of nerve cells, is a fundamental question in philosophy and neuroscience. Whilst biological explanations of mind and consciousness are important, many conceptual and philosophical issues, which inevitably arise from their investigation, also need to be addressed. Candidates will consider issues such as the distinction between mind and consciousness, how we determine the point at which an organism becomes conscious, and whether mind and consciousness arise solely from brain mechanisms. Many researchers view mechanisms such as learning, memory, perception and attention as cognitive components of consciousness. Our understanding of learning and memory processes has significantly increased over the past decade. Candidates need to consider how these processes occur in the brain, at a neural level and at a molecular level, and how knowledge of these mechanisms is being practically applied.

The Mind, Stress and Illness

There are many articles written for the layperson on the relationship between stress and illness, however, candidates need to be encouraged to explore articles with a scientific basis. There are well-written articles in recent issues of journals such as *Scientific American* and *New Scientist*. Once familiar with the complexity of the stress response and the relationship between nervous and immune systems, the complexity of the cancer process can be emphasised. There are a variety of Internet resources which illustrate the biology of cancer and the course taken by various forms of the illness. Candidates need to understand that the work to-date linking stress and cancer is fraught with methodological problems.

Exploration of the healthy and the damaged brain

It is envisaged that, for teaching purposes, this sub-section will be integrated with Sub-section 13.2.3 (Methods and ethical issues in brain research). Material here would benefit from conventional delivery, supplemented by anatomical models, video/DVD and the content of several Internet websites, specified in Sub-section 13.4.3. These websites offer superb *Flash* and *Shockwave* animations to help consolidate processes such as the action potential and synaptic transmission. In addition, candidates have the opportunity to develop their familiarity with spreadsheets and statistical packages. When exploring frontal-lobe function, candidates can make their own version of the Wisconsin Card-Sorting Test and explore how it is used in assessing frontal-lobe information processing. Candidates need to be aware of the variety of approaches to explaining disorders such as schizophrenia and need to refer to balanced documents such as review papers from the *British Medical Journal*.

Methods and ethical issues in brain research

This material will ideally be integrated with that from other sub-sections of this unit, particularly Sub-section 13.2.2 (Exploration of the healthy and the damaged brain), e.g. fMRI can be introduced when studying brain areas and specific cognitive functions. It is essential that candidates are aware of the ethical issues associated with each technique – details of suitable websites are given in Sub-section 13.4.3. These issues will be more apparent for techniques such as foetal brain-tissue grafting and stem-cell therapy than for techniques such as brain scanning. However, candidates need to be aware of the ethics of making predictions about behaviour based on findings from such scanning techniques.

Everyday cognition

Candidates need to understand that, before a particular mental function is investigated, a clear idea of exactly what it is being measured is required. Hence, exploring consciousness is contingent on conceptualising and defining what consciousness is. In this sub-section, candidates address philosophical concerns in the study of mind and brain. This will generate a great amount of class discussion as candidates consider issues such as the emergence of mind (when does mind develop?) and altered states of consciousness (how do drug-induced states differ biologically and phenomenologically from 'normal' consciousness?). Candidates also explore the neurobiological basis of memory, investigating how different forms of amnesia result from impairment to different parts of the memory system, and the techniques developed to circumvent these problems. After studying this sub-section, it is important that candidates are able to apply the knowledge that they have gained.

Whilst this unit requires learning a lot of factual information, there is plenty of scope to *apply* that knowledge and much room for debate. Debate and the practical work need to consolidate knowledge of the various methods employed and the importance of ethics in researching mind and brain, particularly with regard to the new- and evolving-technologies in neuroscience.

13.4.2 Guidance on Assessment

Candidates need to carry out research for this unit; they need to be taught how to find and select the relevant correct information and be aware of the various types of material available. Candidates need to demonstrate analysis and evaluation and need to be taught these skills if they are to achieve the higher marks.

Regular, early and constructive feedback to candidates on their performance is essential and crucial. Help with planning and structuring their portfolio work in a logical manner throughout the course will lead to better understanding of their work and is likely to achieve higher marks.

Giving candidates deadlines for the completion of the various sections of their work and encouraging them to adhere to them, is also essential if candidates are not going to rush to complete and possibly finish up with marks below their potential.

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 13.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below clarifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	1	• Candidates produce an information pack consisting of **two** sets of fact sheets which show knowledge and understanding of Sub-section 13.2.1 (The mind, stress and illness) and Sub-section 13.2.2 (Exploration of the healthy and the damaged brain); • some scientific terminology is used, generally correctly; • candidates may have been guided to the most relevant sources and used these appropriately; • sources may be of **one** type only and the candidate shows limited understanding of the material collected;
	2	• candidates produce an information pack consisting of **two** sets of research which show a detailed knowledge and understanding of Sub-section 13.2.1 (The mind, stress and illness) and Sub-section 13.2.2 (Exploration of the healthy and the damaged brain); • work presented shows suitable selection of information; • they may have used clear diagrams to help and there are few errors present in the explanation of the principles; • research is comprehensive using several different types of information; • candidates have been selective in their use of sources, showing an understanding of the need to evaluate the quality of the information; • scientific terminology is generally used well when explaining information employed in studying the mind and brain;
	3	• candidates produce work which shows thorough knowledge and understanding of Sub-section 13.2.1 (The mind, stress and illness) and Sub-section 13.2.2 (Exploration of the healthy and the damaged brain); • candidates have shown complete understanding of the content of the relevant sections; • language is fluent and scientific terminology is accurate and used consistently; • a wide variety of sources are selected to demonstrate the variety of opinion and assessed for relevance and truth; • the candidate has been able to set out the work logically with limited help and shown suitable selection of relevant material.

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	1	• Candidates have struggled with the academic facts pertaining to scientific methods and techniques employed in studying the mind and brain, and some factual errors are likely in the work; • they have acknowledged basic ethical issues; • candidates have identified basic problems with the prepared experimental protocol and highlighted arising ethical issues; • work shows research into statistical evidence on the selected topic with evidence that basic calculations have been correctly completed;
	2	• candidates have chosen relevant examples of methods used in the experimental **and** clinical study of the mind and brain, and explained the principles well; • they have provided a clear and logical account of prevailing ethical issues; • candidates have shown a clear understanding of the problems with the experimental protocol employed, and arising ethical issues; • work shows research into statistical evidence from a number of sources with evidence that calculations have been correctly completed and recorded;
	3	• candidates have selected a number of methods used in the experimental **and** clinical study of the mind and brain, explained the principles well and completed suitable evaluation; • work is clearly and logically selected and presented; • a comprehensive account is given of the conceptual, moral and ethical issues with different methods and techniques; • candidates have identified conceptual and ethical problems and inappropriate methods where relevant; • work reflects detailed coverage of Sub-section 13.2.3 (Methods and ethical issues in brain research); • all points are backed up with referenced evidence with only minor errors evident in interpretation; • work shows detailed research into statistical evidence on the selected topic with evidence that a selection of sources have been consulted with some evidence of statistical analysis.

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	1	• Candidates have carried out a simple experiment to investigate a particular cognitive function; • suitable risk assessments need to be followed; • there is basic understanding of how to address a research problem and a consideration of some ethical issues; • data collected is clearly presented and correctly plotted without processing and there is clear evidence of an explanation of the results obtained; • there is a simple evaluation;
	2	• candidates have designed and carried out a simple experiment which demonstrates clear conceptualisation of the issue at hand and a consideration of key ethical issues; suitable risk assessments are produced and followed; • evidence of the planning and completion of the chosen research problem/ case study on memory; • data collection is precise and presented using a variety of methods; • results are interpreted reliably with basic assumptions drawn and an attempt made to explain results in terms of underlying brain mechanisms; • there is an understanding of design limitations and how the work could be improved upon;
	3	• candidates have produced and carried out a sound experimental design which attempts to thoroughly investigate the cognitive function; • suitable risk assessments are developed, used and evaluated; • candidates have demonstrated a clear conceptual and ethical understanding of the issues at hand and independently chosen appropriate measures for their investigation; • suitable justification of their work is included; • data collection is thorough, accurate and appropriately tabulated and visualised; • there are simple statistics such as means and standard deviations are evident as well as rates and graphs; • results are fully explained and reference made to likely underlying brain mechanisms where appropriate; • there is a thorough understanding of design constraints.

13.4.3 Resources

Organisations	**British Association For Psychopharmacology** 36 Cambridge Place, Hills Road, Cambridge CB2 1NS Telephone: 01223 358 395 http://www.bap.org.uk/ **British Neuroscience Association** The Sherrington Buildings, Ashton Street, Liverpool L69 3GE Telephone: 0151 794 4943 http://www.bna.org.uk/ **The British Psychological Society** St Andrews House, 48 Princess Road East, Leicester, LE1 7DR Telephone: 0116 254 9568 http://www.bps.org.uk/index.cfm **Headway Brain Injury Association** Foster Drive, Mansfield Road, Nottingham NG5 3FJ Telephone: 0115 967 9669 http://www.headway.org.uk/ **International Stress Management Association** PO Box 348, Waltham Cross, EN8 8ZL Telephone: 0700 078 0430 http://www.isma.org.uk/ **Rethink (National Schizophrenia Fellowship)** 30 Tabernacle Street, London EC2A 4DD Telephone: 020 7330 9100 http://www.bna.org.uk/			
Publications	Scientific American (2002). *The Hidden Mind* Special Issue. Scientific American (2003). *Better Brains* Special Issue. Oct. Scientific American (2004). *Mind Special* Issue #1. The Society For Neuroscience (20002) *Brain Facts – A Primer on The Brain and Nervous System* ISBN: 091 611 000 1			
Textbooks	Damasio A	*Descartes' Error*	Papermac (1996)	033 365 656 3
	Frith C	*Schizophrenia: A very short introduction*	OUP (2003)	019 280 221 6
	Goldberg E	*The Executive Brain: The frontal lobes & the civilised mind*	OUP (2002)	019 556 307 X
	Marmot M & Stansfield S	*Stress & The Heart: Psychosocial pathways to coronary heart disease*	British Medical Journal Books (2001)	072 791 277 1

Textbooks	Pierce HJ	*The Owner's Manual for the Brain: Everyday applications from mind-brain research*.	Natl Book Network (1994)	096 363 891 2
	Pinker S	*The Blank Slate: The modern denial of human nature*	Penguin Press (2003)	014 027 605 X
	Ramachandran VS & Blakeslee S	*Phantoms In The Brain: Human nature and the architecture of the mind*	Fourth Estate (1999)	185 702 895 3
	Schwartz JM & Begley S	*The Mind & The Brain*	Harper Collins (2003)	006 098 847 9
	Smith-Churchland P	*Brain-Wise: Studies in neurophilosophy*	Bradford Book (2002)	026 253 200 X
Websites	**Everyday Cognition** Biological Basis For Learning & Memory Consciousness & The Brain: Annotated Bibliography http://home.earthlink.net/~dravita/ Neuropsychological Assessment & Resources http://www.neuropsychologycentral.com/ Overview & Applications of Artificial Intelligence http://www.aaai.org/Pathfinder/html/overview.html Philosophy of Mind http://www.artsci.wustl.edu/~philos/MindDict/ **Exploration of The Healthy and Damaged Brain** 3-D Brain Anatomy www.bbc.co.uk/science/humanbody/body/interactives/organs/brainmap/index.shtml Central Nervous System Images http://medlib.med.utah.edu/kw/sol/sss/subj2.html Club Drugs http://www.clubdrugs.org/ Mental Health http://www.emental-health.com/ National Institute For Neurological Disorders & Stroke-Disorders http://www.ninds.nih.gov/health_and_medical/disorder_index.htm Neurotransmission Animation http://www.brainexplorer.org/neurological_control/Neurological_Neurotransmission.shtml#			

Websites	**Exploration of The Healthy and Damaged Brain (continued)** Phineas Gage Information Page http://www.deakin.edu.au/hbs/GAGEPAGE/ Society For Neuroscience - Brain Briefings http://web.sfn.org/content/Publications/BrainBriefings/index.html **Methods and Ethical Issues In Brain Research** Brain Scans That Spy On The Senses http://www.hhmi.org/senses/e110.html Probe The Brain http://www.pbs.org/wgbh/nova/mind/probe.html Scanning The Brain http://www.pbs.org/wnet/brain/scanning/index.html The Whole Brain Atlas http://www.med.harvard.edu/AANLIB/home.html

14 Unit 14: Ecology and Managing the Environment
[A2 level, optional, internally assessed]

14.1 ABOUT THIS UNIT

This A2 level unit is optional and is internally assessed.

Ecologists investigate the types and numbers of organisms in ecosystems and then try to explain why they live there. This explanation involves a consideration of the relationships of these organisms with each other and with their physical environment.

There is a very fine balance between each organism in an ecosystem and their physical environment, with each organism having its own niche – its way of life and role within the life of that community. The types and complexity of ecosystems across the world's regions contribute to the vast biodiversity of animal and plant species on the planet. As humans depend, in many ways, on plants and animals to live, it is essential to preserve this biodiversity, but the physical and biological environments affecting ecosystems undergo constant change. Some of these changes have been gradual, some dramatic. Many of these changes have increased plant and animal diversity, and have been the driving force for evolution, but some have also led to at least **five** mass extinctions over **500 million** years.

The Earth's ecosystems and its biodiversity are studied and reviewed by ecologists, evolutionists and many other types of scientist. More than ever before, we are monitoring changes in ecosystems and, as a consequence, introducing measures to repair ecosystems and practices that make the way we exploit plant and animal species sustainable, thereby preserving biodiversity.

By studying this unit, you will learn about the techniques that ecologists use to study ecosystems. You will develop an understanding of the relationships between the biological and physical components of ecosystems and research how these are affected by change. You will discuss the need for humans to maintain species diversity, review the methods which can be used to do this and evaluate **one** example of the measures that ecologists and other scientists are taking to manage an ecosystem.

This unit builds on Unit 1: *Science at work,* Unit 2: *Analysis at work* and Unit 3: *Monitoring the activity of the human body*. There are strong links between this unit and Unit 8: *Investigating the scientist's work* and AS and A2 units in GCE Biology and Geography.

This unit will help you to prepare for higher education courses in biology, ecology, environmental science or geography, or for work in environment-related occupations. It will also provide the background for evaluating environmental policies within employment in all industries and services.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will investigate ecology and managing ecosystems. Your evidence will include:

- a knowledge and understanding of the effects of change on ecosystems and biodiversity, describing ecological selection and researching the effects of agricultural practice, human habitation and greenhouse gas production;
- a discussion of the reasons for preserving ecosystems and biodiversity, describing the methods available to do this, and carrying out a study and evaluation of the methods used to manage an ecosystem;
- a planned investigation of an ecosystem.

14.2 WHAT YOU NEED TO LEARN

You need to learn about:

- investigating ecosystems;
- effects of change on ecosystems;
- investigating the management of ecosystems.

14.2.1 Investigation of Ecosystems

In order to understand ecosystems fully, ecologists use a range of methods to measure the physical factors that affect the ecosystem. They also have to examine and measure the biological factors that affect the ecosystem. The number and types of species in any particular place is called its biodiversity. No ecosystems exist that are made up of only **one** or just a few organisms. Within any stable ecosystem, there is a close, finely balanced relationship between the physical factors that make up an ecosystem and the organisms that live there, with each organism having its own way of life and role within the life of that community.

You need to examine the range of methods ecologists use and apply them in a selected ecosystem to carry out a detailed study. You then need to use your findings to try to explain the relationships between the organisms and their physical environment.

When measuring physical factors, ecologists use techniques including chemical measurement, electronic measurement and the use of indicator species. When measuring the distribution of organisms making up the biological environment, it is not usually practical to count every organism in an ecosystem, so ecologists use sampling techniques.

You need to:

- describe methods available to measure the physical factors that affect the distribution of organisms in ecosystems, including the way in which ICT is used in ecological research;
- describe methods available to measure the distribution of organisms using appropriate sampling techniques (quadrats, sampling randomly and along a line or belt transect) and counting methods (species density, species cover) throughout the ecosystem studied;
- plan and carry out an investigation of **one** ecosystem, selecting and using appropriate equipment and techniques to make measurements of physical and biological factors;
- present and display data using appropriate tables and graphs;
- summarise data using the appropriate descriptive statistics (mean, standard deviation);
- manipulate data using appropriate statistics, e.g. Simpson's diversity index;
- relate the suitability of the methods used to collect data to the particular habitat and the organisms being studied;
- use the appropriate statistics, e.g. chi-squared test or t-test, to test the validity of any possible trends in data;
- form valid conclusions on the distribution of organisms based on data and statistical analysis;
- explain the relationships between the organisms in the ecosystem and their physical environment;
- evaluate the validity of the data based on the monitoring methods used.

14.2.2 Effects of Change on Ecosystems

The physical and biological factors within any ecosystem are subject to change. Organisms themselves can modify their environment. Billions of years ago, the photosynthesis of blue-green bacteria is thought to have produced all the oxygen gas present in the Earth's atmosphere. Changes that can be seen today are usually more modest and include ecological successions. Many organisms are adapted to changes that occur in their physical environment, such as seasonal changes, but events, such as volcanic eruptions, have more dramatic effects on ecosystems. In addition, in today's world, the often desperate need for human habitation, food and raw materials and the necessity for industrial processes and transport have also affected ecosystems and biodiversity.

You need to:

- describe the process of succession within ecosystems;
- research and describe how agricultural practice (monoculture and hedgerow removal, use of pesticides and fertilisers) has led to changes in ecosystems and biodiversity;
- research and describe how the requirement for human habitation has affected ecosystems and biodiversity;
- research and discuss how greenhouse gas production (natural and man-made) may affect ecosystems and biodiversity.

14.2.3 Investigation of the Management of Ecosystems

Humans are dependent on the planet's biodiversity. Ecologists consider the value of this biodiversity. Plants provide organisms with the oxygen they need and act as a 'sink' for carbon dioxide, limiting its build-up from natural and human activity. Many organisms provide us with food, drugs, dyes and materials such as timber, paper and rubber. Many more may, one day, be shown to yield other products. In addition, all our crops and domestic animals have wild relatives. These may have genes that it may be useful to breed back into our domesticated species. Finally, all organisms within an ecosystem are dependent on each other. The removal of one will have effects on others.

In addition to these reasons, many scientists also see an 'intrinsic' value to species biodiversity. They value the presence of other living organisms on the planet, irrespective of economics or biology. Many people would question the right of any species to deprive another of its habitat or existence.

Our understanding of the effects of ecological change now, however, means that scientists may wish to manage world ecosystems. We can limit the build up of greenhouse gases, use bioremediation to remove toxic materials from the environment and use sustainable practices in agriculture and in the production of other resources, to help to preserve the planet's ecosystems and rich biodiversity.

You need to:

- identify scientific, moral and ethical reasons for preserving biodiversity on the planet;
- evaluate the effectiveness of sustainable practices to agriculture and use of natural resources in preserving species diversity;
- evaluate how the management of designated areas (conservation areas, ecotourism, bioremediation to remove toxic material) is used to preserve ecosystems and biodiversity;
- evaluate the methods used to decrease the emission of man-made greenhouse gases (cleaner industrial production, legislation) and discuss the ways in which levels of greenhouse gases in the atmosphere could be reduced (carbon sinks);
- evaluate the methods used in the management of an ecosystem by one ecologist, a team of ecologists, a professional body, or group of scientists; you need to examine information and other data on the project and evaluate fully the effectiveness of the management techniques.

14.3 ASSESSMENT EVIDENCE GRID

Please see over.

<table>
<tr><td colspan="5">Unit 14: Ecology and managing the environment</td></tr>
<tr><td colspan="5">What you need to do:</td></tr>
<tr><td colspan="5">You need to produce evidence of your investigation on ecology and managing ecosystems [50 marks].
This evidence needs to include:
AO1: a knowledge and understanding of the effects of change on ecosystems and biodiversity, describing ecological selection and researching the effects of agricultural practice, human habitation and greenhouse gas production [10];
AO2: a discussion of the reasons for preserving ecosystems and biodiversity, describing the methods available to do this, and carrying out a study and evaluation of the methods used to manage an ecosystem [14];
AO3: a planned investigation of an ecosystem [26].</td></tr>
<tr><td colspan="5">How you will be assessed:</td></tr>
<tr><th>Assessment Objective</th><th>Mark Band 1</th><th>Mark Band 2</th><th>Mark Band 3</th><th>Mark Awarded</th></tr>
<tr><td rowspan="2">AO1</td><td>You will demonstrate a basic knowledge and understanding of the relationship between the organisms, their physical environment and each other in ecological succession; [0 1]</td><td>you will demonstrate a sound knowledge and understanding of the relationship between the organisms, their physical environment and each other in ecological succession;
you will use appropriate scientific terms and conventions accurately; [2 3]</td><td>you will demonstrate a thorough knowledge and understanding of the relationship between the organisms, their physical environment and each other in ecological succession;
you will use appropriate scientific terms and conventions accurately. [4 5]</td><td rowspan="2">/10</td></tr>
<tr><td>you will research the effect of agricultural practice, human habitation and greenhouse gas production on ecosystems and biodiversity, selecting information and presenting it clearly; [0 1]</td><td>you will research the effect of agricultural practice, human habitation and greenhouse gas production on ecosystems and biodiversity, selecting a wide range of information, giving reasons for your choice of resources, and presenting it clearly and logically; [2 3]</td><td>you will research the effect of agricultural practice, human habitation and greenhouse gas production on ecosystems and biodiversity, selecting a wide range of relevant information and presenting it clearly and logically;
you will evaluate the information available and justify the choice you included. [4 5]</td></tr>
<tr><td rowspan="3">AO2</td><td>you will identify some of the scientific, moral and ethical reasons for preserving ecosystems and species diversity; [0 1]</td><td>you will identify and explain the scientific, moral and ethical reasons for preserving ecosystems and species diversity; [2 3]</td><td>you will organise information to evaluate the scientific, moral and ethical reasons for preserving ecosystems and species diversity. [4]</td><td rowspan="3">/14</td></tr>
<tr><td>you will describe some of the methods used to manage ecosystems and preserve species diversity;
you will give a limited interpretation of information relating to the success of a project managing one ecosystem; [0 1]</td><td>you will describe methods used to manage ecosystems and preserve species diversity;
you will describe and interpret data relating to the success of a project managing one ecosystem; [2 3]</td><td>you will describe a range of methods used to manage ecosystems and preserve species diversity;
you will interpret, explain and evaluate a range of data relating to the success of a project managing one ecosystem. [4 5]</td></tr>
<tr><td>you will carry out straightforward calculations on ecological data (e.g. mean, standard deviation) and you will sometimes obtain the correct solutions; [0 1]</td><td>you will carry out complex calculations on ecological data, involving some use of statistics (e.g. diversity indices);
you will obtain the correct solutions; [2 3]</td><td>you will carry out complex calculations on ecological data involving the statistical analysis of the data obtained (e.g. chi-squared or t test);
you will obtain the correct solutions to an appropriate degree of accuracy and demonstrate an understanding of the significance of the outcomes. [4 5]</td></tr>
</table>

Unit 14: Ecology and managing the environment (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO3	you will produce risk assessments; you will carry out measurements of some factors affecting the ecosystem you studied; you will use a range of techniques and equipment; **[0 1 2 3 4]**	you will produce risk assessments, consistent with COSHH guidelines; you will carry out measurements of factors affecting the ecosystem you studied, using a range of techniques and equipment; you will have repeated measurements, working with an appropriate degree of accuracy; **[5 6]**	you will produce your own detailed risk assessments, consistent with COSHH guidelines; you will carry out measurements of a wide range of factors affecting the ecosystem you studied and explain why you used a range of techniques and equipment; you will explain the need to have repeated measurements, and work with an appropriate degree of accuracy. **[7 8]**	
	you will make and record relevant observations and measurements in the ecosystem; **[0 1 2]**	you will make and record relevant observations and measurements in the ecosystem, using precision in your measurements; **[3 4]**	you will make and record a detailed set of relevant observations and measurements in the ecosystem, using the appropriate precision in your measurements. **[5 6]**	
	you will display the ecological data obtained using tables, with help; **[0 1]**	you will display the ecological data accurately in a range of ways; **[2 3]**	you will process and display accurately ecological data in a range of ways chosen to best illustrate the trends in the data. **[4]**	
	you will give some interpretation of the results and relate these to the occurrence and distribution of species within the ecosystem studied; **[0 1 2 3 4]**	you will interpret the results, and draw basic conclusions, relating your results to the occurrence and distribution of species within the ecosystem studied; **[5 6]**	you will interpret the results in detail, and draw conclusions relating your results to the occurrence and distribution of species within the ecosystem studied. **[7 8]**	**/26**
			Total mark awarded:	**/50**

14.4 GUIDANCE FOR TEACHERS

14.4.1 Guidance on Delivery

This unit needs to draw on the scientific knowledge, skills and understanding provided by study of Unit 1: *Science at work*, Unit 2: *Analysis at work* and Unit 3: *Monitoring the activity of the human body*. It should be possible to carry out this unit early in the second year, allowing the development of basic biological skills in an appropriate context, but this may depend on the seasonality of the ecosystem studied. The ecological concepts studied and the manipulation of ecological information and data, much of which is objective, although it can also be subjective or emotive, will build on the knowledge, understanding and evaluative skills from KS4 Science, in GCSE Science or Applied Science.

This unit focuses on the principles of ecology – the relationships of organisms with their biological and physical environment. Candidates use a range of ecological methods to examine and make measurements of **one** ecosystem in detail and apply these principles to their findings. It is suggested that candidates review and practise the techniques available before carrying out the study.

The remainder of this unit looks at the effects of environmental change and, with our knowledge of the effects of such changes, the methods employed to prevent or reduce any negative effects. The focus will range from simple candidate research to a more in-depth analysis and evaluation. Candidates need to be encouraged to take an objective view of scientific data, discarding any preconceived ideas. Many of the effects of environmental change throughout geological time have been positive and have been responsible for evolutionary change. Many candidates may also assume automatically that some of the most detrimental effects of change are caused by man, but need to appreciate that many, e.g. the production of greenhouse gases, may have more significant natural causes. Some of the effects of change may be unequivocal, while others are subject to debate.

The principle aim of the unit is to give candidates a sufficient grounding in this area to allow them to appraise critically the work of ecologists and the moral issues confronting them and to review how these problems might be addressed by professional biologists and society as a whole.

Candidates also need to consider the varied reasons for managing ecosystems, from biological and economic reasons to more moral and ethical considerations.

The success of this unit will depend on the availability of up-to-date information and access to resources. Where centres anticipate that candidates will find difficulty in locating appropriate sources, case-study material may be substituted.

Investigating ecosystems

The investigation of the ecosystem comprises the major part of this sub-section, but it is essential for candidates to examine all the techniques available to the ecologist for making measurements within ecosystems before they can plan and carry out their investigation. The investigation itself, and subsequent analysis, needs to comprise just over one-third of the allotted time for this unit. With preliminary work, it will comprise around half the unit in total. The ecosystem selected, ideally, should be local to your centre, and sufficiently complex in terms of biodiversity to generate sufficient data and discussion. Ecosystems should be avoided where there is insufficient expertise to help candidates with identification of organisms. Marine environments are ideal because every animal phylum is represented and organisms are, in the main, relatively easy to identify, but the study of these may not be practical for many centres.

Candidates need to appreciate that in determining the types and numbers of organisms in an ecosystem, ecologists need to use a range of techniques to make careful and accurate observations and measurements, and quantify these where possible.

For the physical environment the following measurements need to be considered, although for the study proper, candidates will select those appropriate to use:

- temperature – using thermometers, data-loggers, and/or thermistors;
- water pH – using indicators, pH meters, and/or data-loggers;
- oxygen content – using oxygen electrodes, data-loggers, chemical techniques (such as the permanganate method);
- salinity – using density methods, conductivity, or titration;
- dissolved substances – using chemical methods, e.g. testing kits for nitrates, phosphates;
- pollutants – using indicator species for detecting pollutants, e.g. the Trent Biotic Index, the River Invertebrate Prediction and Classification System (RIVPACS);
- organic matter – using turbidity measurements;
- micro-organisms – using plating techniques;
- light intensity – using light meters, data-loggers.

The use of data-loggers demonstrates how ICT can be valuable in ecological research.

A range of methods is available to display ecological data, e.g. line graphs, bar graphs, histograms, kite diagrams, pictographs, pie graphs, rose diagrams and scattergraphs. Calculations and statistical tests, carried out by hand calculation, or using computers, are particularly useful in ecology and are necessary to determine whether differences in data are the result of chance. It needs to be emphasised, though, that the first time candidates use statistics, calculations need to be carried out manually.

Appropriate statistics can be used to:

- summarise data using descriptive statistics (mean, standard deviation);
- manipulate data, e.g. using Simpson's diversity index;
- test the validity of trends or differences in data using comparative statistics (correlation coefficient, chi-squared test or t-test).

The effects of change on ecosystems

It is important that candidates appreciate that not all environmental changes are man-made. They need to consider and examine natural change in the environment, e.g. from seasonal changes to volcanic eruptions. They also need to describe the changes that occur during an ecological succession. This could be accompanied by practical work, if time allows. A study of ecological successions in sand dunes (although the process is now complete in dune systems in the UK, the mature dunes still illustrate the process) could also comprise candidates' study of an ecosystem. Interesting alternatives include studies of the fermentation of lambic beers (enabling excellent applied comparisons) or of copraphagic fungi.

For the research aspect, candidates need to consult appropriate references to ensure that they get a balanced view of the problem. They need to apply the ecological principles first encountered in Key Stage 4, when examining: the effects of agricultural practice, habitation and greenhouse gases, e.g., in agricultural activity; the bioaccumulation of insecticides, e.g. DDT; inorganic nitrate and phosphate fertilisers causing eutrophication of natural waters. This could be extended to include the toxicity of fungicides or herbicides, e.g. dioxin impurities in 2,4-D. Natural processes leading to the build up of greenhouse gases need to be considered in detail by candidates, as well as the contribution from industrial emissions.

Investigating the management of ecosystems

To begin this sub-section, candidates need to consider the biological and economic reasons for preserving ecosystems, but then consider moral and ethical reasons, including intrinsic arguments. Ecological ethics are defined by the United Nations as the 'moral principles governing the human attitude towards the environment, and rules of conduct for environmental care and preservation'. It will be necessary to define, and have a preliminary discussion about, moral justification (is it simply 'right or wrong' to carry out activities without regard to ecosystems/preserve ecosystems?) and ethical concerns (reasons and justifications as to whether it is right or wrong), and intrinsic arguments, such as, is it acceptable to interfere with nature?

Discussion could be based on questions such as:

- Is it morally wrong to destroy a plant or animal species, or an ecosystem, regardless of whether such destruction has any consequences for human beings?
- Is the intrinsic value of non-human life dependent on the usefulness this life may have for human purposes?
- Do non-human organisms have 'rights' to exist? Should we think of animals and plants differently in this respect?

Examples to be considered could include:

- killing elephants for ivory;
- picking wild flowers;
- fishing;
- farming;
- building new houses.

There is a wide range of options for candidates to study while investigating the management of ecosystems. Opportunities exist to study global initiatives, but ideally candidates need to experience ecological management first hand. Centres need to tailor this to local circumstances. Most local councils practise some form of environmental management, but it is also hoped that candidates will have the opportunity to visit managed areas such as National Parks, National Trust land, WWT and other reserves, county conservation trusts, wildlife parks, reservoirs, rivers, lakes and areas managed for fishing. It is also recommended that candidates meet and question one or more ecologists. Even the most urban environments offer opportunities for such liaison between professional ecologists/environmental managers and candidates.

14.4.2 Guidance on Assessment

It needs be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 14.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below amplifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• Candidates produce evidence showing a knowledge of some of Sub-section 14.2.2 (Effects of change on ecosystems) to link with the requirements of the task; • some scientific terminology is used, generally correctly; • candidates are guided to the most relevant information and use this correctly; • some research is done, with guidance, but understanding is limited; • descriptive work is presented clearly;
	2	• candidates produce evidence showing some detailed knowledge and understanding of most of Sub-section 14.2.2 (Effects of change on ecosystems); • scientific terminology is generally used well when explaining information; • candidates select the most relevant information and use it correctly; • a suitable range of research is carried out and relevant information is selected and presented clearly and logically in candidates' own words with sources credited; • suitably detailed descriptive work on ecological selection is presented clearly and logically;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	3	• candidates produce evidence showing thorough knowledge and understanding of Sub-section 14.2.2 (Effects of change on ecosystems) to reflect the requirements of the task; • language is fluent and scientific terminology is accurate and used consistently; • suitable comprehensive research is carried out, using a wide variety of sources, and suitable material is selected and used; • relevant information is selected and presented clearly and logically, with suitable evaluation and justification of the work produced; • relevant detailed descriptive work on ecological selection is presented clearly and logically with little help.
AO2	1	• Candidates identify adequately a variety of reasons for preserving ecosystems and species' diversity and provide a description of methods available to do this, focusing on the requirements of Sub-section 14.2.3 (Investigation of the management of ecosystems); • they carry out, with guidance, a basic study and evaluation of methods used to manage **one** ecosystem; • some basic straightforward calculations on ecological data are completed correctly, as identified in Sub-section 14.2.1 (Investigation of ecosystems);
	2	• candidates identify clearly, and explain clearly, a variety of reasons for preserving ecosystems and species' diversity and provide a detailed description of methods available to do this focusing on the requirements in Sub-section 14.2.3 (Investigation of the management of ecosystems); • they carry out a detailed study and evaluation of methods used to manage **one** ecosystem; • some complex calculations on ecological data are completed correctly as identified in Sub-section 14.2.1 (Investigation of ecosystems);
	3	• candidates identify fully, and explain fully, a variety of reasons for preserving ecosystems and species' diversity and provide a detailed description of a range of methods available to do this, focusing on the requirements in Sub-section 14.2.3 (Investigation of the management of ecosystems); • they carry out a detailed study and evaluation of a range of methods used to manage **one** ecosystem with detailed explanation and evaluation; • complex calculations on ecological data, involving statistical analysis, are completed correctly as identified in Sub-section 14.2.1 (Investigation of ecosystems) with correct solutions to an appropriate degree of accuracy; • candidates show that they understand the significance of the outcomes.

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	1	• Candidates use and produce risk assessments and carry out any practical work using a range of techniques and equipment; • relevant observations and measurements from the work are recorded; the data are displayed appropriately, with help; • there is some interpretation, a conclusion and simple evaluation;
	2	• candidates use and produce risk assessments consistent with COSHH guidelines and carry out any practical work using a range of techniques and equipment, using good practical technique; • repeated measurements are carried out where appropriate; • relevant observations and measurements from the work are recorded; • the data are displayed accurately in a range of ways; • there is an interpretation of all results, conclusions and relevant evaluation;
	3	• candidates, with little guidance, use and produce detailed risk assessments consistent with COSHH guidelines, and carry out practical work competently using a range of techniques and equipment, consistently using good practical technique; • repeated measurements are carried out, where appropriate, with suitable explanations; • detailed observations and accurate measurements are recorded consistently; • the data are displayed logically and accurately in a range of ways; • there is a full interpretation of all results, conclusions and relevant justification and evaluation.

14.4.3 Resources

Textbooks	Allen D & Williams G	*Collins Advanced Modular Sciences: Applied Ecology*	Collins Educational (2001)	000 327 741 0
	Chapman JL & Reiss MJ	*Ecology. Principles and Applications*	CUP (1992)	052 138 951 8
	Dresner S	*The Principles of Sustainability*	Earthscan (2002)	185 383 842 X
	Hayward G	*Applied Ecology*	Nelson Thornes (1992)	017 448 187 X
	Odum EP	*Fundamentals of Ecology*	Saunders College Publishing (1971)	072 166 941 7
	Topfer K	*Global Environment Outlook 3: Past, Present and Future Perspectives*	Earthscan. (2002),	185 383 845 4

Websites	**Bioremediation** Arizona State University: http://photoscience.la.asu.edu/photosyn/courses/BIO_343/lecture/bioremed.html National Agricultural Library (plus links to other sites): http://www.nal.usda.gov/bic/Biorem/biorem.htm US Geological Survey: http://water.usgs.gov/wid/html/bioremed.html **Carbon sinks** BBC News Sci/Tech: http://news.bbc.co.uk/1/hi/sci/tech/1426453.stm Environmental Literacy Council: http://www.enviroliteracy.org/article.php/48.html Ethics and the environment: http://www.ul.ie/~philos/vol1/paper4.html National Geographic: http://news.nationalgeographic.com/news/2001/06/0621_carbonsinks.html Royal Forestry Society: http://www.rfs.org.uk/thirdlevel.asp?ThirdLevel=122&SecondLevel=67 **General and environmental ethics** Environmental Literacy Council: http://www.enviroliteracy.org/ Food and Agriculture Organisation of the United Nations Biological Diversity in Food and Agriculture: http://www.fao.org/biodiversity/link_en.asp United Nations: http://www.un.org/english WWF – The Conservation Organisation: http://www.panda.org **Greenhouse gases** Climatic Research Unit: http://www.cru.uea.ac.uk/ Earth Science Australia: http://earthsci.org/teacher/basicgeol/change/change.html#Greenhouse (US) Energy Information Administration: http://www.eia.doe.gov/oiaf/1605/gg98rpt/emission.html World Resources Institute: http://climate.wri.org

15 Unit 15: Applications of Biotechnology
[A2 level, optional, internally assessed]

15.1 ABOUT THIS UNIT

This A2 level unit is optional and is internally assessed.

Biotechnology is the use of organisms, cells and parts of cells, for instance, in recombinant DNA technology and vaccine production, for commercial, industrial and medical purposes. Few scientific subjects generate as much media interest as biotechnology and once you have completed this unit you will be able to separate the myth from reality.

This unit extends the knowledge and skills covered in Unit 1: *Science at work*, Unit 2: *Analysis at work*, Unit 4: *Cells and molecules* and Unit 6: *Forensic science*. There are strong links between this unit and Unit 8: *Investigating the scientist's work* and A2 units in GCE Biology.

This unit will help to prepare you for higher education courses in applied biology, biochemistry or for other vocational qualifications in areas of agriculture, horticulture or biotechnology.

This unit is assessed through your portfolio work and the mark on that assessment will be your mark for the unit. You will investigate the use of biotechnology to solve agricultural, medical and industrial problems. Your evidence will include:

- the production of a public information booklet to include information on the science of genetic engineering, and the use of recombinant DNA technology in medicine or agriculture;
- an evaluation of the effectiveness of techniques, benefits and impact on society of the production of genetically modified food plants, including evidence of associated financial calculations, consideration of the moral and ethical issues and the impact of legislation associated with the production of genetically modified food plants;
- a practical investigation into enzyme technology, to include construction of a simple bioreactor and the effect of temperature on enzyme activity.

15.2 WHAT YOU NEED TO LEARN

You need to learn about:

- the science of genetic engineering;
- use of recombinant DNA technology in medicine;
- production of genetically modified food plants;
- enzyme technology.

15.2.1 The Science of Genetic Engineering

A lot of current research in biotechnology centres on the use of producing lengths of DNA and placing them into bacteria. These will then produce useful substances such as insulin. This technology can also be used to treat genetic diseases, where a copy of the working gene is inserted into the cells of the patient. There are significant advantages to this technology.

You need to understand the scientific background to recombinant DNA technology. This includes:

- the genetic code is a degenerate, non-overlapping sequence read as triplets of bases;
- proteins are synthesised inside the cell using DNA as a template;
- restriction enzymes are used to cut DNA fragments and produce sticky ends;
- DNA ligase is used as molecular glue to produce recombinant DNA strands;
- vectors such as viruses and plasmids are used to insert genes into target cells;
- the polymerase chain reaction (PCR) is used as a means of making large numbers of copies of DNA fragments;
- how electrophoresis is used in producing gene probes.

15.2.2 Use of Recombinant DNA Technology in Medicine

Much of the research that goes on in this area is novel and, at the moment, experimental. In many instances, gene technology has clear advantages over conventional methods, such as the production of insulin. You need to look at **one** specific example of how gene therapy is used to diagnose and treat genetic disorders.

You need to:

- make an assessment on the effectiveness of the treatments and products (gene therapy, products such as human insulin);
- identify the moral and ethical issues that they raise (inserting foreign genes, using genetically engineered bacteria);
- describe the use of genetic probes as a means of finding genes that code for useful proteins and genetic screening for disease;
- explain the difference between germ and somatic cell gene therapy and why germ cell gene therapy is banned in many countries;
- explain the specific advantages and disadvantages to the patient of gene therapy;
- discuss whether pre-natal genetic screening should be carried out as a matter of course, who should have the information and the moral dilemmas that can arise from this;
- discuss the potential benefits and dangers of having the Human Genome mapped out for each individual from birth with respect to health management and individual rights.

None of this new technology goes on without legislation and control from government. You need to look into the work of the:

- Gene Therapy Advisory Committee (GTAC);
- Advisory Committee on Genetic Testing.

15.2.3 Production of Genetically Modified (GM) Food Plants

Genetically modified plants have the capacity to do enormous amounts of good in a world that needs more and more food to feed its growing population. It could mean the food plants could be grown in deserts or by the sea, where it has not been possible before. You need to understand the benefits to agriculture and concerns for the environment from genetically-modified plants. You need to be aware of the financial implications involved in producing genetically-modified crop plants.

You need to:

- describe techniques used in the genetic modification of plants:
  – gene transfer using Agrobacterium;
  – gene guns;
  – marker genes;
  – regeneration of the plant;
  – checking that genes work;
  – checking for stable inheritance;
- describe the use of micro-propagation to produce large numbers of novel, identical plantlets;
- give **two** examples of successful genetically-modified food plants (**one** herbicide resistant and **one** insect-pest resistant);
- describe how the technology can be used to:
  – increase plant yields;
  – modify plant development or adaptation to extreme environments, e.g. tolerance to drought, salt, cold and frost;
  – reduce the use of pesticides and herbicides;
- investigate the financial aspects of GM food plant production;
- discuss the concerns about the use of genetically modified organisms (GMOs) in food production:
  – genetic pollution (spread of genes to related organisms);
  – overuse of herbicides linked to resistant crop plants;
  – possible toxicity of pest-resistant plants to beneficial insects;
  – uncontrolled spread of GMOs to become weeds;
  – cost of seed too high for farmers from developing countries;

- list the legislative processes involved with GM foods:
  – in the UK:
    Food Safety Act, (1990);
    The Advisory Committee on Novel Foods and Processes (ACNFP);
  – in the EU:
    The Genetically Modified Organisms (Deliberate Release) Regulations, (2002).

15.2.4 Enzyme Technology

A wide variety of enzymes are used commercially as industrial catalysts. Enzymes can be used to make products cheaply and the bulk of enzymes are used in the detergent and food industry. There are some very specialised uses in the medical field. These include biosensors.

You need to learn about the synthesis and action of enzymes, why they are useful in a medical or agricultural context and how they can be made more efficient.

You need to:

- explain how enzymes work (lock and key and induced fit hypothesis for enzyme action, rates of reaction and limiting factors);
- describe how batch- and continuous-systems are used for producing large amounts of product;
- explain the techniques used in enzyme immobilisation;
- discuss the advantages and disadvantages of enzyme immobilisation;
- describe and explain how enzyme technology is applied in **one** medical or **one** agricultural context.

You also need to apply your knowledge to produce a simple bioreactor and assess its effectiveness in producing useful chemicals in bulk.

You need to:

- produce a simple reactor and investigate the effect of increased temperature on **one** chosen enzyme;
- produce an immobilised enzyme and investigate its effect on the speed and efficiency of **one** biochemical reaction;
- discuss the results of all the practical work completed;
- calculate the efficiency of the bioreactor used.

15.3 ASSESSMENT EVIDENCE GRID

Please see over.

Unit 15: Applications of biotechnology				
What you need to do:				
You need to produce evidence of your investigation into the use of biotechnology to solve agricultural, medical and industrial problems [**50** marks]. This evidence needs to include**:** **AO1:** the production of a public information booklet to include information on the science of genetic engineering and the use of recombinant DNA technology in medicine **or** agriculture [**10**]; **AO2:** an evaluation of the effectiveness of techniques, benefits and impact on society of the production of genetically modified food plants, including evidence of associated financial calculations, consideration of the moral and ethical issues and the impact of legislation associated with the production of genetically modified food plants [**14**]; **AO3:** a practical investigation into enzyme technology, to include construction of a simple bioreactor and the effect of temperature on enzyme activity [**26**].				
How you will be assessed:				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO1	You will produce a clearly presented booklet about the science of genetic engineering; **[0 1 2]**	you will produce a researched, detailed booklet about the science of genetic engineering with relevant information selected that is clearly and logically presented; **[3]**	you will produce a booklet about the science of genetic engineering, based on thorough research, with evidence that relevant information has been selected from a variety of sources, that is clearly and logically presented. **[4 5]**	
	You will produce a clearly presented booklet about the use of recombinant DNA technology in medicine **or** agriculture; **[0 1 2]**	you will produce a researched, detailed booklet about the use of recombinant DNA technology in medicine **or** agriculture with relevant information selected that is clearly and logically presented; **[3]**	you will produce a booklet about the use of recombinant DNA technology in medicine **or** agriculture, based on thorough research, with evidence that relevant information has been selected from a variety of sources, that is clearly and logically presented. **[4 5]**	**/10**
AO2	You will describe how successful recombinant DNA technology is in solving problems associated with food production by crop plants and come to a simple conclusion on the overall benefits of the technology; **[0 1 2]**	you will describe how successful recombinant DNA technology is in solving problems associated with food production by crop plants and come to a conclusion based on clear evidence; some evidence of evaluation of at least **two** specific examples of the technology is needed; **[3]**	you will produce a comprehensive evaluation of the success of specific examples of the production of genetically modified plants; there will be clearly referenced evidence for your case and a summary of your main findings. **[4 5]**	
	You will present some financial, statistical evidence involving basic calculations; **[0 1]**	you will present detailed financial, statistical analysis including calculations; **[2]**	you will present financial evidence with appropriate complex calculations. **[3]**	
	You will carry out a simple analysis of the moral and ethical case for **one** aspect of using recombinant DNA technology in the production of GM plants and explain **one** of the controls placed on scientists working in this field, using some relevant evidence; **[0 1 2]**	you will summarise some of the moral, ethical and environmental issues concerning the use of recombinant DNA technology in the production of GM plants; you will need to explain **two** types of controls placed on scientists that work in this field; **[3 4]**	you will explain fluently what you consider to be the main moral, ethical and environmental issues concerning the use of recombinant DNA technology in the production of GM plants; you will need to evaluate **two** types of controls placed on scientists that work in this field for how effective they are. **[5 6]**	**/14**

Unit 15: Applications of biotechnology (continued)				
Assessment Objective	**Mark Band 1**	**Mark Band 2**	**Mark Band 3**	**Mark Awarded**
AO3	You will plan your practical work with help, including risk assessments; you will construct a simple reactor and be able to produce and use an immobilised enzyme; **[0 1 2]**	you will produce a clear plan with limited help which includes risk assessments consistent with COSHH guidelines; **[3]**	you will produce a clear plan of action of your own, including detailed risk assessments consistent with COSHH guidelines, using secondary sources. **[4 5]**	
	You will carry out measurements from the reactor, with help; you will use a range of techniques and equipment; **[0 1 2]**	you will carry out measurements from the constructed bioreactor using an immobilised enzyme system; you will use a range of techniques and equipment and have repeated measurements, working with an appropriate degree of accuracy; **[3]**	you will carry out measurements from the constructed bioreactor, using an immobilised enzyme system, on factors affecting your bioreactor; you will explain the use of a range of techniques and equipment and will have repeated measurements when appropriate; you will work with an appropriate degree of accuracy. **[4 5]**	
	You will make and record relevant observations and measurements on the effect of temperature on the constructed bioreactor, with help; you will display the data obtained using tables and simple graphs, with help; **[0 1 2 3]**	you will make and record relevant observations and measurements on both the bioreactor and the immobilised enzymes, using precision in your measurements; you will display the scientific data accurately in a range of ways including some simple calculations on rates of reaction; **[4 5 6 7]**	you will make and record a detailed set of relevant observations with limited help, using the appropriate precision in your measurements; you will display the scientific data accurately in a range of ways, and process them in a manner chosen to best illustrate the trends in data; you will collect sufficient data to complete simple statistics on the results. **[8 9]**	
	You will give some interpretation of the results and relate these to how enzymes work and enzyme immobilisation; **[0 1 2]**	you will interpret the results and draw basic conclusions relating your results to how enzymes work, the advantages of using bioreactors and enzyme immobilisation; **[3 4 5]**	you will interpret the results in detail using secondary sources to support your findings; you will draw conclusions relating your results to the use of bioreactors and enzyme immobilisation, specifying named examples in either medicine or industry; you will discuss the significance of your findings in terms of how enzymes work and the advantage of enzyme technology to industry. **[6 7]**	**/26**
			Total mark awarded:	**/50**

15.4 GUIDANCE FOR TEACHERS

15.4.1 Guidance on Delivery

The intention is that this unit will provide candidates with an introduction to some of the applications of biotechnology. The unit focuses on **three** key areas:

Biotechnology is such a diverse subject that Sub-sections 15.2.1, 15.2.2 and 15.2.3 concentrate on areas of work that are frequently in the news, and should allow candidates to intelligently join the debate.

Sub-section 15.2.1 outlines the basic scientific background to recombinant DNA technology. Sub-section 15.2.2 is about the use of recombinant gene technology to treat current genetic diseases and produce novel proteins like insulin or human-growth hormone. Again, the science behind gene therapy, genetic testing and the production of bio-molecules needs to be clear in the minds of candidates, but is not the main focus of this sub-section. Sub-section 12.2.3 is on the genetic manipulation of plants, another contentious area and the same applies here. Once in possession of the facts, candidates can enter the debate on legal constraints, problems with the environment and the clear benefits that this technology could provide to society.

Once clear on the technology, candidates need to assess the successes of these technologies and look at the moral and legal issues that they raise. It cannot be emphasised enough that candidates need to be in a position, after having been taught the bald facts, to formulate in their own minds what their feelings are for this technology. They then need to communicate this on paper or in presentation adequately.

Sub-section 15.2.4 concentrates on the established use of enzymes in industrial processes, including the production of beverages, an area with which candidates are likely to be familiar. Although candidates do need to know the theory behind this activity, primarily this is a practical sub-section and the emphasis needs to be on investigative work on the merits of fermenters and immobilisation. Candidates need to be given at least some freedom to come up with their own design (within the constraints of your centre's science equipment and budgets) and grapple with the problems in making new technology work.

Research will be a critical factor in the successful completion of this unit and it would be wise to collect useful articles and journals well before candidates start on this work. Candidates need access to a variety of quality resources from sources that reflect the full range of feeling in this area. If the academic science is taught in fairly conventional ways before candidates start to research the technology, the materials found will have more meaning and work will be more focused.

The science of genetic engineering

Although candidates need to have a clear idea as to the theory behind genetic engineering, this does not preclude a great deal of practical activities to aid the learning that needs to go on before the applications are tackled. Candidates could make their own models of DNA and protein synthesis to help the thought processes, and actually extract DNA from onion or kiwi fruit so that they can actually see it in action. Some investigation into the discovery of the structure of DNA may also be appropriate. Although expensive, the NCBE (National Centre for Biotechnology Education) kits that use restriction enzymes to cut up phage DNA come highly recommended (see Sub-section 15.4.3), and it is much easier to explain the process once candidates have seen it done. Electrophoresis is best taught this way. Candidates need careful supervision when doing this practical, since they are often not used to the levels of accuracy needed to be successful. A good split between practical and theory is sensible to keep motivation levels up, and it would probably pay off to test candidates on the material before moving on to the applications. After teaching this sub-section, it is vital that candidates are able to apply the knowledge that they have gained to the medical and agricultural applications they will face later on.

Using recombinant DNA technology in medicine

It is quite easy to get snowed under by the amount of information available in this area and the temptation for many candidates is to submit page after page of Internet resources with little analysis and comment. As far as possible, written work needs to be properly referenced and clear conclusions drawn from the material. The ideal is that all candidates will understand that every source may have a bias, and that they need to collect a range of views. Although able candidates may not need it, you may find it useful to prepare a resource box with a variety of different materials that candidates can access. Some candidates will need a few quality articles to get them started and the best place to begin would be the range of GCE textbooks dedicated to this area (please see Sub-section 15.4.3 – Textbooks), for example, references on page162 of *Applied Genetics 16-19* (Hayward) and on page 48 of *Microbiology and Biotechnology* (Lowrie & Wells). Once more confident, they could then move to more difficult material in journals like *Biological Science Review* and the *New Scientist*. You may find it helpful to supervise the initial research to ensure that candidates are focused on the criteria and collect only relevant information. A great deal of time needs to be spent on finding and deciphering information. Pooling information within a class would not be a problem as long as the labour is equally divided.

There is plenty of scope for debate in this unit and it is a good way of investigating the true feelings of the group to the technology. It is interesting to explore what they would do if placed in a situation where they would have to decide whether to use the technology to save a life. Hopefully, debate and research will lead all candidates to form at least a basic understanding of the morals and ethics in this area, with the best candidates able to justify their opinions with fluent argument backed with fact.

Production of genetically modified food plants

Much of what has been already said holds true for genetically modified plants as well. However, environmental concerns can be investigated more efficiently in this sub-section than any other. Since the public is so 'anti' genetically modified food, it would be easy to present quite a biased view. Candidates need to look at balanced documents that look at the facts, such as the Royal Society report, as well as material from pro- and anti- organisations and pressure groups. Although not required, practical work in this area is likely to supplement theory as before. It is possible to infect sunflowers with plasmids and micro-propagate food plants quite cheaply. Since, as a society, we are less and less aware of how food is produced, practical examples can only help.

Enzyme technology

Although this sub-section is integrated into the teaching of the other material, it could be taught as a discrete *unit* if required. It is **not** expected that candidates will have to come up with relevant strategies on their own. It would be acceptable to use existing methods found in the literature, and weaker candidates may have to be directed to this material. Some centres already have working fermenters available, but it would be useful if the investigative approach were retained and candidates try to make their own, using simple laboratory equipment. There is substantial opportunity to develop skills in ICT here, such as data logging and the use of spreadsheets. Data need not be laboriously plotted by hand, as long as candidates are able to explain what the software is doing.

15.4.2 Guidance on Assessment

It needs to be stressed that you determine only the *mark* for a candidate's portfolio evidence and not the *grade* which will be determined by OCR.

You need to mark each portfolio according to the assessment objectives and content requirements in the *Assessment Evidence Grid* (Section 15.3).

The information on this *grid* will eventually be transferred onto a *Unit Recording Sheet* to be attached to the front of each candidate's piece of work at the point when the work is submitted for moderation. A *Coursework Administration Pack* will be supplied, containing all relevant *Unit Recording Sheets*. Where marking for this unit has been carried out by more than **one** teacher in a centre, there must be a process of internal standardisation carried out to ensure that there is a consistent application of the criteria as laid down in the *Assessment Evidence Grids*.

Each row in the *grid* comprises a strand showing the development of an assessment objective, each row corresponding to (part of) an assessment objective descriptor in the banner (the top section of the *grid*).

The maximum mark for each strand is shown in the far right hand column of the *grid* and this maximum mark is further broken down into a number of mark bands across each row with a range of descriptors.

You use your professional judgement to determine which descriptor in a strand best suits the individual candidate's work and from the range of marks available within that particular mark band, you circle the mark that best fits the work. You then record this mark (or sum of marks if there is more than one row for that particular assessment objective) in the column headed *Mark*.

You need to use the full range of marks available to you. You need to award full marks in any strand for work which fully meets the criteria. This is work which is the best one could expect from candidates working at A2 level.

Only **one** mark per AO strand will be entered (although this may be the sum from several rows – **one** mark per row – for that particular AO strand). The final mark for the candidate is out of a total of **50** and is found by totalling the marks for each AO strand.

The further guidance below clarifies the criteria in the *Assessment Evidence Grid* and will help you to determine the appropriate mark to be awarded for each strand.

Amplification of Criteria		
AO	**Mark Band**	**Characteristics of the work one may expect to see at this mark band can be summarised as follows:**
AO1	**1**	• Candidates produce information which shows knowledge and understanding of Sub-section 15.2.1 (The science of genetic engineering) and Sub-section 15.2.2 (Use of recombinant DNA technology in medicine); • some omissions are acceptable at this level but candidates aim to address the majority of the information listed by the bullet points; • some evidence of how material has been selected and used to provide an information document; • candidates show evidence of research and an awareness of the legislation; • some scientific terminology is used, generally correctly; candidates may have been guided to the most relevant sources and used these appropriately; • candidates include some evidence of statistical research and evidence backed up by basic calculations;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO1	2	• candidates produce information which shows detailed knowledge and understanding of Sub-section 15.2.1 (The science of genetic engineering) and Sub-section 15.2.2 (Use of recombinant DNA technology in medicine); • candidates include the majority of the information listed by the bullet points and show evidence of selection of suitable factual data and suitable discussion of ethical and moral issues; • detailed evidence of how material has been selected and linked to the requirements of the set task – public information document; • candidates have carried out some of their own research into some of the topics listed with an understanding of legislation and control; • candidates have been selective in their use of sources, showing an understanding of the need to evaluate the quality of the information; • scientific terminology is generally used well when explaining gene technology; • candidates will complete some detailed statistical analysis with evidence of analysis with reasons;
	3	• candidates produce information which shows thorough knowledge and understanding of Sub-section 15.2.1 (The science of genetic engineering) and Sub-section 15.2.2 (Use of recombinant DNA technology in medicine); • candidates address all of the information listed by the bullet points with clear evidence of appropriate detailed information being selected and logically presented for the public information booklets; • the work includes logical discussion of chosen topics linked to ethical and moral issues where appropriate; • candidates show evidence of thorough research and an awareness and a clear understanding of the legislation and control; • language is fluent and scientific terminology is accurate and used consistently; • a wide variety of sources are selected to demonstrate the variety of opinion; • candidates are able to set out the work logically with limited help; • candidates produce evidence of thorough research on financial evidence with statistical analysis and justification.
AO2	1	• Candidates produce suitable evidence to show they have understood some of the bullet points listed in Sub-section 15.2.3 (Production of genetically modified food plants) and are aware of the effectiveness of the techniques used and provide a list of the benefits; • candidates, in addition, discuss the impact on society of production of genetically modified (GM) plants, there is limited evidence from research to support the findings; • candidates have produced a simple analysis, possibly in tabular form of what they see are the rights and wrongs of this technology to society; • although some evidence of independent thought is evident, candidates rely on the published material for their views to a greater extent; • **one** piece of legislation is described, with no attempt at evaluation;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO2	2	• candidates show clear evidence of evaluation of many of the bullet points listed in Sub-section 15.2.3 (Production of genetically modified (GM) food plants) and they are able to explain some of the successes and failures of the technology and link them to the impact on society focussing on at least **two** specific examples; • all points are backed up with evidence with some errors evident in interpretation; • candidates are able to assess several of the issues of society concerning this technology, again quoting clear examples; • **two** pieces of legislation are described and there is some evidence of evaluation;
	3	• candidates show clear evidence of an understanding of all bullet points listed in Sub-section 15.2.3 (Production of genetically modified (GM) food plants) and a thorough evaluation of the effectiveness and success of the techniques with limited help; • they are able to explain the successes and failures of the technology and justify their own opinion on the impact of society and potential for the future; • all points are backed up with referenced evidence with only minor errors evident in interpretation; • candidates are able to assess the major issues facing society concerning this technology, again quoting clear examples and rank them for relative importance; • legislation is evaluated for how effective it is in controlling scientific activity.
AO3	1	• Candidates produce a basic plan and safely carry out an investigation into enzyme technology; • evidence of understanding some of the bullet points in Sub-section 15.2.4 (Enzyme technology) is evident in the investigation; • candidates construct a simple reactor and are able to produce and use an immobilised enzyme but need help to do it; • candidates use a range of techniques and equipment; • data collected is correctly recorded and displayed – with help; • there is clear evidence of some interpretation of results relating them to how enzymes work and enzyme immobilisation an explanation of the results obtained;

AO	Mark Band	Characteristics of the work one may expect to see at this mark band can be summarised as follows:
AO3	2	• candidates produce a clear plan with little help and safely carry out an investigation into enzyme technology; • there is evidence that candidates are aware of the COSHH guidelines; • evidence of understanding of the majority of the bullet points in Sub-section 15.2.4 (Enzyme technology) is evident in the investigation; • with support, candidates are able to produce a clear strategy to investigate the effect of temperature on the rate of reaction in the bioreactor and can describe the advantages of immobilised enzymes; • candidates confidently use a range of techniques and equipment in the majority of their work; • candidates produce evidence of the recording of relevant observations and measurements on both the bioreactor and the immobilised enzymes and data is clearly and accurately displayed; • rates of reaction are correctly calculated and plotted; • conclusions show candidates are able to apply some of the theory on enzyme action to the results obtained;
	3	• candidates produce a clear and detailed plan and safely carry out an investigation into enzyme technology; • there is evidence of detailed risk assessments and that candidates are aware of the COSHH guidelines; • evidence of understanding the bullet points in Sub-section 15.2.4 (Enzyme technology) is evident in the investigation and candidates produce a wide-ranging investigation into the effect of temperature on enzyme activity in immobilised enzyme systems; • planning is relevant with a good use of secondary sources to guide strategy; • candidates confidently use a range of techniques and equipment with an explanation of why they are used; • repeats of experiments and adaptations of the plan are evident throughout; • candidates produce evidence of the recording of a detailed set of relevant observations and measurements on both the bioreactor and the immobilised enzymes with limited help; • all data is clearly and accurately displayed; • simple statistics such as means and standard deviations are evident as well as rates and graphs; • results are fully explained in terms of enzyme activity and clearly related to the biotechnology industry.

15.4.3 Resources

Organisations	**Biotechnology and Biological Sciences Research Council (BBSRC)** Polaris House North Star Avenue Swindon SN2 1UH Tel: 01793 413200 **National Centre for Biotechnology Education (NCBE)** School of Food Biosciences The University of Reading Whiteknights PO Box 226 READING RG6 6AP Tel: 01189 873 743			
Textbooks	Boyle M	*Genes and Genetic Engineering* (AQA(B) Biology)	Collins	000 327 710 0
	Chenn P	*Micro-organisms and Biotechnology*	(1997)	071 957 509 5
	Freeland P	*Microbes, Medicine and Commerce*	Hodder & Stoughton (1999)	034 073 103 6
	Gregory J	*Applications of Genetics*	Cambridge Advanced Science	
	Hayward G	*Applied Genetics 16-19*	Nelson-Thornes (1992)	
	King T & Reiss M	*Practical Advanced Biology*		
	Lowrie P & Wells S	*Microbiology and Biotechnology*	CUP (2000)	
	Mannion K & Hudson T	*Microbes and Disease*	Harper Collins (2001)	000 327 742 9
	Mannion K & Hudson T	*Microbes, Medicine and Biotechnology*	Collins	
	Taylor J	*Micro-organisms and Biotechnology*	Bath Science (1990)	
	Trevan MD *et al*	*Biotechnology: The Biological Principles*	John Wiley (1991)	
Websites	Select biotechnology link for gene technology and genetically modified organisms, range of articles and activities: http://www.agresearch.co.nz/scied/search/index.htm Downloadable discussion documents on ethical issues: http://www.bbsrc.ac.uk/ Background information on Plant Biotechnology: http://www.biotechknowledge.monsanto.com/biotech/bbasics.nsf/index.html?OpenPage Index of useful sites for biotechnology: http://www.biozone.co.uk/biolinks/BIOTECHNOLOGY.html			

Websites	Introductory article on use of gene therapy to treat cystic fibosis: http://www.cfgenetherapy.org.uk/ Comprehensive site – Browse: http:www.advisorybodies.doh.gov.uk/genetics/gtac/ Documents related to effect of GM trials on honey production: http://www.foe.co.uk/resource/briefings/bees_honey_gm_crops.html Documents related to GM crops used as animal feed: http://www.foe.co.uk/resource/briefings/gm_crops_animal_feed.html General site includes articles on GM foods: http://www.food.gov.uk/gmfoods National Centre for Biotechnology Education – good for articles and supply of teaching resources including enzymes: http://www.ncbe.reading.ac.uk/ Article: Genetically modified plants for food use: www.royalsoc.ac.uk/displaypagedoc.asp?id=7543 Article 'Code of practice on the provision of information relating to GM crops': http://www-saps.plantsci.cam.ac.uk/articles/broad_code.htm

16 Unit 16: Working Waves
[A2 level, externally assessed]

16.1 ABOUT THIS UNIT

This A2 level unit is an optional part of the single award and a mandatory part of the double award and is externally assessed.

This unit looks at a range of applications of electromagnetic waves. Waves have always been vital tools in communication. Without them, we could neither see nor hear. Today, modern communications engineers use fibre optics, mobile phone networks and satellites to link us together as never before. Scientists, engineers and medical professionals use waves in measurement and diagnosis. Doctors also harness the energy carried by waves in applications such as therapeutic uses of Gamma rays and in laser surgery. By studying this unit, you will be able to understand the principles involved in the use of waves for a variety of purposes in the modern world.

There are strong links between this unit and AS and A2 units in GCE Physics. This unit builds on Unit 3: *Monitoring the activity of the human body* and complements Unit 6: *Forensic science*.

This unit will help you to prepare for higher education courses in applied science or for work in communications-related occupations.

This unit is assessed through an external assessment. The mark on that assessment will be your mark for the unit.

16.2 WHAT YOU NEED TO LEARN

You need to learn about:

- electromagnetic radiation;
- how infrared imaging works;
- how optical fibres carry data;
- modern communication systems – how cell-phones and broadband work;
- the work of radiologists X- and γ-ray imaging and therapy.

16.2.1 Electromagnetic Radiation

You need to:

- describe the features common to all waves;
- describe the features belonging to some waves, but not others;
- describe the features unique to electromagnetic waves;
- recall and use $v = f\lambda$;
- identify the regions of the electromagnetic spectrum and describe qualitatively the similarities and differences of:
  – speed;
  – wavelength;
  – frequency production;
  – detection;
  – properties, e.g. penetration of matter.

16.2.2 How Infrared Imaging Works

All bodies emit electromagnetic radiation. We can see the light from the sun or a red-hot poker with our eyes. Cooler objects emit less energy. The radiation from cooler objects will be in the infra-red (IR) region of the spectrum, which has a longer wavelength and is not visible to the eye. Infra-red radiation lies between visible light and microwaves in the electromagnetic spectrum. IR can be monitored using special detectors. Infra-red imaging is used by forensic scientists to reveal disturbed ground, by engineers to detect ‘hot spots’ in machines and circuit boards, and by soldiers to see the enemy in the dark. Infra-red imaging uses the small variations in the wavelength of infra-red radiation emitted by objects at different temperatures, to reveal objects not visible to the eye.

You need to:

- describe how the spectrum of ‘hot-body’ radiation varies with temperature;
- describe how the total radiation given off by a surface varies with temperature;
- describe how thermal imaging cameras produce images corresponding to surface temperatures;
- explain applications of thermal imaging, including:
  – detection of disturbed ground;
  – night sights;
  – weapon systems;
  – burglar alarms;
  – remote sensing from satellites;
  – detecting survivors in collapsed buildings;
  – medical, e.g. to reveal quantitative details of circulatory problems, arthritis and rheumatism;
  – forensic;
  – engineering, e.g. non-destructive testing, electric circuit fault detection;

- outline the advantages of thermal detecting/imaging systems.

16.2.3 How Optical Fibres Carry Data

The transmission of light signals along optical fibres has revolutionised telecommunications. Previously, signals were usually transmitted by electric currents in metallic conductors. The cables were bulky, ungainly and had to be amplified at frequent intervals. Scientists have developed a very pure form of glass and made this into thin fibres. By sending light along these fibres, engineers send signals without too much attenuation. Lasers can be used to emit pulsed signals which can carry enormous amounts of information. Total internal reflection prevents light from leaking through the sides of the fibres.

You need to explain:

- how ASCII code can be used to convert text to binary signals and use this to encode a short message;
- total internal reflection and critical angle in terms of refraction at glass-air and glass-glass interfaces – you will be expected to relate critical angle to refractive index and wave velocity;
- how total internal reflection prevents light from leaking through the sides of the fibres;
- applications of coherent and incoherent optical fibre bundles;
- why step-index fibres are coated with glass of lower refractive index;
- how the shape of a square wave signal is degraded in multimode (multipath or step-index) fibres (diameter ~ 60μm) and how this can be overcome with graded index or monomode (single path) fibres (diameter ~ 1-10μm);
- that solid-state lasers are normally used to produce the light used in fibre optics communications and to suggest values for the infra-red wavelengths and frequencies used.

You need to:

- measure the refractive index of glass;
- measure the critical angle of a sample of glass and relate this to the refractive index;
- send a light signal down an optical fibre and detect it with a photodiode.

You need to:

- identify the advantages of fibre-optic transmission:
  – very large information capacity;
  – low material costs;
  – small cable size;
  – negligible crosstalk;
  – high immunity to interference;
  – complete electrical isolation;
  – large repeater spacings.

16.2.4 Modern Communication Systems – How Cell-Phones and Broadband Work

Modern communication systems such as mobile phones and Broadband networks are so simple to use that a child (and even some of their grandparents!) can operate them. In this part of the unit you will learn about the systems which communications engineers have developed to allow many users to share the same limited bandwidth available in the form of radio waves, or down a single transmission line.

You need to explain:

- the difference between AM and FM radio transmissions;
- how broadband transmission increases the speed of data connection to the Internet.

You need to:

- distinguish between analogue and digital systems;
- use and understand binary coding;
- explain Pulse Code Modulation (PCM), analogue-to-digital conversion and digital-to-analogue conversion;
- explain how the splitting of a geographic area into many small cells (0.5-20 miles in radius) increases the number of users a network can carry and the range over which an individual user can communicate;
- discuss the factors affecting the distribution of these base stations;
- state the factors affecting mobile phone signal strength (intensity), e.g. obstructions, distance from base station (inverse-square law);
- the terms *up-link* and *down-link* bands as applied to mobile phones;
- compare the full duplex system used for mobile phones with half-duplex devices such as CB radios;
- compare cellular access technologies:
  – Frequency Division Multiple Access (FDMA);
  – Time Division Multiple Access (TDMA);
  – Code Division Multiple Access (CDMA);
  and recognise TDMA as the standard known as the Global System for Mobile Communications (GSM);
- compare the advantages of dual-band and dual-mode technologies.

16.2.5 The Work of Radiologists X- and γ-Ray Imaging and Therapy

Ordinary X- and γ-ray imaging has been used as a tool by doctors and engineers for many years. Modern techniques reduce dose rates from simple images to a minimum and CAT scanners extend the information that can be obtained. Ionising radiation is normally harmful to the body, but radiotherapy deliberately uses targeted doses to treat cancer.

You need to:

- state *qualitatively* the differential absorption of X-rays by air, fat, other soft tissues and bone and the appearance of X-rays on film after passing through these media;
- explain techniques for improving quality of X-ray images; use of a grid, narrow beam, filtration;
- explain how X- and γ-radiations damage cells through ionisation;
- evaluate the consequent health hazards and identify the radiological protection measures taken in X- and γ-ray imaging and radiotherapy treatment areas, to monitor and minimise the dose received by staff and the damage done to healthy tissue of patients; the half-thickness value of lead screening used;
- describe how the use of image-intensifying screens reduces dose rates;
- describe how CAT scanners can produce much more detailed information than conventional X-rays;
- describe the principle of the γ-camera used to image radioactive tracers administered to the body;
- identify the advantages of technetium-99m as a radioactive tracer;
- describe how X- and γ-radiations are used therapeutically.

16.3 GUIDANCE FOR TEACHERS

16.3.1 Guidance on Delivery

This unit focuses on some of the applications of electromagnetic waves which are most likely to be of interest to candidates. This is intended to allow sufficient time for these topics to be covered in as much depth as is appropriate at this level. However it is important that the content needs to be firmly rooted in the context of the electromagnetic spectrum as a whole, recognising the similarities and differences between electromagnetic and other types of waves. Although it may be appropriate to introduce some of Sub-section 16.2.1 (Electromagnetic radiation) as an introduction to this unit, other concepts need to be developed as they arise, in the context of the applications.

Electromagnetic radiation

Although it may be appropriate to introduce some of this sub-section as an introduction to this unit, other concepts need to be developed as they arise in the context of the applications.

The features common to all waves include:

- repeating wave patterns;
- speed;
- wavelength;
- frequency;
- phase.

In considering the features belonging to some waves, but not others, candidates need to learn about:

- transverse or longitudinal waves;
- polarisation;
- sine- and square-wave shapes;
- monochromatic waves, line spectra and continuous combinations of sine-wave frequencies.

The features unique to electromagnetic waves might be introduced as follows:

- discuss the electric field produced by a single charge, then by a pair of equal- and opposite-stationary charges;
- develop the idea that oscillating a pair of equal- and opposite-charges will produce oscillating electric fields;
- note that electric fields are detectable at a distance even if there is a vacuum between the source and the detector;
- there is a time delay between changes occurring at the source and reaching the detector; the signal travels at the speed of light; the oscillating field forms a wave between the source and detector;
- the oscillations can carry information encoded into them;
- changes in field can transmit energy, e.g. oscillations in radio antennae, light from the sun;
- a changing electric field always has an associated magnetic field at right angles, hence the term electromagnetic radiation;
- high frequencies are needed to create electromagnetic radiation electronically; radio waves were forecast by Maxwell before they could be produced;
- electromagnetic radiation is also produced by hot bodies and by molecules, electrons in atoms and nuclei falling to lower energy levels and shedding excess energy as electromagnetic radiation;
- all electromagnetic radiation is part of the same family varying only in:
  – the order of magnitude of frequency, wavelength and amplitude;
  – the combinations of frequencies – monochromatic, line or continuous spectra;

- electromagnetic radiation may be formed by:
  – artificial means such as oscillating charges;
  – artificially excited atoms;
  – natural occurrences such as sunlight and radiation from uranium found in the earth.

Understanding of the electromagnetic spectrum needs to build on GCSE learning. Candidates need to be encouraged to consider whether dividing lines between the regions of the spectrum can be precisely drawn and, in particular, how the regions might be defined. Candidates need to recognise the regions of the electromagnetic spectrum and their similarities and differences of speed, wavelength, frequency and penetration of matter.

How infrared imaging works

Candidates need to understand that the term ‘hot-body’ radiation can be a misnomer and that radiation is emitted even by objects at cryogenic temperatures. More able candidates may be encouraged to think about the shape of the hot-body spectrum and research the elementary quantum mechanics concepts which can be used to explain it.

How optical fibres carry data

After an introduction identifying the limitations of traditional wire transmission of signals, learning about optical fibres could start with the question ‘why doesn’t the light leak out?’ The answer – that it is reflected – should then lead to the concept of total internal reflection and the conditions for this to occur. This lays the ground for introducing the traditional theory of refractive index, total internal reflection and critical angle.

ASCII coding is the standard system by which alpha-numeric characters are expressed in binary form for computing. Sub-section 16.2.3 includes a reference to ASCII coding where candidates need to have a ‘hands-on’ feel for the concept of binary coding rather than any need to learn the ASCII system as such.

Modern communication systems – how cell-phones and broadband work

Learning about mobile phone technology could start with the questions:

- Why didn’t we have mobile phones years ago?
- Why were personal radios restricted to the emergency services and a restricted number of radio ‘hams’?

The answer – limitation in available frequencies – can then lead to an understanding of how multiplexing and cellular technologies overcome this problem and hence to more detailed considerations of the technologies themselves.

Solid state lasers with wavelengths 0.8-0.9 μm, or 1.3-1.55 μm are commonly used in optical-fibre systems.

One activity which may capture the interest of candidates might be to investigate the variation of mobile phone signal strength using the meter built into a phone, including, in their risk assessment, a discussion of mobile phone safety.

The International Telecommunications Union (ITU) has allocated the radio band 890-915 MHz for the up-link (the signals *transmitted by* mobile phones) and the band 935-960 MHz for the down-link (the signal *received by* mobile phones) (*Skelding*). UK mobile phones use the ranges 872-960 MHz, 1710-1875 MHz and 1920-2170 MHz. GSM = 900 and 1800 bands and UMTS are expected to use 2 GHz (*Dobson et al*).

Investigating the work of radiologists X- and γ-ray imaging and therapy

Centres fortunate enough to have an X-ray machine such as the Tel-X-ometer will be able to give candidates the opportunity to produce an X-ray image themselves. In most cases, practical work in this sub-section of the unit will not be an option. A visit to the radiography and radiotherapy departments of a local hospital is an excellent way to bring the ideas of the CAT scanner and radiotherapy techniques to life.

Candidates need to understand that X- and γ-rays are hazardous in a way that other parts of the electromagnetic spectrum are not, because of their ionising properties. They need to understand that ionisation in living cells can lead to death or mutation of the cell and be able to give examples of the acute and long-term effects of such radiation and distinguish between the somatic and genetic effects.

Candidates need to understand the difference between a substance that has been irradiated and one which is radioactive.

Candidates need to understand the difference between the activity of a source, measured in becquerel (Bq) and the dose equivalent measured in sievert (Sv). Inclusion of the absorbed dose measured in gray (Gy) is not essential as the quality factor for X- and γ-rays is close to 1.

Candidates need to know that the dose to staff can be reduced by:

- reducing the size of source used;
- increasing distance from the source (inverse-square rule);
- reducing time of exposure;
- inserting materials such as lead or concrete between the source and the person.

The dose to X-ray patients can be reduced if more sensitive X-ray emulsions or image intensifying screens are used. For radiotherapy patients, careful planning can reduce the dose to parts of the body not undergoing treatment. Candidates need to understand the balance that needs to be struck between risk and benefit to patients when exposed to radiation as part of medical diagnosis or treatment.

Candidates need to understand the terms physical and biological half-life as applied to technetium-99m tracer.

16.3.2 Guidance on Assessment

This unit is assessed through a 1½ hour question paper with **90** marks which assesses AO1 (**45-55** %) and AO2 (**45-55** %).

16.3.3 Resources

Equipment	Can be obtained from: Phillip Harris Scientific & Chemical Griffin			
Publications	Badawi R	*Nuclear Medicine*	Physics Education	Vol. 36 No 6 Nov 2001
	ldham M	*Radiation physics and applications in Therapeutic Medicine*	Physics Education	Vol. 36 No 6 Nov 2001
	Michael G	*X-Ray Computed Tomography*	Physics Education	Vol. 36 No 6 Nov 2001
Software	Krucible, Immersive Education www.immersiveeducation.com			
Textbooks	Adams S & Allday J	*Advanced Physics*	Oxford (2000)	019 914 680 2
	Dobson K Grace D & Lovett D	*Physics*	Collins (2002)	000 713 598 X
	England N Milward C & Barratt P	*Physics in Perspective*	Hodder & Stoughton (1990)	034 040 709 3
	Hollins M	*Medical Physics* (Bath Advanced Science)	Nelson Thornes (2001)	017 448 253 1
	Hutchings R	*Physics* (Bath Advanced Science)	Nelson Thornes (1990)	017 438 510 2
	McCormick & Elliot A	*Health Physics* (Cambridge Modular Science)	CUP (2001)	052 178 726 2
	Muncaster R	*Medical Physics*	Stanley Thornes (1966)	074 872 324 2
	Pope J	*Medical Physics* (Heinemann Advanced Science)	Heinemann (2003)	043 557 086 2
	Skelding R	*Physics Phones Home* (Supported Learning In Physics Project)	Heinemann (1998)	043 568 840 5
Video	'Medical Physics', UCL Images, 1995			

Websites	Useful source of information about mobile phone technology: http://electronics.howstuffworks.com/cell-phone.htm Networks and data communication: http://infj.ulst.ac.uk/~cbem23/b1.html Broadband: http://www.bwww.co.uk/broadband/what-is-broadband.php