Oxford Cambridge and RSA Examinations

OCR AS GCE in Chemistry (3882)

OCR Advanced GCE in Chemistry (7882)

Approved Specifications – Revised Edition

First Advanced Subsidiary GCE certification was 2001 QAN (3882) 100/0595/X
First Advanced GCE certification was 2002 QAN (7882) 100/0423/3

Foreword to Revised Edition

This Revised Edition has been produced to consolidate earlier revisions to these specifications and any changes contained within have previously been detailed in notices to centres. **There is no change to the structure. Four new assessment outcomes have been added to the specification (see below). Other differences are cosmetic or clarifications**. Sidelining will be used to indicate any significant changes.

The main changes are listed below:

Re-sits of Units - The restrictions on re-sitting units have been removed, enabling candidates to re-take units more than once (for details see page 23).

Unit Availability– Please note that certain options within Unit 2815 will no longer be available in January sessions (for details see page 21).

New Assessment Outcomes:

- A new assessment outcome has been added to Section 5.1.1 *Atoms, Molecules and Stoichiometry* (see page 36 (i)).
- Three new assessment outcomes have been added to Module 5.4 *Chains, Rings and Spectroscopy* as follows:

  Section 5.4.3 *Carboxylic Acids and Esters* (see page 58(e))
  Section 5.4.4 *Nitrogen compounds* (see page 59(a)(ii) and (iii))
  Section 5.4.5 *Stereoisomerism and organic synthesis* (see page 60(f))

Foreword (continued)

This booklet contains OCR's Advanced Subsidiary GCE (AS) and Advanced GCE (A level) Chemistry specifications for teaching from September 2004.

The AS GCE is assessed at a standard appropriate for candidates who have completed the first year of study of a two year Advanced GCE course, i.e. between GCSE and Advanced GCE. It forms the first half of the Advanced GCE course in terms of teaching time and content. When combined with the second half of the Advanced GCE course, known as 'A2', the AS forms 50% of the assessment of the total Advanced GCE. However, the AS can be taken as a 'stand-alone' qualification. A2 is weighted at 50% of the total assessment of the Advanced GCE.

In these specifications the term **module** is used to describe specific teaching and learning requirements. The term **unit** describes a unit of assessment.

Each teaching and learning module is assessed by its associated unit of assessment.

These specifications meet the requirements of the Common Criteria (Qualifications and Curriculum Authority, 1999), the GCE AS and Advanced Level Qualification-Specific Criteria (QCA, 1999) and the relevant Subject Criteria (QCA, 1999).

These specifications are part of a suite of linked specifications in the sciences. All have similar structures and schemes of assessment. The suite comprises:

Biology	**3881 & 7881**
Human Biology	**3886 & 7886**
Chemistry	**3882 & 7882**
Physics A	**3883 & 7883**
Geology	**3884 & 7884**
Science	**3885 & 7885**

Contents

Specification Summary

Outline

The OCR AS GCE and Advanced GCE Chemistry specifications are designed to be flexible. Candidates cover material in the AS and Advanced GCE Chemistry subject criteria in compulsory modules. For AS, there is no choice of module content, but optional modules in A2 give candidates the opportunity to explore an area of chemistry in greater depth. Some optional modules deal with modern applications of chemistry whilst others cover more traditional areas. The assessment of Experimental Skills is flexible, with coursework and practical examination alternatives in both AS and A2.

Specification Content

All modules draw, as appropriate, on the content identified in the QCA Subject Criteria for Chemistry (1999). The content is chosen to provide a balanced and coherent study of chemistry. The AS provides a foundation of chemistry that is built upon in A2. In addition, both specifications provide opportunities for the development of key skills.

Scheme of Assessment

The AS GCE forms 50% of the assessment weighting of the full Advanced GCE. AS GCE is assessed at a standard between GCSE and Advanced GCE and can be taken as a stand-alone specification or as the first part of the full Advanced GCE course.

Assessment is by means of **three Units of Assessment** for AS GCE and **six Units of Assessment** for Advanced GCE:

Candidates must take the following combination of units:

AS GCE Candidates take units 2811, 2812 **and** 2813.

Advanced GCE	Candidates take Units 2811, 2812, 2813, 2814, 2815 **and** 2816.
	In Unit 2813 candidates take either Components 01 and 02 or Components 01 and 03.
	In Unit 2815 candidates take Component 01 and one of Components 02-06.
`	In Unit 2816 candidates take either Components 01 and 02 or Components 01 and 03

Units of Assessment

Level	Unit/ Component (where relevant)	Name	Duration	Mode of Assessment	Weighting	
					AS	Advanced GCE
AS	2811	Foundation Chemistry	1 hour	Written Examination	30%	15%
AS	2812	Chains and Rings	1 hour	Written Examination	30%	15%
AS	2813	How Far, How Fast?/Experimental Skills 1				
	/01	How Far, How Fast?	45 mins	Written Examination	20%	10%
	/02	Coursework 1	-	Coursework	20%	10%
	/03	Practical Examination 1	1 hour 30 mins	Practical Examination	20%	10%
A2	2814	Chains, Rings and Spectroscopy	1 hour 30 mins	Written Examination	-	15%
A2	2815	Trends and Patterns/ Options in Chemistry				
	/01	Trends and Patterns	1 hour	Written Examination	-	7.5%
	/02	Biochemistry	50 mins	Written Examination	-	7.5%
	/03	Environmental Chemistry	50 mins	Written Examination	-	7.5%
	/04	Methods of Analysis and Detection	50 mins	Written Examination	-	7.5%
	/05	Gases, Liquids and Solids	50 mins	Written Examination	-	7.5%
	/06	Transition Elements	50 mins	Written Examination	-	7.5%
A2	2816	Unifying Concepts in Chemistry /Experimental Skills 2				
	/01	Unifying Concepts in Chemistry	1 hour 15 mins	Written Examination		10%
	/02	Coursework 2	–	Coursework		10%
	/03	Practical Examination 2	1 hour 30 mins	Practical Examination		10%

Question Paper Requirements

The question papers for Units 2811, 2812, 2813 (component 01), 2814, 2815 (components 01–06) and 2816 (component 01) have a common format. They contain both structured questions and questions requiring more extended answers. All questions on these papers are compulsory. Quality of written communication is assessed within those parts of questions requiring more extended answers.

The question papers for 2815 (component 01) and 2816 (component 01) contain questions covering synoptic assessment requiring candidates to draw together their knowledge and understanding of the compulsory modules: 2811, 2812, 2813 (component 01), 2814, 2815 (component 01) and 2816 (component 01).

All questions on the practical examination papers, 2813 (component 03) and 2816 (component 03), are compulsory. The practical examination papers 2813 (component 03) and 2816 (component 03) are alternatives to coursework units 2813 (component 02) and 2816 (component 02) respectively.

Experimental and Investigative Skills

Experimental skills for AS and Advanced GCE are assessed by

- **either** coursework components (Unit 2813 (component 02) and Unit 2816 (component 02)),
- **or** by external practical examination components (Units 2813 (component 03) and Unit 2816 (component 03)).

Candidates may combine the two methods of assessment by taking the coursework unit in AS and the practical examination unit in A2 or *vice versa*.

Coursework

In each of AS and Advanced GCE, candidates can be internally assessed on four experimental and investigative skills. For each candidate, one mark per skill must be awarded for AS Unit 2813 (component 02) with one further mark per skill for A2 Unit 2816 (component 02). Work is marked by the teacher, internally standardised in the Centre, and externally moderated by OCR. There is some synoptic assessment in Unit 2816 (component 02).

External examination

In each of AS and Advanced GCE, candidates can take an externally set and marked practical examination. There is an element of synoptic assessment in Unit 2816 (component 03).

Overlap with other qualifications

These specifications have some overlap with OCR Advanced GCE specifications in Biology, Geography, Physics and Science and with the OCR Advanced GNVQ in Science. Full details are given in Section 1.3.

1 Introduction

Introduction

These OCR specifications lead to qualifications at AS GCE and Advanced GCE in **Chemistry**. Candidates take three Units of Assessment for AS GCE and a further three for A2. AS and A2 combined constitute the full Advanced GCE specification.

These specifications have been developed from existing A level modular courses in Chemistry. These courses have gained increasing popularity during the 1990s and there is a tradition of dedicated textbooks to support individual modules. The development of these specifications has offered the opportunity to strengthen the best features of existing courses whilst updating the provision in line with new educational initiatives.

These specifications conform to the QCA Subject Criteria for Chemistry (1999), the QCA AS/A Level qualification-specific Criteria (1999) and the QCA Common Criteria (1999). All of the content in the AS Chemistry Subject Criteria is covered in Module 2811: Foundation Chemistry, Module 2812: Chains and Rings and Module 2813 (component 01): How Far, How Fast? All of the content in the A2 Chemistry Subject Criteria is covered in Module 2814: Chains, Rings and Spectroscopy, Module 2815 (component 01): Trends and Patterns and Module 2816 (component 01): Unifying Concepts in Chemistry. Other content in both AS GCE and Advanced GCE specifications allows for further study and amplification of the Chemistry Subject Criteria.

The variety of interests and needs of different students is addressed by building some flexibility into the course with a choice of options in A2. The Options are drawn both from applied areas of Chemistry: Biochemistry, Environmental Chemistry and Methods of Analysis and Detection; and from more traditional areas: Transition Elements and Gases, Liquids and Solids. Teachers and candidates have the flexibility to develop their own interests or to utilise particular strengths within the Centre. The specifications has been designed to ensure that each of these options is developed from the content of the ‘core’ teaching modules and comparability is ensured using units of assessment with a similar structure, the same weightings of assessment objectives, but independent grading arrangements.

Experience of the role of experimental and investigative work is important in any chemistry course and these specifications provide for two comparable practical assessment routes, assessed either internally by coursework or externally by practical examinations. This flexibility meets the demands of different Centres. Many teachers value the opportunity to assess students’ practical work internally, assessing their candidates as their experimental and investigative skills develop during the course. The practical examination addresses the needs of some candidates as well as Centres with large groups of candidates (where safety considerations may prevent other forms of practical assessment).

These specifications also provide numerous opportunities for students to develop their proficiency in the Key Skills.

Broad aims and objectives

The aims of these AS GCE and Advanced GCE specifications are to provide, through well-designed studies of experimental and practical chemistry, a worthwhile educational experience for all candidates, whether or not they go on to study chemistry at a higher level.

In particular, these specifications are aimed to enable candidates to acquire sufficient understanding and knowledge to

- become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
- recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
- be suitably prepared for employment and/or further studies beyond AS GCE or Advanced GCE in Chemistry;
- develop abilities and skills that are relevant to the study and practice of chemistry; are useful in everyday life; encourage efficient and safe practice; encourage the presentation of information and ideas appropriate for different audiences and purposes; promote self motivation and the ability to work in a sustained fashion;
- develop attitudes relevant to chemistry such as accuracy and precision, objectivity, integrity, enquiry, initiative and insight;
- be aware that the study and practice of chemistry are co-operative and cumulative activities, and are subject to social, economic, environmental, technological, ethical and cultural influences and limitations;
- stimulate interest in, and care for, the environment;
- be aware that, whilst the applications of chemistry may bring great benefits, there may be detrimental effects to the individual, the community and the environment, which may be minimised by responsible use of chemical technology.

In addition for A2, candidates are able to demonstrate that they can bring together and synthesise knowledge, principles and concepts from different areas of chemistry.

Social, economic, environmental, ethical, medical and technological aspects of chemistry are integrated into modules throughout these specifications. It is expected that references to these aspects of chemistry will be incorporated into the delivery of these specifications.

For more details, see Section 2: Specification Aims and Section 3: Assessment Objectives.

Recommended prior learning

The AS GCE specification builds from grade CC in GCSE Science: Double Award, or equivalent in Science: Chemistry. However, candidates from other educational backgrounds with equivalent experience will have the necessary prior knowledge. Thus, students who have studied and have a passed an Intermediate GNVQ Science course should also have sufficient knowledge and understanding to study the AS Chemistry course. Mature students without Level 2 qualifications may have acquired sufficient ‘life skills’ to enable progression onto this course.

For this reason, recommended prior knowledge within the AS units in Section 5 is described in terms of National Curriculum statements and these are shown in the introduction to each AS module.

The assessment of experimental and investigative skills builds from GCSE. The skills cover the same areas as Sc1 of GCSE, and the mark descriptors are formulated in the same way as the GCSE mark descriptors.

The A2 modules build upon the knowledge and understanding acquired in the AS modules and recommended prior learning for the A2 course would be a successful performance at AS Chemistry.

Progression

Chemistry at Advanced GCE is a prerequisite for many courses in Higher Education and for many areas of employment. It is also a long-established and respected qualification that can allow progression into a number of career areas. The AS GCE provides for candidates who may wish to follow a chemistry course for only one year in order to broaden their curriculum. Many universities and employers value the strengths of the 'broader student'. Other candidates will progress for a further year extending their course to Advanced GCE. Such a course serves the needs of candidates desiring to progress into further or higher education to follow courses in chemistry, one of the other sciences or related subjects, or to enter employment where a knowledge and understanding of chemistry would be useful. Study of chemistry to AS GCE or Advanced GCE should also be seen as improving the education base of the population as a whole and as making a contribution towards life-long learning.

1.1 Certification Title

These specifications are shown on a certificate as

- OCR Advanced Subsidiary GCE in Chemistry.
- OCR Advanced GCE in Chemistry.

1.2 Language

These specifications and associated assessment materials are in English only.

1.3 Overlap with other qualifications

Links with other AS and Advanced GCE specifications

Chemistry sits centrally within the Sciences and this course provides overlap with other A-level specifications, particularly Biology and Physics. The specification in Science emphasises links between Chemistry and related subjects such as Biology, Geography, Physics and Science.

Examples of overlap include

Biology

- **Module 2814: Chains, Rings and Spectroscopy.** Amino acids, peptides.
- **Module 2815 (component 02): Biochemistry.** Proteins, enzymes, carbohydrates, lipids and nucleic acids.

Note that the emphasis within this module is on molecular structure and not biological functions.

- **Module 2815 (component 03): Environmental Chemistry.** The atmosphere, hydrosphere, lithosphere, waste treatment.
- **Module 2815 (component 04): Methods of Analysis and Detection.** Chromatography, electrophoresis, genetic fingerprinting.

Environmental Science

- **Module 2812: Chains and Rings.** Many environmental issues are discussed within the content of this module, especially those related to fuels, pollution, depletion of the ozone layer, the Greenhouse Effect and the development of renewable alternatives to finite energy resources.
- **Module 2815 (component 03): Environmental Chemistry.** The atmosphere, hydrosphere, lithosphere, waste treatment.

Geography

- **Module 2812: Chains and Rings.** Many environmental issues are discussed within the content of this module, especially those related to fuels, pollution, depletion of the ozone layer, the Greenhouse Effect and the development of renewable alternatives to finite energy resources.
- **Module 2815 (component 03): Environmental Chemistry.** The atmosphere, hydrosphere, lithosphere, waste treatment.

Physics

- **Module 2811: Foundation Chemistry.** Atomic structure.
- **Module 2815 (component 04): Methods of Analysis and Detection.** Atomic emission spectra.

Science

- **Module 2811: Foundation Chemistry.** Atomic structure, bonding and structure.
- **Module 2812: Chains and Rings.** Many environmental issues are discussed within the content of this module, especially those related to fuels, pollution, depletion of the ozone layer, the Greenhouse Effect and the development of renewable alternatives to finite energy resources.
- **Module 2813 (component 01): How Far, How Fast?** Enthalpy changes, rates of reaction, catalysis.
- **Module 2815 (component 02): Biochemistry.** Proteins, enzymes, carbohydrates, lipids and nucleic acids.
- **Module 2815 (component 03): Environmental Chemistry.** The atmosphere, hydrosphere, lithosphere, waste treatment.
- **Module 2815 (component 04): Methods of Analysis and Detection.** Atomic emission spectra, infra-red spectroscopy, chromatography.

Links with Advanced GNVQ specifications

There is overlap in content of the compulsory chemistry modules in these AS GCE and Advanced GCE specifications with chemistry-based units in GNVQ Advanced Science courses, although the academic and vocational approaches are different. The mandatory chemistry-related GNVQ units are: Unit 7437 Controlling Chemical Processes and Unit 7439 Synthesising Organic and Biochemical Compounds. Compared with these AS GCE and Advanced GCE specifications, there is a much greater emphasis placed upon experimental and investigative work in the GNVQ course. The chemistry that underpins the GNVQ mandatory units cuts across many of the AS and A2 modules. Specific links are shown below. Despite the amount of common material, the distribution of GNVQ materials between the AS and A2 modules and the different inherent approaches mean that any joint delivery of courses would need to be extremely well-planned.

Unit 7437: Controlling Chemical Processes

- **Module 2811: Foundation Chemistry.** The Mole Concept, equations and reacting quantities.
- **Module 2812: Chains and Rings.** Percentage yields.
- **Module 2813 (component 01): How Far, How Fast?** Chemical equilibria, le Chatelier's principle, Haber process, energetics, Hess's Law, factors affecting reaction rates.
- **Module 2816 (component 01): Unifying Concepts in Chemistry in Chemistry.** Equilibrium constants, K_c and K_p. rate constants, orders and rate equations.

Unit 7439: Synthesising Organic and Biochemical Compounds

- **Module 2812: Chains and Rings.** Alkanes, alcohols, structural isomerism.
- **Module 2814: Chains, Rings and Spectroscopy.** Carboxylic acids, amines, esters, stereoisomerism.
- **Module 2815 (component 02): Biochemistry.** Many aspects of enzymes.

1.4 Exclusions

Candidates who enter for this AS GCE specification may not also enter for any other AS GCE specification with the certification title Chemistry in the same examination session.

Candidates who enter for this Advanced GCE specification may not also enter for any other Advanced GCE specification with the certification title Chemistry or Science in the same examination session.

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 1110.

1.5 Code of Practice

These specifications will comply in all respects with the 2004 revised Code of Practice.

2 Specification Aims

The aims of these AS GCE and Advanced GCE specifications in chemistry are to encourage students to:

- develop essential knowledge and understanding of the concepts of chemistry, and the skills needed for the use of these in new and changing situations;
- develop an understanding of the link between theory and experiment;
- be aware of how advances in information technology and instrumentation are used in chemistry;
- appreciate the contributions of chemistry to society and the responsible use of scientific knowledge and evidence;
- sustain and develop their enjoyment of, and interest in, chemistry.

In addition, the aims of the Advanced GCE specification encourage students to:

- bring together knowledge of ways in which different areas of chemistry relate to each other.

2.1 Spiritual, Moral, Ethical, Social and Cultural Issues

These specifications provides an opportunity for candidates to appreciate the following:

- a sense of awe and wonder at the atomic and molecular workings of the material world (see Module 2811: Foundation Chemistry 5.1.2, 5.1.3);
- the endeavour of chemists and other scientists in the development of knowledge and understanding of the material world (see Module 2813 (component 01): How Far, How Fast? 5.3.2(f), (i), (k));
- ethical and moral implications of some of the applications of chemistry (see Module 2812: Chains and Rings 5.2.3(e); Module 2813 (component 01): How Far, How Fast? 5.3.3(d));
- cultural issues, driven by society, are often perceived as ‘chemical’, for example drug dependency or pollution (see Module 2812: Chains and Rings 5.2.4(k); Module 2813 (component 01): How Far, How Fast? 5.3.2(j)).

2.2 Environmental Education

Aspects of environmental education present in these specifications enable candidates to appreciate the following:

- An awareness that chemicals are essential components of living organisms (see Module 2812: Chains and Rings 5.2; Module 2814: Chains, Rings and Spectroscopy 5.4; Module 2815 (component 02): Biochemistry 5.6);
- The work of chemists in combating pollution, for example in developing unleaded and lead-replacement petrols or controlling pollutants present in exhaust emissions (see Module 2812: Chains and Rings 5.2.3(d));
- Catalytic converters developed by chemists reduce gaseous pollutants from petrol-driven vehicles (see Module 2813 (component 01): How Far, How Fast? 5.3.2(k));
- The need to control pollution within acceptable environmental limits (see Module 2812: Chains and Rings 5.2.4(m); Module 2813 (component 01):: How Far, How Fast? 5.3.2(j); Module 2815 (component 01): Environmental Chemistry 5.7.1);
- Conservation of finite resources and reduction of waste can be achieved by recycling of materials such as polymers and metals (see Module 2812: Chains and Rings 5.2.3(e); 5.2.4(l));
- Responsible care initiative is creating clean technology for use in industrial processes (see Module 2812: Chains and Rings 5.2.4(l), (m); Module 2813 (component 01): How Far, How Fast? 5.3.2(j), (k));
- Depletion of the ozone layer is a consequence of leakage of CFCs from air conditioners and refrigerators (see Module 2812: Chains and Rings 5.2.6(f), (g); Module 2815 (component 03): Environmental Chemistry 5.7.1(e), (f)).

Candidates following Module 2815 (component 03): Environmental Chemistry will meet many more environmental aspects of chemistry in the contexts of the atmosphere, hydrosphere and lithosphere.

2.3 European Dimension

There have been many contributions to the understanding of chemistry by European chemists. Haber, Boltzmann, Avogadro, Bohr and le Chatelier appear in the specifications and the work of many others could be drawn upon whilst teaching the specifications. There are also other aspects, not mentioned in the specifications, which could be developed during the course. For example:

- chemical companies are frequently multi-national and many UK companies have sites in Europe;
- chemical pollution does not recognise national boundaries, for example: Scandinavia experiences acid rain which originates from the UK and other European countries; the ozone layer is depleted by emissions of CFCs (see Module 2812: Chains and Rings 5.2.6(g); Module 2815 (component 03): Environmental Chemistry 5.7.1).

2.4 Health Education

Aspects of Health Education that feature in these specifications enable candidates to appreciate the following:

- chlorine is used in potable water to prevent disease (see Module 2811: Foundation Chemistry 5.1.6(e); Module 2813 (component 03): Environmental Chemistry 5.7.2(h));
- ethanol is the drug in alcoholic drinks (see Module 2812: Chains and Rings 5.2.5(b), (g));
- design and synthesis of medicines have played a major role in improving the health and standard of life (see Module 2814: Chains, Rings and Spectroscopy: 5.4.5(c)).

2.5 Economic and Industrial Understanding

These specifications promote understanding of the following:

- the chemical industry is important to the economy of the UK (see Module 2813 (component 01): How Far, How Fast? 5.3.3(c));
- many aspects of our everyday lives, such as provision of new materials and the prevention of disease, depend on the contribution made by the chemical industry (see Module 2812: Chains and Rings 5.2.3(a), (c), (e); 5.2.4(j); 5.2.5(g); Module 2813 (component 01): How Far, How Fast? 5.3.3(d); Module 2814: Chains, Rings and Spectroscopy: 5.4.1(h); 5.4.4(d); 5.4.5(e));
- sufficient food is provided by using artificial fertilisers (see Module 2813 (component 01): How Far, How Fast? 5.3.3(c), (d), (i));
- new polymers and new medicines are designed by chemists (see Module 2812: Chains and Rings 5.2.4(j)); Module 2814: Chains, Rings and Spectroscopy: 5.4.5(e));
- appropriate choice of conditions is important in chemical manufacture (see Module 2813 (component 01): How Far, How Fast? 5.3.3(c)).

2.6 Avoidance of Bias

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

3 Assessment Objectives

Knowledge, understanding and skills are closely linked. These specifications require that candidates demonstrate the following assessment objectives in the context of the content and skills prescribed. Assessment Objectives AO1–AO3 are the same for AS GCE and Advanced GCE; AO4 applies only to the A2 part of the Advanced GCE course.

- Assessment objectives AO1–AO3 are tested using the context of the content and skills within each teaching module.
- Assessment objective AO4 will be tested using contexts which bring together content and skills from different teaching modules.

AO1 Knowledge with understanding

Candidates should be able to:

- recognise, recall and show understanding of specific chemical facts, terminology, principles, concepts and practical techniques;
- draw on existing knowledge to show understanding of the responsible use of chemistry in society;
- select, organise and present relevant information clearly and logically, using specialist vocabulary where appropriate.

AO2 Application of knowledge and understanding, analysis, synthesis and evaluation

Candidates should be able to:

- describe, explain and interpret phenomena and effects in terms of chemical principles and concepts, presenting arguments and ideas clearly and logically, using specialist vocabulary where appropriate;
- interpret and translate, from one form into another, data presented as continuous prose or in tables, diagrams and graphs;
- carry out relevant calculations;
- apply chemical principles and concepts to unfamiliar situations, including those related to the responsible use of chemistry in society;
- assess the validity of chemical information, experiments, inferences and statements.

AO3 Experiment and investigation

Candidates should be able to:

- devise and plan experimental and investigative activities, selecting appropriate techniques;
- demonstrate safe and skilful practical techniques;
- make observations and measurements with appropriate precision and record these methodically;
- interpret, explain, evaluate and communicate the results of their experimental and investigative activities clearly and logically using chemical knowledge and understanding, and using appropriate specialist vocabulary.

In addition, when planning practical activities, candidates should use their own chemical knowledge and suitable reference sources to:

- identify any hazards in the chemicals to be used or made, or in the procedures to be followed;
- evaluate how likely it is that the hazard will actually cause harm and, if so, how serious the harm would be;
- identify appropriate control measures (e.g. fume cupboard, eye protection, protective gloves, extinguishing naked flames).

AO4 Synthesis of knowledge, understanding and skills

In addition, for A2, candidates should be able to:

- bring together knowledge, principles and concepts from different areas of chemistry, including experiment and investigation, and apply them in a particular context, expressing ideas clearly and logically and using appropriate specialist vocabulary;
- use chemical skills in contexts which bring together different areas of the subject.

The assessment objectives are weighted as follows:

Assessment Objective	AS GCE	A2	Advanced GCE
AO1	48%	25%	36.5%
AO2	32%	25%	28.5%
AO3	20%	10%	15%
AO4	0%	40%	20%

3.1 Specification Grid

The relationship between the assessment objectives and the units of assessment is shown in the specification grid below.

Unit of Assessment	Level	Percentage of Advanced GCE				Total
		AO1	AO2	AO3	AO4	
2811	AS	9	6	0	0	**15**
2812	AS	9	6	0	0	**15**
2813/01	AS	6	4	0	0	**10**
2813/02 or 2813/03		0	0	10	0	**10**
2814	A2	7	8	0	0	**15**
2815/01	A2	1	1.5	0	5	**7.5**
2815/02–06		4.5	3	0	0	**7.5**
2816/01	A2	0	0	0	10	**10**
2816/02 or 2816/03		0	0	5	5	**10**
Total		**36.5**	**28.5**	**15**	**20**	**100**

3.2 Quality of Written Communication

The requirement for all AS and Advanced GCE specifications to assess candidates' quality of written communication is met through all four assessment objectives. Questions which provide an assessment of quality of written communication are included in question papers for units 2811, 2812, 2813 (component 01), 2814, 2815 (components 01–06) and 2816 (component 01), and in the assessment of experimental and investigative skills in 2813 (components 02–03) and 2816 (components 02–03).

4 Scheme of Assessment

Candidates take three Units of Assessment including an experimental skills component, at AS, followed by three Units of Assessment, including an experimental skills component, at A2.

Units of Assessment

Unit	Level	Name of unit	Duration	Mode of Assessment	Weighting	
					AS	Advanced GCE
2811	AS	Foundation Chemistry	1 hour	Written Examination	30%	15%
2812	AS	Chains and Rings	1 hour	Written Examination	30%	15%
2813	AS	How Far, How Fast? / Experimental Skills 1				
/01		How Far, How Fast?	45 mins	Written Examination	20%	10%
/02		Coursework 1	-	Coursework	20%	10%
/03		Practical Examination 1	1 hour 30 mins	Practical Examination	20%	10%
2814	A2	Chains, Rings and Spectroscopy	1 hour 30 mins	Written Examination	-	15%
2815	A2	Trends and Patterns / Options in Chemistry				
/01		Trends and Patterns	1 hour	Written Examination	-	7.5%
/02		Biochemistry	50 mins	Written Examination	-	7.5%
/03		Environmental Chemistry	50 mins	Written Examination	-	7.5%
/04		Methods of Analysis and Detection	50 mins	Written Examination	-	7.5%
/05		Gases, Liquids and Solids	50 mins	Written Examination	-	7.5%
/06		Transition Elements	50 mins	Written Examination	-	7.5%
2816	A2	Unifying Concepts in Chemistry / Experimental Skills 2				
/01		Unifying Concepts in Chemistry	1 hour 15 mins	Written Examination		10%
/02		Coursework 2	-	Coursework		10%
/03		Practical Examination 2	1 hour 30 mins	Practical Examination		10%

In Unit 2813, candidates take **either** Components 01 and 02 **or** Components 01 and 03.

In Unit 2815, candidates take Component 01 and **one** of Components 02 – 06.

In Unit 2816, candidates take **either** Components 01 and 02 **or** Components 01 and 03.

For Units 2813, 2815 and 2816, both chosen assessment components **must** be taken in the same examination session.

If a candidate retakes Unit 2813 and/or Unit 2816 within 12 months, they have the opportunity to carry forward the mark for the coursework component.

All candidates for units 2813 and 2816 should be entered under the relevant unit code with one of the following option codes.

Option Code	Components to be taken	
A	01	Written Paper
	02	Coursework
B	01	Written Paper
	82	Coursework Mark carried forward
C	01	Written Paper
	03	Practical examination

All candidates for Unit 2815 should be entered under the relevant unit code with one of the following option codes.

Option Code	Components to be taken	
A	01	Trends and Patterns
	02	Biochemistry
B	01	Trends and Patterns
	03	Environmental Chemistry
C	01	Trends and Patterns
	04	Methods of Analysis and Detection
D	01	Trends and Patterns
	05	Gases, Liquids and Solids
E	01	Trends and Patterns
	06	Transition Elements

Rules of Combination

Candidates must take the following combination of Units of Assessment:

AS GCE	candidates take Units 2811, 2812 and 2813;
Advanced Level GCE	candidates take units 2811, 2812, 2813, 2814, 2815 and 2816.

Unit Availability

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

The availability of units is shown below.

Level	Unit	Unit title	January 2005	June 2005
AS	2811	Foundation Chemistry	✓	✓
AS	2812	Chains and Rings	✓	✓
AS	2813	How Far, How Fast?/Experimental Skills 1	✓	✓
A2	2814	Chains, Rings and Spectroscopy	✓	✓
A2	2815†	Trends and Patterns/Options in Chemistry	✓†	✓
A2	2816	Unifying Concepts in Chemistry/ Experimental Skills 2	✓	✓

† Centres should note that the following options within Unit 2815 will **no longer be available in January sessions** as follows:

- Gases, liquids and solids 2815/05 (last January session was 2004)
- Environmental Chemistry Option 2815/03 (last January session will be 2005)

Both options will continue to be available in the June sessions.

The availability shown for 2005 will be the same for subsequent years.

Sequence of Units

Units may be taken in any sequence. The normal sequence in which the units could be taken is Units 2811, 2812 and 2813 in the first year of a course of study, leading to an AS award, then Units 2814, 2815 and 2816 in the second year, together leading to the an Advanced GCE award.

Alternatively, candidates may take all units at the end of their Advanced GCE course in a ‘linear’ fashion, if desired.

Synoptic Assessment

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. Assessment Objective AO4 relates specifically to synoptic assessment.

Synoptic assessment:

- requires candidates to make and use connections between different areas of chemistry, for example, by applying knowledge from different areas of the course to a particular situation or context;
- provides opportunities for candidates to use ideas and skills which permeate chemistry, for example, the analysis and evaluation of empirical data and other information in contexts which may be new to them.

Questions are set requiring candidates to demonstrate these abilities in Unit 2815 (component 01) and Unit 2816 (component 01). Unit 2815 and Unit 2816 should normally, therefore, be taken at the end of the course, but this is no longer a requirement.

During experimental and investigative work, synoptic assessment

- allows candidates to apply knowledge and understanding of principles and concepts of chemistry in planning experimental work and in the analysis and evaluation of data.

All practical work assessed internally by Centres for the A2 unit 2816 (component 02) should draw on the range of experience that the candidate has acquired during the AS course. It is particularly important that an exercise used to evaluate planning skills should involve an element of research which goes beyond the repetition of an experiment that simply reflects the use of ideas or techniques met within the module currently being studied. Likewise an assessment involving the analysing and evaluation of evidence must require a candidate to use knowledge and understanding acquired outside the confines of a standard experiment recently practised. During the process of moderation, evidence will be sought that such breadth has been achieved.

In the A2 practical examination – unit 2816 (component 03) - practical tasks will be set using the principles set out above.

Therefore, the experimental and investigative unit 2816 (components 02 and 03) will include an element of synoptic assessment.

Certification

Candidates may enter for:

- AS GCE certification;
- AS GCE certification, bank the result, and complete the A2 assessment at a later date;
- Advanced GCE certification.

Candidates must enter for the appropriate AS and A2 units to qualify for the full Advanced GCE award.

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

Re-sits of Units

The restrictions on re-sitting units have been removed, enabling candidates to re-take units more than once. Upon making an entry for certification, the best attempt will be counted towards the final award. This change applies to all candidates, including those who have already been entered for any units or full qualifications.

Re-sits of AS GCE and Advanced GCE

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

4.1 Question Papers

All question papers will have available with them a single *Data Sheet* containing i.r. and n.m.r. spectral data (see Appendix G) backed by a Periodic Table (see Appendix H).

4.1.1 AS

Unit 2811 - Foundation Chemistry (1 hour) (60 marks)
Unit 2812 - Chains and Rings (1 hour) (60 marks)
Unit 2813, Component 01 - How Far, How Fast? (45 mins) (45 marks)

The question papers for Unit 2811, Unit 2812 and Unit 2813 (component 01) have a common format. Each question paper will comprise both structured questions and questions requiring more extended answers.

- The distribution of marks in Units 2811 and 2812 is approximately 50 marks for the structured parts and 10 marks for extended answers.
- The distribution of marks in Unit 2813 (component 01) is approximately 38 marks for the structured parts and 7 marks for extended answers.

All questions on these examination papers are compulsory. Quality of written communication is assessed within those parts of the questions requiring more extended answers.

4.1.2 A2

Unit 2814 - Chains, Rings and Spectroscopy (1 hour 30 minutes) (90 marks)

The question paper for Unit 2814 has the same format as the question papers for Units 2811 and 2812. The question paper will comprise both structured questions and questions requiring more extended answers.

- The distribution of marks is approximately 65 marks for the structured parts and 25 marks for extended answers.

All questions on this paper are compulsory. Quality of written communication is assessed within those parts of the questions requiring more extended answers.

Unit 2815, Component 01 – Trends and Patterns (1 hour) (45 marks)
Unit 2815, Components 02–06 – Options in Chemistry (50 minutes) (45 marks)

Candidates take Component **01** and **one** optional component chosen from:

- Component 02: Biochemistry
- Component 03: Environmental Chemistry
- Component 04: Methods of Analysis and Detection
- Component 05: Gases, Liquids and Solids
- Component 06: Transition Elements

The subject matter in Module 2815 (component 01): Trends and Patterns is synoptic in nature and synoptic assessment relates the content in this module with knowledge and understanding acquired elsewhere in the course. Thus, candidates have the opportunity to link together different key areas of chemistry within the context of this module.

- The question paper for Unit 2815 (component 01) comprises both structured questions and questions which require more extended answers.
- The distribution of marks is approximately 15 marks based directly on the content of Unit 2815 (component 01) and 30 marks for synoptic assessment.

The question papers for the optional Components 02–06 have the same format as the question paper for Component 01. The question papers comprise both structured questions and questions requiring more extended answers.

- The distribution of marks is approximately 35 marks for the structured parts and 10 marks for extended answers.

All questions on these papers are compulsory. Quality of written communication is assessed within those parts of the questions requiring more extended answers.

Module 2816, Component 01 - Unifying Concepts in Chemistry (1 hour 15 minutes) (60 marks)

The question paper for Component 01 contains questions covering synoptic assessment. The subject matter in Module 2816 (component 01): Unifying Concepts in Chemistry is synoptic in nature and synoptic assessment relates content in this module with knowledge and understanding acquired elsewhere in the course. Thus, candidates have the opportunity to link together different key areas of chemistry within the context of this module.

The question paper for Unit 2816 (component 01) comprises both structured questions and questions requiring more extended answers. There are 60 marks available.

All questions on this paper are compulsory. Quality of written communication is assessed within this paper.

4.2 Experimental and Investigative Skills

C3.1, C3.2, C3.3; N3.1, N3.2, N3.3; IT3.1, IT3.2, IT3.3.	**WO3.1, WO3.2, WO3.3; LP3.1, LP3.2, LP3.3; PS3.1, PS3.2, PS3.3.**

Experimental and Investigative skills may be assessed either **internally** (by coursework) or **externally** (by a combination of an externally marked task and a practical examination).

In each of Units 2813 (in AS) or 2816 (in A2) candidates must take two components - a written paper (Component 01) which assesses specification content and one of the above two assessments of experimental and investigative skills (Components 02 or 03). Both written paper and skills assessment components must be taken in the same examination session.

In Unit 2813, Components 02 and 03, marks contribute towards Assessment Objective AO3, Experiment and Investigation.

In Unit 2816, Components 02 and 03, marks contribute equally to Assessment Objectives AO3 and AO4, Synthesis of Knowledge, Understanding and Skills. There is assessment of AO4 because:

- candidates are required to use chemical knowledge and understanding from other modules of the specification in planning their experimental and investigative work, and in analysing evidence and drawing conclusions;
- in the assessment of all four experimental skills in Components 02 and 03, taken at the end of the course of study, candidates are expected to draw on their experience of such work throughout the course, and in particular on the outcome of the assessment of these skills in Components 02 and 03.

The Skills

Four experimental and investigative skills are assessed.

Skill P Planning

Candidates should:

- identify and define the nature of a question or problem using available information and knowledge of chemistry;
- retrieve and evaluate information from multiple sources, including computer databases where appropriate;
- choose effective and safe procedures, selecting appropriate reagents and apparatus, with due regard to precision of measurement, purity of reagents and products, scale of working and the control of variables.

Skill I Implementing

Candidates should:

- demonstrate the manipulative skills needed for specific laboratory techniques, showing a due regard for safety;
- carry out work in appropriate contexts, including: techniques for the preparation and purification of materials; qualitative and quantitative exercises;
- make and record sufficient relevant observations and measurements to an appropriate degree of precision using, where appropriate, data-logging and IT.

Skill A Analysing Evidence and Drawing Conclusions

Candidates should:

- present work appropriately in written, graphical or other forms, using scientific nomenclature and terminology;
- interpret experimental results including: manipulation of data; recognition of patterns and trends in a set of data or information; identification of sources of error and recognition of limitations of experimental measurements;
- draw valid conclusions by applying scientific knowledge and understanding, reporting quantitative data to an appropriate number of significant figures.

Skill E Evaluating Evidence and Procedures.

Candidates should:

- assess the reliability and precision of experimental data and the conclusions drawn from it;
- evaluate the techniques used in the experimental activity, recognising their limitations.

Internal Assessment (Coursework option)

Unit 2813, Component 02 – Coursework 1 (60 Marks)
Unit 2816, Component 02 – Coursework 2 (60 Marks)

In each of AS and A2, the time required for internal assessment is normally expected to be between five and ten hours in total, the majority of which should be supervised laboratory time.

Assessment of candidates' experimental and investigative work as detailed above is made by the teacher (as coursework) as Unit 2813 (component 02) (in AS) or Unit 2816 (component 02) (in A2), internally standardised by the Centre, and moderated externally by OCR.

Skills **P** and **A** are each marked out of 8 and Skills **I** and **E** are each marked out of 7. One mark per skill must be submitted for each candidate for AS (Component 02) and for A2 (Component 02). Hence, a mark out of 30 is initially calculated for each component. The marks are then doubled so that the final mark submitted for each component is out of 60.

In AS GCE and in A2 the skills may be assessed in the context of separate practical exercises, although more than one skill may be assessed in any one exercise. They may also be assessed all together in the context of a single 'whole investigation' in which the task is set by the teacher, or using individual investigations in which each candidate pursues his or her own choice of assignment.

The skills may be assessed at any time during the course using suitable laboratory-based practical activities related to, or part of, the content of the teaching course.

The context(s) for the assessment of the coursework for Unit 2813 (component 02) should be drawn from the content of the AS modules: 2811 Foundation Chemistry, 2812 Chains and Rings and Unit 2813 (component 01) How Far, How Fast?

The context(s) for the assessment of the coursework for Unit 2816 (component 02) should be drawn from the content of the A2 modules: 2814 Chains, Rings and Spectroscopy, 2815 Trends and Patterns/Options and 2816 (component 01) Unifying Concepts in Chemistry in which the level of demand of the related scientific knowledge and understanding is higher.

A similar set of mark descriptors is used for AS and A2 (see Appendix C). The assessment descriptors for the skills of Planning (**P**) and Analysing Evidence and Drawing Conclusions (**A**), include statements that relate specifically to synoptic assessment. These are shown in bold and should be applied only when assessing A2 work. The descriptors have been written to provide clear continuity from the assessment of Sc1 in GCSE Science. The difference in standard of AS and A2 is a product of the level of demand of the related scientific knowledge and understanding and the complexity and level of demand of the tasks set.

Notes for Guidance on Coursework assessment and submission are given in Appendix B. Mark descriptors for the experimental and investigative skills are fully detailed in Appendix C.

External Assessment (Practical Examination option)

Unit 2813, Component 03 - Practical Examination 1 (AS)
(1 hour 30 minutes) (60 Marks)
Unit 2816, Component 03 - Practical Examination 2 (A2) (1 hour 30 minutes) (60 Marks)

External assessment of Experimental and Investigative Skills addresses the same skills as those covered by the Coursework option, as listed above.

In the examination, candidates are provided with a single *Data Sheet* containing i.r. and n.m.r. spectral data (see Appendix G) and a Periodic Table (see Appendix H).

Skill P Planning

Skill P is assessed using an OCR-set task which is externally marked. Candidates are asked to plan an investigation set by OCR in the context of the modules they have studied.

Thus, for the AS Unit 2813 (component 03), the task will be set in the context of the content of the AS modules: 2811 Foundation Chemistry, 2812 Chains and Rings and Unit 2813, (component 01) How Far, How Fast?

For the A2 Unit 2816 (component 03), the task is set in the context of the content of modules: 2814 Chains, Rings and Spectroscopy, 2815 (component 01), Trends and Patterns and 2816, (component 01), Unifying Concepts in Chemistry (but not the optional components in Module 2815 (components 02–06). In addition, this task will draw upon knowledge, understanding and knowledge from the AS modules.

At a date which will be published on the examination timetable, before the date of the practical examination, candidates are given the planning task. The work must be handed in on or before the day of the practical examination, at the discretion of the Centre. The Centre is required to despatch this work to the examiner, together with the practical examination scripts, and it must therefore be kept securely until the day of the examination. Candidates may be given access, if they request it and at the discretion of the Centre, to laboratory space and facilities in order to be able to carry out preliminary work which will help in constructing their plan. It should be noted that the responsibility for health and safety during this period rests with the Centre, and the attention of teachers is drawn to the Health and Safety section in Appendix B. Access to suitable library and other resources may also be required and, while time at home or in private study will be necessary to complete the task to a high standard, sufficient work must be completed under direct supervision to allow the teacher to authenticate the work with confidence as that of the candidates concerned.

It should be recognised that the Planning Tasks contribute just 2.5% to the full Advanced GCE award for each of the AS and A2 assessments. Candidates should thus be guided to spend an appropriate amount of time on the work and it is suggested that they should be given between 7–10 days to complete it. Candidates should keep their plan to no more than 1000 words.

The Planning Task should be fastened to the front of the practical examination script. If a candidate is given guidance during the period in which the task has to be completed, this must be recorded.

The mark scheme for this task is closely based on the coursework mark descriptors for Skill P, (see Appendix C), and a copy of these descriptors should be provided to candidates to assist them in their work.

Skill I **Implementing**
Skill A **Analysing Evidence and Drawing Conclusions**
Skill E **Evaluating Evidence and Procedures**

These skills are assessed in the practical examination itself. Candidates are asked to carry out a practical experiment which may be set in the same general context as that used for the planning exercise, but will **not** be the same task. Thus, while the research work carried out for the planning task may assist candidates in their interpretation of the results of the experiment, they will **not** be asked to carry out the investigation they have planned.

Skill **I** is assessed on the conduct of the experiment and the observations and/or measurements taken, and Skills **A** and **E** are assessed on candidates' analysis and evaluation of the results of the experiment, together with other data and information given in the paper itself.

The mark scheme for the paper will be closely based on the coursework mark descriptors for these skills (see Appendix C) and teachers are recommended to draw these to the attention of candidates in their preparation for the paper.

Details of the apparatus and/or materials required for the practical examination are sent to Centres before the date of the examination. Centres should contact OCR if Instructions are not received. It is essential that confidentiality be maintained in advance of the examination date.

Further details concerning the administration and conduct of this option are given in Appendix D.

4.2.1 Differences between the Assessment of Experimental and Investigative Skills at AS and A2

The assessment descriptors given in Appendix C are used for the assessment of coursework in both AS and A2. The mark schemes for the practical examinations are also based on these descriptors.

Assessments at AS and A2 are differentiated by the complexity of the tasks set and the contexts of the underlying scientific knowledge and understanding. In A2, candidates are required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning experimental work and in the analysis of results to reach conclusions.

At AS, experimental and investigative work is likely to be qualitative or to require processing in a context that is familiar to students.

- **Planning** exercises, although novel, focus on apparatus and techniques which have previously been encountered, based on knowledge and understanding from a limited part of the AS specification.

- **Implementing** involves manipulation of simple apparatus and application of easily recognised safety procedures.

- **Analysing and concluding** involves simple data handling, reaching conclusions based on a limited part of the AS specification.
- **Evaluation** involves the recognition of the main sources of error and direct methods for improving accuracy.

At A2, assessments demand a greater level of sophistication and higher levels of skill.

- **Planning** exercises require research to provide a satisfactory solution to a problem which can be addressed in more than one way. The underlying knowledge, understanding and skills are likely to be drawn from several different parts of the AS and A2 specifications.
- **Implementing** involves a detailed risk assessment and the careful use of sophisticated techniques or apparatus to obtain results that are precise and reliable.
- **Analysing and concluding** involves sophisticated data handling and the synthesis of several strands of evidence. In developing conclusions, candidates have the opportunity to demonstrate their skills in drawing together principles and concepts from different parts of the AS and A2 specifications.
- **Evaluation** requires recognition of the key experimental limitations and other sources of error as well as an understanding of the methods that may be used to limit their effect. The evaluation is likely to draw together principles and concepts from different parts of the specification.

Detailed advice on the choice of experimental and investigative work suitable for AS and A2 and guidance on the application of the assessment descriptors to exemplar tasks, are provided in coursework guidance material published separately by OCR. Exemplar Summary Grids for some AS and A2 tasks are in Appendix B.

The exemplars referred to above also provide a guide to the complexity of tasks that are likely to be set in the practical examination. Teachers should also consult the specimen question papers that are available from OCR.

4.2.2 Assessment and Moderation

Coursework for Units 2813 (component 02) and 2816 (component 02) is marked by the teacher and internally standardised by the Centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each Centre, and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

Coursework submissions should be clearly annotated by the Centre to support the marks awarded to the candidates.

The sample of work submitted to the Moderator for moderation must show how the marks have been awarded in relation to the marking criteria.

4.2.3 Minimum Coursework Requirements

If a candidate submits no work for Unit 2813 (component 02) **or** Unit 2816 (component 02), then the candidate should be indicated as being absent from that component on the coursework mark sheets submitted to OCR. If a candidate completes any work at all for the coursework component then the work should be assessed according to the mark descriptors and marking instructions and the appropriate mark awarded, which may be 0 (zero).

4.2.4 Authentication of Coursework

As with all coursework, the teacher must be able to verify that the work submitted for assessment is the candidate's own. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the coursework marks with confidence.

4.3 Special Arrangements

For candidates who are unable to complete the full assessment or whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*. In such cases advice should be sought from OCR as early as possible during the course. Applications for special consideration in coursework components should be accompanied by Coursework Assessment Forms giving the breakdown of marks for each skill.

4.4 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 coursework, differentiation is by task and by outcome. Candidates should undertake assignments which enable them to display positive achievement.

4.5 Awarding of Grades

The AS has a weighting of 50% when used in an Advanced GCE award. An Advanced GCE award is based on the certification of the weighted AS (50%) and A2 (50%) marks.

Both AS GCE and Advanced GCE results are awarded on the scale A to E, or U (unclassified).

4.6 Grade Descriptions

The following grade descriptions indicate the level of attainment characteristic of the given grade at **Advanced GCE**. They give a general indication of the required learning outcomes at each specified grade. The descriptions should be interpreted in relation to the content outlined in the specification; they are not designed to define that content. The grade awarded will

depend in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

Grade A

Candidates recall and use chemical knowledge from the whole specification with few significant omissions and show good understanding of the principles and concepts they use. They are thoroughly conversant with the construction of chemical equations and use them quantitatively in a range of contexts. They select chemical knowledge relevant to most situations and present their ideas clearly and logically, making use of appropriate chemical terminology.

Candidates carry out calculations in a logical manner even when little guidance is given. They demonstrate good understanding of principles, applying them in familiar and new contexts, *for example, in determining the order of reaction from empirical results, in predicting the conditions which might be used in an industrial process, in using knowledge of the periodic table to predict reactions of unfamiliar elements or compounds or in predicting the reactions of organic compounds containing specific functional groups.* They bring together and use knowledge and understanding from more than one area of the specification, *for example, in suggesting a method for synthesising a particular compound or in interpreting evidence relating to the structure of a molecule or ion*.

In experimental activities, candidates independently formulate a clear and accurate plan. They use a range of manipulative techniques safely and skilfully, making and recording observations with appropriate precision. They interpret, explain and evaluate results, using appropriate chemical knowledge and terminology.

Grade C

Candidates recall chemical knowledge from many parts of the specification and show good understanding of some fundamental principles and concepts. They routinely represent most reactions, *for example, those for inorganic redox processes*, by chemical equations and use them quantitatively. They frequently select chemical knowledge relevant to a particular situation or context and present their ideas clearly and logically, making use of chemical terminology.

Candidates carry out a range of calculations, making progress in some where little guidance is given. They show knowledge of fundamental principles in applying these in some new contexts, *for example, in using information about reactions to distinguish between compounds containing different functional groups*. They bring together information from more than one area of the specification in interpreting information, *for example, in explaining trends in* K_a *for a range of organic acids*.

In experimental activities, candidates formulate a plan which may need some modification. They use a range of techniques safely, making and recording observations and measurements which are adequate for the task. They interpret and explain experimental results, relating these to chemical knowledge and understanding and, with help, evaluate how good their results are.

Grade E

Candidates recall chemical knowledge from some parts of the specification and demonstrate some understanding of fundamental principles and concepts, *for example, in relating the properties of some compounds to the bonding found in them*. They write chemical equations for straightforward, frequently-encountered chemical reactions and use simple equations quantitatively. They select discrete items of knowledge in response to structured questions and use basic chemical terminology.

Candidates carry out straightforward calculations where guidance is given. They apply knowledge and chemical principles contained within the specification to material presented in a familiar or closely related context, *for example, in using information about reactions to identify the functional groups in some organic compounds.* They use some fundamental chemical skills in contexts which bring together different areas of the subject.

In experimental activities, candidates formulate some elements of a practical approach when provided with guidance. They carry out frequently encountered practical procedures in a reasonably skilful manner, recognising the risks in familiar procedures and obtain some appropriate results. They interpret and explain some experimental results but need assistance to relate these to chemical knowledge and understanding.

5 Specification Content

These specifications are set out in the form of teaching modules.

Each teaching and learning module is assessed by its associated unit of assessment. Throughout this section the symbol is used in the margin to highlight where Key Skills development opportunities are signposted. For more information on Keys Skills coverage please refer to Appendix A.

5.1 Module 2811: Foundation Chemistry

LP3.1, LP3.2, LP3.3; PS3.1, PS3.2, PS3.3.

Preamble

In addition to the aims of the scheme, this module is intended to act as a foundation module for all of the chemistry modules. It is a bridge into AS chemistry from the study of chemistry within science courses at GCSE level.

This module is intended to provide candidates with a knowledge and understanding of chemical ideas that underpin any further study of chemistry:

- quantitative chemistry, formulae, equations and the ole;
- atomic structure;
- chemical bonding and structure;
- the Periodic Table: periodic and group properties.

The importance of these basic chemical concepts is seen as a prerequisite for all further chemistry modules and it is recommended that this module should be studied first during the course.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this module to new situations and/or to solve related problems.

Science in the National Curriculum

This expands upon the Key Stage 4: Programme of Study in Double Science:

Materials and their Properties

1. Classifying materials: atomic structure, bonding.

2. Changing materials: representing equations, quantitative chemistry.

3. Patterns of behaviour: the Periodic Table.

Recommended Prior Knowledge

Students should have achieved Grade CC or above in GCSE Science: Double Award (or equivalent in Science: Chemistry).

5.1.1 Atoms, Molecules and Stoichiometry

N3.1, N3.2.

Content

- Relative masses of atoms and molecules.
- The mole, the Avogadro constant.
- The determination of relative atomic masses, A_r, from mass spectra.
- Chemical equations.
- The calculation of empirical and molecular formulae.
- The calculation of reacting masses, mole concentrations and volumes of gases.

Assessment outcomes

(The term relative formula mass or M_r will be used for ionic compounds.)

Candidates should be able to:

(a) define the terms relative atomic, isotopic, molecular and formula masses, based on the ^{12}C scale.

(b) describe the basic principles of the mass spectrometer limited to ionisation, acceleration, deflection and detection.

- Limited to ions with single charges.
- Detailed knowledge of the mass spectrometer is not required.

(c) outline the use of mass spectrometry

- in the determination of relative isotopic masses;
- as a method for identifying elements, for example: use in Mars space probe.

(d) interpret mass spectra in terms of isotopic abundances.

(e) calculate the relative atomic mass of an element given the relative abundances of its isotopes, or its mass spectrum.

(f) define the mole in terms of the Avogadro constant; molar mass as the mass of 1 mole of a substance.

(g) define the terms empirical formula and molecular formula.

(h) calculate empirical and molecular formulae, using composition by mass.

(i) understand the terms anhydrous, hydrated and water of crystallisation.

(j) construct balanced chemical equations (full and ionic).

(k) perform calculations (including use of the Mole Concept, formulae and equations) involving

- reacting masses;
- volumes of gases;
- volumes and concentrations of solutions in simple acid-base titrations.

(l) deduce stoichiometric relationships from calculations such as those in (j).

5.1.2 Atomic Structure

C3.2, C3.3; IT3.3.

Content

- The nucleus of the atom: protons and neutrons, atomic (proton) and mass (nucleon) numbers.
- Ionisation energies.
- Electrons: electronic energy levels, atomic orbitals, electronic configuration.

Assessment outcomes

Candidates should be able to:

(a) recognise and describe protons, neutrons and electrons in terms of relative charge and relative mass.

(b) describe the distribution of mass and charge within an atom.

(c) describe the contribution of protons and neutrons to the nucleus of an atom, in terms of atomic number and mass number.

(d) deduce the numbers of protons, neutrons and electrons in

- an atom given its atomic and mass number;
- an ion given its atomic number, mass number and ionic charge.

(e) distinguish between the isotopes of an element in terms of their different masses and different numbers of neutrons.

(f) explain the terms first ionisation energy and successive ionisation energy of an element in terms of 1 mole of gaseous atoms or ions (see also 5.1.4(e), (f)).

(g) explain that ionisation energies are influenced by nuclear charge, electron shielding and the distance of the outermost electron from the nucleus.

(h) predict the number of electrons in each principal quantum shell of an element from its successive ionisation energies.

(i) describe the shapes of s- and p- orbitals.

(j) describe the numbers and relative energies of s-, p- and d- orbitals for the principal quantum numbers 1, 2, 3 and also the 4s- and 4p- orbitals.

(k) deduce the electronic configurations of

  (i) atoms, given the atomic number, up to Z=36;

  (ii) ions, given the atomic number and ionic charge, limited to s and p blocks up to Z = 36.

- *Candidates should use sub-shell notation, i.e. for oxygen:* $1s^2 2s^2 2p^4$.

5.1.3 Chemical Bonding and Structure

Content

- Ionic bonding.
- Covalent bonding and dative covalent (co-ordinate) bonding.
- The shapes of simple molecules.
- Electronegativity and bond polarity.
- Intermolecular forces.
- Metallic bonding.
- Bonding and physical properties.

Assessment outcomes

Candidates should be able to:

(a) describe ionic bonding as the electrostatic attraction between two oppositely-charged ions.

(b) describe, including the use of 'dot-and-cross' diagrams, ionic bonding, for example, as in sodium chloride and magnesium oxide.

(c) describe, in simple terms, the lattice structure of sodium chloride.

(d) describe a covalent bond as a shared pair of electrons.

(e) describe, including the use of 'dot-and-cross' diagrams,

(i) covalent bonding, for example, as in hydrogen, chlorine, oxygen, hydrogen chloride, water, ammonia, methane, carbon dioxide and ethene;

(ii) dative covalent (co-ordinate) bonding, for example, as in the ammonium ion.

(f) explain the shapes of, and bond angles in, molecules and ions by using the qualitative model of electron-pair repulsion for up to 4 electron pairs (including lone pairs), for example, as in BF_3 (trigonal), CO_2 (linear), CH_4 and NH_4^+ (tetrahedral), NH_3 (pyramidal) and H_2O (non-linear).

(g) predict the shapes of, and bond angles in, molecules and ions analogous to those specified in (f).

(h) appreciate that, between the extremes of ionic and covalent bonding, there is a gradual transition from one extreme to the other.

(i) describe electronegativity as the ability of an atom to attract the bonding electrons in a covalent bond.

(j) explain that

(i) bond polarity may arise when covalently-bonded atoms have different electronegativities;

(ii) polarisation may occur between cations of high charge density and anions of low charge density.

(k) describe intermolecular forces based on permanent dipoles, as in hydrogen chloride, and instantaneous dipoles (van der Waals' forces), as in the noble gases.

(l) describe hydrogen bonding between molecules containing –OH and –NH groups, typified by water and ammonia.

(m) describe and explain the anomalous properties of water resulting from hydrogen bonding, for example:

(i) the density of ice compared with water;

(ii) its relatively high freezing point and boiling point.

(n) describe, in simple terms, the giant covalent network structures of diamond and graphite.

(o) describe metallic bonding, present in a giant metallic lattice structure, as the attraction of a lattice of positive ions to a sea of mobile electrons.

(p) describe, interpret and/or predict physical properties, for example: melting and boiling points, electrical conductivity and solubility in terms of

(i) the types, motion and arrangement of particles (atoms, molecules and ions) and the forces between them;

(ii) the different types of bonding (ionic bonding, covalent bonding, hydrogen bonding, other intermolecular interactions, metallic bonding).

(q) deduce the type of bonding present from given information.

5.1.4 The Periodic Table: Introduction

C3.2, C3.3; IT3.1, IT3.2, IT3.3.	WO3.1, WO3.2, WO3.3

Content

- The structure of the Periodic Table in terms of groups and periods.
- Periodicity of physical properties of elements.

Assessment outcomes

Candidates should be able to:

(a) describe the Periodic Table in terms of the arrangement of elements

   (i) by increasing atomic number;

   (ii) in periods showing repeating trends in physical and chemical properties;

   (iii) in groups having similar physical and chemical properties.

(b) describe, for the elements of Period 3, the variation in electronic configurations, atomic radii, electrical conductivities, melting points and boiling points.

(c) explain variations in (b) in terms of the structure and bonding of the elements.

(d) classify the elements into s-, p- and d- blocks.

(e) interpret successive ionisation energies of an element in terms of its position in the Periodic Table (see also 5.1.2(f)–(h)).

(f) describe and explain the variation of the first ionisation energies of elements shown by

   (i) a decrease down a group in terms of increasing atomic radius and electron shielding;

   (ii) a general increase across a period, in terms of increasing nuclear charge;

   (iii) the periodic decrease between Groups 2 and 3, in terms of the higher energy level of the p sub-shell compared with that of the s sub-shell;

(g) the periodic decrease between Groups 5 and 6, in terms of an increase in energy from mutual repulsion of paired electrons in a Group 6 p-orbital.

- Periodic trends in ionisation energies will consider s and p blocks only.

(h) interpret data on electronic configurations, atomic radii, electrical conductivities, first ionisation energies, melting points and boiling points to demonstrate periodicity.

5.1.5 The Periodic Table: The Group 2 elements and their compounds

IT3.1 | **WO3.1, WO3.2, WO3.3**

Content

- Similarities and trends in the properties of the Group 2 metals magnesium to barium and their compounds.
- Oxidation number.
- Redox processes as electron transfer and changes in oxidation number.
- The relative reactivity of the Group 2 elements.
- Trends in some reactions of Group 2 compounds.

Assessment outcomes

Candidates should be able to:

(a) describe and explain the trends in electronic configurations, atomic radii and ionisation energies of the Group 2 elements, Mg to Ba.

(b) use the rules for assigning oxidation state (number) with elements, compounds and ions.

(c) describe oxidation and reduction in terms of

  (i) electron transfer;
  (ii) changes in oxidation state.

(d) describe the redox reactions of the elements (Mg to Ba) with oxygen and with water and explain the trend in reactivity in terms of ionisation energies.

(e) describe the reactions of Mg, MgO and $MgCO_3$ with hydrochloric acid (see also 5.3.3(f), (g)).

(f) describe the thermal decomposition of $CaCO_3$ (limestone) to form CaO (lime) and the subsequent formation of $Ca(OH)_2$ (slaked lime) with water.

(g) describe lime water as an aqueous solution of $Ca(OH)_2$ and state its approximate pH.

(h) describe the reaction of lime water

  (i) with carbon dioxide forming $CaCO_3$(s);
  (ii) with excess carbon dioxide, forming $Ca(HCO_3)_2$(aq), as in hard water.

(i) interpret and make predictions from the chemical and physical properties of the Group 2 elements and their compounds.

(j) show awareness of the importance and use of Group 2 elements and their compounds, with appropriate chemical explanations, for example: the use of $Ca(OH)_2$ in agriculture to neutralise acid soils; the use of $Mg(OH)_2$ in some indigestion tablets as an antacid.

5.1.6 The Periodic Table: The Group 7 elements and their compounds

IT3.1.	WO3.1, WO3.2, WO3.3.

Content

- Similarities and trends in the properties of the Group 7 non-metals chlorine to iodine.
- Characteristic physical properties.
- The relative reactivity of the elements.
- Characteristic reactions of halide ions.
- The reaction of chlorine with water and with sodium hydroxide .

Assessment outcomes

Candidates should be able to:

(a) explain the trend in the volatilities of chlorine, bromine and iodine in terms of van der Waals' forces.

(b) describe the relative reactivity of the elements Cl_2, Br_2 and I_2 in displacement reactions.

(c) explain the trend in (b) in terms of oxidising power, i.e. the relative ease with which an electron can be captured.

(d) describe the characteristic reactions of the ions Cl^-, Br^- and I^- with aqueous silver ions followed by aqueous ammonia (knowledge of complex formulae not required).

(e) describe and interpret, in terms of changes in oxidation state,

(i) the reaction of chlorine with water, as used in water purification to prevent life-threatening diseases;

(ii) the reaction of chlorine with cold, dilute aqueous sodium hydroxide, as used to form bleach.

5.2 Module 2812: Chains and Rings

LP3.1, LP3.2, LP3.3; PS3.1, PS3.2, PS3.3.

Preamble

In addition to the aims of the scheme, this module is intended to:

- provide a foundation for the study of organic chemistry;
- illustrate and raise issues regarding the applications of organic chemistry to everyday life.

The material within this module builds upon the chemical concepts in Module 2811: Foundation Chemistry.

This module is intended to provide candidates with a knowledge and understanding of chemical ideas that underpin the study of organic chemistry:

- nomenclature and formula representation, functional groups, organic reactions and isomerism;
- aliphatic hydrocarbons;
- organic synthesis using alcohols and halogenoalkanes.

Organic redox reactions

- In equations for organic redox reactions, the symbols [O] and [H] are acceptable.

Reaction mechanisms

- When describing reaction mechanisms, candidates should use diagrams wherever possible showing clearly the movement of an electron pair with 'curly arrows'. Any relevant lone pairs and dipoles should be included. For free-radical mechanisms, 'half curly arrows' are **not** required and it is sufficient to use equations in which the free radical is clearly identified with a single 'dot'.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this module to new situations and/or to solve related problems.

Science in the National Curriculum

This module expands upon the Key Stage 4: Programme of Study in Double Science:

Materials and their Properties

- 2. Changing materials: useful products from oil, quantitative chemistry.

Recommended Prior Knowledge

Candidates should have studied Module 2811: Foundation Chemistry.

5.2.1 Basic Concepts

N3.2

Content

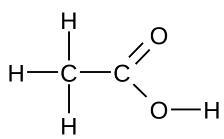
- Representing formulae of organic compounds.
- Functional groups and the naming of organic compounds.
- Structural and *cis-trans* isomerism.
- Percentage yields.

Assessment outcomes

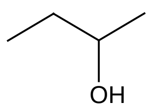
Candidates should be able to:

(a) interpret, and use the terms: nomenclature, molecular formula, general formula, structural formula, displayed formula, skeletal formula, homologous series and functional group.

- Nomenclature should follow IUPAC rules for naming of organic compounds, for example: 3-methylhexane for $CH_3CH_2CHCH_3CH_2CH_2CH_3$.
- A general formula is used to represent any member of a homologous series, for example: C_nH_{2n+2} for an alkane.
- A structural formula is accepted as the minimal detail, using conventional groups, for an unambiguous structure, for example: $CH_3CH_2CH_2CH_3$ for butane, not C_4H_{10} (the molecular formula).
- A displayed formula should show both the relative placing of atoms and the number of bonds between them. The displayed formula for ethanoic acid is shown below.

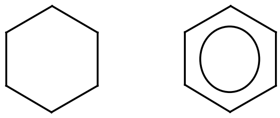


- A skeletal formula is used to show a simplified organic formula by removing hydrogen atoms from alkyl chains, leaving just a carbon skeleton and associated functional groups. The skeletal formula for butan-2-ol is shown below.



- In structural formulae, the carboxyl group will be represented as COOH and the ester group as COOR.

- The symbols below for cyclohexane and benzene are acceptable.



(b) describe and explain

(i) structural isomerism in compounds with the same molecular formula but different structural formulae;

(ii) *cis-trans* isomerism in alkenes, in terms of restricted rotation about a double bond.

(c) determine the possible structural and/or *cis-trans* isomers of an organic molecule of given molecular formula.

(d) perform calculations, involving use of the Mole Concept and reacting quantities, to determine the percentage yield of a reaction (see also 5.1.1(j) ,(k)).

5.2.2 Hydrocarbons: Alkanes

Content

- Physical properties of alkanes.
- Chemical reactions of alkanes.

[For simplicity, this module refers to substitution reactions of methane. It is more convenient to use a liquid alkane in practical work. For example, cyclohexane can be used to demonstrate the reactions specified below.]

See also 5.2.3 Hydrocarbons: Fuels.

Assessment outcomes

Candidates should be able to:

(a) state that alkanes are saturated hydrocarbons.

(b) explain, in terms of van der Waals' forces, the variations in boiling points of alkanes with different carbon chain length and branching.

(c) describe the lack of reactivity of alkanes, in terms of the non-polarity of C–H bonds.

(d) describe the chemistry of alkanes, typified by the following reactions of methane:

(i) combustion (see also, 5.2.3(c));

(ii) substitution by chlorine and by bromine to form halogenoalkanes.

(e) describe how homolytic fission leads to the mechanism of free-radical substitution in alkanes, typified by methane and chlorine, in terms of initiation, propagation and termination reactions.

- Candidates are not required to use 'half curly arrows' in this mechanism. Equations should clearly show which species are free radicals using a single 'dot' to represent the unpaired electron.

5.2.3 *Hydrocarbons: Fuels*

C3.1a, C3.1b, C3.2, C3.3; IT3.1, IT3.2, IT3.3.	**WO3.1, WO3.2, WO3.3.**

Content

- Crude oil as a source of organic chemicals.
- Cracking, isomerisation and reforming.
- Hydrocarbons as fuels.

Assessment outcomes

Candidates should be able to:

(a) explain the use of crude oil as a source of hydrocarbons (separated by fractional distillation) which can be used directly as fuels or for processing into petrochemicals.

(b) describe the use of

(i) cracking to obtain more useful alkanes and alkenes;

(ii) isomerisation to obtain branched alkanes;

(iii) reforming to obtain cycloalkanes and arenes.

(c) describe and explain how the combustion reactions of alkanes (see also, 5.2.2(d)) lead to their use as fuels in industry, in the home and in transport.

(d) state that branched alkanes, cycloalkanes and arenes are used in petrol to promote efficient combustion (see also, 5.2.5(g), alcohols as fuels; 5.3.2(i)–(k), catalytic converters).

(e) outline

(i) the value to society of fossil fuels in relation to needs for energy and raw materials;

(ii) the non-renewable nature of fossil fuel reserves;

(iii) the need to develop renewable fuels, for example biofuels, which do not further deplete finite energy resources.

5.2.4 *Hydrocarbons: Alkenes*

Content

- Reactions of alkenes.
- Polymers.
- Industrial importance of alkenes.

[For simplicity, this module refers to reactions of ethene and propene. It is more convenient to use a liquid alkene in practical work. For example, cyclohexene can be used to demonstrate the reactions specified below.]

See also 5.2.3 Hydrocarbons: Fuels.

Assessment outcomes

Candidates should be able to:

(a) state that alkenes are unsaturated hydrocarbons.

(b) state and explain the bonding in alkenes in terms of the overlap of adjacent p-orbitals to form a π-bond.

- *Treatment in terms of hybridisation is not required.*

(c) state and explain the shape of ethene and other related molecules (see also 5.1.3(f)).

(d) describe the chemistry of alkenes, for example, by the addition reactions of ethene and propene with:

(i) hydrogen in the presence of a suitable catalyst, for example Ni, to form alkanes;

(ii) halogens to form dihalogenoalkanes, including the use of bromine to detect the presence of a double C=C bond as a test for unsaturation;

(iii) hydrogen halides to form halogenoalkanes;

(iv) steam in the presence of an acid catalyst, for example H_3PO_4, to form alcohols (see also 5.2.5(b)).

- *Candidates are expected to realise that addition to an unsymmetrical alkene such as propene may result in two isomeric products. However candidates will **not** be required to predict the relative proportions of these isomers, **nor** to apply or explain Markovnikoff's rule.*

(e) define the term electrophile as an electron pair acceptor.

(f) describe how heterolytic fission leads to the mechanism of electrophilic addition in alkenes, typified by bromine and ethene to form 1,2-dibromoethane.

- Candidates should show 'curly arrows' in this mechanism and include any relevant lone pairs and dipoles.

(g) describe the addition polymerisation of alkenes, for example: ethene and propene.

(h) deduce the repeat unit of an addition polymer obtained from a given monomer.

(i) identify, in a given section of an addition polymer, the monomer from which it was obtained.

(j) outline the use of alkenes in the industrial production of organic compounds, typified by:

   (i) the manufacture of margarine by catalytic hydrogenation of unsaturated vegetable oils using hydrogen and a nickel catalyst;

   (ii) the formation of a range of polymers using unsaturated monomer units based on the ethene molecule, for example, CH_2CHCl, CF_2CF_2 (see also, 5.2.6(f)).

(k) outline the difficulties in disposing of polymers, for example: non-biodegradability or toxic combustion products.

(l) outline, for waste polymers, the movement towards

   (i) recycling,

   (ii) combustion for energy production,

   (iii) use as a feedstock for cracking in the production of useful organic compounds.

(m) outline the role of chemists in minimising damage to the environment by, for example, the removal of toxic waste products (such as HCl) during disposal by combustion of halogenated plastics (such as pvc) (see also, 5.2.6(f)).

5.2.5 Alcohols

Content

- Preparation of ethanol.
- Properties of alcohols.
- Reactions of alcohols.
- Infra-red absorption of O–H and C=O bonds.

Assessment outcomes

Candidates should be able to:

(a) explain, in terms of hydrogen bonding, the water solubility and the relatively low volatility of alcohols.

(b) describe and explain the industrial production of ethanol by

- (i) fermentation from sugars, for example glucose;
- (ii) the reaction of steam with ethene in the presence of H_3PO_4 (see also 5.2.4(d)).

(c) describe the classification of alcohols into primary, secondary and tertiary alcohols.

(d) describe the chemistry of alcohols, typified by the following reactions of ethanol:

- (i) combustion;
- (ii) substitution using HBr (e.g. $NaBr/H_2SO_4$) to form a bromoalkane;
- (iii) reaction with sodium to form a sodium alkoxide and hydrogen;
- (iv) dehydration with hot, concentrated sulphuric acid or hot pumice/Al_2O_3 to form an alkene;
- (v) esterification with carboxylic acids in the presence of an acid catalyst.

(e) describe the action of $Cr_2O_7^{2-}/H^+$ (e.g. $K_2Cr_2O_7/H_2SO_4$) on alcohols, typified by

- (i) the oxidation of primary alcohols to form aldehydes and carboxylic acids, and the control of the oxidation product using different reaction conditions;
- (ii) the oxidation of secondary alcohols to form ketones;
- (iii) the resistance to oxidation of tertiary alcohols.

- *In equations for organic oxidation reactions, the symbol [O] is acceptable.*

(f) identify, using an infra-red spectrum,

- (i) an alcohol from absorption of the O–H bond;
- (ii) a carbonyl compound from absorption of the C=O bond;
- (iii) a carboxylic acid from absorption of the C=O bond and broad absorption of the O–H bond.

- *[In examinations, infra-red absorption data will be provided on the Data Sheet (see page 116).]*
- *Candidates will only be required to use an infra-red spectrum as an analytical tool to show the presence of O–H and C=O bonds in alcohols and their oxidation products.* ***No*** *background theory will be tested. Infra-red spectroscopy is built upon in Section 5.4.7(a) of the A2 module: Chains, Rings and Spectroscopy.*

(g) outline the use of:

- (i) ethanol in alcoholic drinks, as a solvent in the form of methylated spirits, and as a fuel, particularly as a petrol substitute in countries with limited oil reserves;
- (ii) methanol as a petrol additive to improve combustion and its increasing importance as a feedstock in the production of organic chemicals. (See also, 5.2.3(d), petrol as a fuel).

5.2.6 Halogenoalkanes

C3.1a, C3.1b, C3.2, C3.3; IT3.1, IT3.2, IT3.3.	**WO3.1, WO3.2, WO3.3.**

Content

- Reactions of halogenoalkanes.
- Relative strength of carbon–halogen bonds.
- Uses of halogenoalkanes and synthetic importance.

Assessment outcomes

Candidates should be able to:

(a) describe substitution reactions of halogenoalkanes, typified by the following reactions of bromoethane:

(i) hydrolysis with hot aqueous alkali to form alcohols;

(ii) reaction with excess ethanolic ammonia to form primary amines.

(b) define the term nucleophile as an electron pair donor.

(c) describe the mechanism of nucleophilic substitution in the hydrolysis of primary halogenoalkanes.

- *Candidates should show 'curly arrows' in this mechanism and include any relevant lone pairs and dipoles.*

(d) explain the rates of hydrolysis of primary halogenoalkanes in terms of the bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I). (See also 5.3.1(f).)

- *aqueous silver nitrate in ethanol can be used to compare these rates.*

(e) describe the elimination of hydrogen bromide from halogenoalkanes, typified by bromoethane, with hot ethanolic sodium hydroxide.

(f) outline the uses of

(i) fluoroalkanes and fluorohalogenoalkanes, for example: chlorofluorocarbons, CFCs (refrigerants, propellants, blowing polystyrene, dry cleaning, degreasing agents);

(ii) chloroethene and tetrafluroethene to produce the plastics pvc and ptfe. (See also 5.2.4(g)–(m)) and 5.4.6(a).)

(iii) (iii) halogenoalkanes as synthetic intermediates in chemistry.

(g) outline the role of chemists in minimising damage to the environment by, for example, the development of alternatives to CFCs so that depletion of the ozone layer (see also 5.3.2 (i), (l))can be reversed. *The equations will not be tested in Unit 2812.)*

5.3 Module 2813, Component 01: How Far, How Fast?

LP3.1, LP3.2, LP3.3

Preamble

In addition to the aims of the scheme, this component is intended to act as a foundation for the study of physical chemistry. The material within this module builds upon the chemical concepts in Module 2811: Foundation Chemistry.

This component is intended to provide candidates with a knowledge and understanding of chemical reasoning that underpins the study of physical chemistry:

- enthalpy changes, their uses and calculations including enthalpy cycles;
- the ways in which a change in conditions (temperature, concentration or pressure) can affect the rate of a chemical reaction, including activation energy, the Boltzmann distribution and catalysis;
- the dynamic nature of chemical equilibrium, the tendency of reactions to move towards equilibrium and the influence of conditions upon it;
- how an understanding of enthalpy changes, rates and equilibria can help to improve industrial processes.

This component provides a qualitative coverage of reaction rates and chemical equilibria.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems.

Science in the National Curriculum

This module expands upon the Key Stage 4 Programme of Study in Double Science:

Materials and their Properties

- 2. Changing materials: useful products from the air.
- 3. Patterns in behaviour: rates of reaction, reactions involving enzymes, reversible reactions, energy transfer in reactions.

Recommended Prior Knowledge

Candidates should have studied Module 2811: Foundation Chemistry.

5.3.1 Enthalpy changes

N3.1, N3.2; IT3.2.

Content

- Enthalpy changes: ΔH of reaction, formation, combustion.
- Bond enthalpy.
- Hess's Law and enthalpy cycles.

Assessment outcomes

Candidates should be able to:

(a) explain that some chemical reactions are accompanied by enthalpy changes, principally in the form of heat energy; the enthalpy changes can be exothermic (ΔH, negative) or endothermic (ΔH, positive).

(b) recognise the importance of oxidation as an exothermic process, for example, in the combustion of fuels and the oxidation of carbohydrates such as glucose in respiration.

(c) recognise that endothermic processes require an input of heat energy, for example, the thermal decomposition of calcium carbonate (see also 5.1.5(f)) and in photosynthesis.

(d) construct a simple enthalpy profile diagram for a reaction to show the difference in the enthalpy of the reactants compared with that of the products.

(e) explain chemical reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds.

(f) explain and use the terms:

(i) *enthalpy change of reaction* and *standard conditions*, with particular reference to formation and combustion;

- *standard conditions can be considered as 100 kPa and a stated temperature, e.g. 298 K.*

(ii) average bond enthalpy (ΔH positive; bond breaking of 1 mole of bonds).

(g) calculate enthalpy changes from appropriate experimental results directly, including the use of the relationship: energy change = $mc\Delta T$.

(h) use Hess's Law to construct enthalpy cycles and carry out calculations using such cycles and relevant enthalpy terms, with particular reference to enthalpy changes that cannot be found by direct experiment, for example:

(i) an enthalpy change of formation from enthalpy changes of combustion;

(ii) an enthalpy change of reaction from enthalpy changes of formation;

(iii) an enthalpy change of reaction from average bond enthalpies.

5.3.2 Reaction rates

C3.1a, C3.1b, C3.2, C3.3; IT3.1, IT3.2, IT3.3.	**WO3.1, WO3.2, WO3.3.**

Content

- Simple collision theory.
- Effect of temperature and concentration on reaction rate.
- Activation energy.
- Use of catalysts.

Assessment outcomes

Candidates should be able to:

(a) describe qualitatively, in terms of collision theory, the effect of concentration changes on the rate of a reaction.

(b) explain why an increase in the pressure of a gas, increasing its concentration, may increase the rate of a reaction involving gases.

(c) explain qualitatively, using the Boltzmann distribution and enthalpy profile diagrams, what is meant by the term *activation energy*.

(d) describe qualitatively, using the Boltzmann distribution, the effect of temperature changes on the rate of a reaction.

(e) explain what is meant by a *catalyst*.

(f) describe catalysts as having great economic importance, for example: in fertiliser production (see also 5.3.3(c), (d)), petroleum processing (see also 5.2.3(b)) and margarine production (see also 5.2.4(j)).

(g) explain that, in the presence of a catalyst, a reaction proceeds via a different route, i.e. one of lower activation energy, giving rise to an increased reaction rate.

(h) interpret the catalytic behaviour in (g) in terms of the Boltzmann distribution and enthalpy profile diagrams.

(i) state what is meant by

  (i) homogeneous catalysis, for example: H^+(aq) in esterification (see also 5.2.5(d)) and chlorine free radicals with ozone (see also (l) below);

  (ii) heterogeneous catalysis, for example: Fe in the Haber process (see also 5.3.3(c)) and Rh/Pt/Pd in catalytic converters (see also (k) below).

(j) for carbon monoxide, oxides of nitrogen and unburnt hydrocarbons:

(i) describe their presence and/or formation from the internal combustion engine;

(ii) state their environmental consequences in terms of low-level ozone and photochemical smog (equations not required).

(k) outline, as an example of heterogeneous catalysis, how a catalytic converter decreases carbon monoxide and nitrogen monoxide emissions from internal combustion engines (see also 5.3.2(i); 5.7.1(h)) by:

(i) adsorption of carbon monoxide and nitrogen monoxide to the catalyst surface;

(ii) chemical reaction;

(iii) subsequent desorption of carbon dioxide and nitrogen from the catalyst surface.

- *Candidates should understand that bonding to the catalyst surface must be weak enough for adsorption/desorption to take place but strong enough to weaken bonds and allow reaction to take place.*

(l) outline, as an example of homogeneous catalysis, how gaseous chlorine free radicals, formed by the action of ultraviolet radiation on CFCs, catalyse the breakdown of the gaseous ozone layer into oxygen (see also 5.2.2(g); 5.2.6(g); 5.7.1(e)) by a reaction route via ClO radicals (as the intermediate), for example:

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O \longrightarrow Cl + O_2$$

- *No equations will be required beyond a simple representation of this catalysis such as that shown in the equations above.*
- *Note that O is continuously being formed in the stratosphere by the action of ultraviolet radiation on O_2 and O_3. This will not be tested in this unit 2813, (component 01).*

5.3.3 Chemical Equilibrium

PS3.1, PS3.2, PS3.3.

Content

- Chemical equilibria: reversible reactions, dynamic equilibria.
- Factors affecting chemical equilibria in terms of le Chatelier’s principle.
- Industrial processes: the Haber process.
- Acid-base equilibria: strong and weak acids.

Assessment outcomes

Candidates should be able to:

(a) explain the features of a *dynamic equilibrium*.

- *Reference should be made to the need for a closed system, the equal rates of the forward and reverse reactions and the constancy of macroscopic properties.*

(b) state le Chatelier's principle and apply it to deduce qualitatively (from appropriate information) the effect of a change in temperature, concentration or pressure, on a homogeneous system in equilibrium.

(c) describe and explain the conditions used in the Haber process for the formation of ammonia, as an example of the importance of a compromise between chemical equilibrium and reaction rate in the chemical industry.

(d) outline the importance of ammonia and nitrogen compounds derived from ammonia, for example, fertilisers, polyamides and explosives.

(e) describe an acid as a species that can donate a proton.

(f) describe the reactions of an acid, typified by hydrochloric acid with metals, carbonates, bases and alkalis (see also 5.1.5(e)).

(g) interpret the reactions in (f) using ionic equations to emphasise the role of $H^+(aq)$.

(h) explain qualitatively, in terms of dissociation, the differences between strong and weak acids.

(i) describe ammonia as a base, in terms of its reaction with an acid (e.g. sulphuric acid) to form ammonium salts, used in fertilisers.

5.4 Module 2814: Chains, Rings and Spectroscopy

	LP3.1, LP3.2, LP3.3; PS3.1, PS3.2, PS3.3

Preamble

In addition to the aims of the scheme, this module builds upon the chemical concepts that have been developed during AS Chemistry.

This module is intended to provide candidates with a deeper knowledge and understanding of how organic chemistry shapes the natural world and how organic chemicals have provided mankind with many important materials.

The main areas of organic chemistry studied include

- aromatic compounds;
- carboxylic acids and esters;
- organic nitrogen compounds: amines and amino acids;
- synthetic organic chemistry and the importance of chirality in pharmaceuticals;
- polymerisation: addition polymers and condensation polymers;
- the importance of modern analytical techniques in organic analysis.

This module develops knowledge and understanding of organic chemistry by extending the study of the functional groups first introduced in AS Chemistry. The importance of organic chemistry is emphasised using examples from pharmaceuticals, synthesis and polymers. This module includes the application of some of the important instrumentation techniques used in organic and forensic analysis.

Organic redox reactions

- In equations for organic redox reactions, the symbols [O] and [H] are acceptable.

Reaction mechanisms

- When describing reaction mechanisms, candidates should use diagrams wherever possible showing clearly the movement of an electron pair with ‘curly arrows’. Any relevant lone pairs and dipoles should be included. For free-radical mechanisms, ‘half curly arrows’ are **not** required and it is sufficient to use equations in which the free radical is clearly identified with a ‘dot’.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this module to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should have studied AS Chemistry.

The subject content in this component builds upon the following sections from AS Chemistry:

Module 2811: Foundation Chemistry

5.1.1 Atoms, Molecules and Stoichiometry (f) – (k)

5.1.3 Chemical Structure and Bonding (e) – (g), (i), ((j)(i)), (k), (l), (p), (q)

Module 2812: Chains and Rings

5.2.1 Basic Concepts

5.2.2 Hydrocarbons: Alkanes

5.2.3 Hydrocarbons: Fuels

5.2.4 Hydrocarbons: Alkenes

5.2.5 Alcohols

5.2.6 Halgenoalkanes

This module develops understanding and knowledge of organic chemistry by extending the study of functional groups first introduced in AS Chemistry and introducing the use of different spectroscopic techniques in organic chemistry.

*An understanding of general concepts from AS could be tested but candidates will **not** be expected to recall reagents and conditions for any specific reaction from the AS specification.*

5.4.1 Arenes

Content

- Review of appropriate material from AS Chemistry – Module B: Chains and Rings, 5.2.2 Hydrocarbons: Alkanes; 5.2.3 Hydrocarbons: Fuels; 5.2.4 Hydrocarbons: Alkenes.
- Structure of arenes, typified by benzene.
- Nitration, halogenation and alkylation of arenes.
- Phenols.

[For simplicity, the module refers to reactions of benzene and phenol. However, because of the toxic nature of benzene and the caustic character of phenol, safer alternatives should be used in any practical work. For example, the nitration of arenes can be performed experimentally using methyl benzoate instead of benzene. For reactions involving phenol, methyl 4-hydroxybenzoate is a far safer alternative.]

Assessment outcomes

Candidates should be able to:

(a) show understanding of the concept of delocalisation of electrons as used in a model of bonding in benzene.

(b) describe the electrophilic substitution of arenes with:

(i) concentrated nitric acid in the presence of concentrated sulphuric acid;

(ii) a halogen in the presence of a halogen carrier;

(iii) a halogenoalkane such as chloromethane in the presence of a halogen carrier (Friedel-Crafts reaction).

- Halogen carriers include iron, iron halides and aluminium halides.

(c) describe the mechanism of electrophilic substitution in arenes, using the mononitration of benzene as an example.

- Candidates should show ‘curly arrows’ in this mechanism and include an equation to show formation of the nitronium ion.

(d) understand that reactions of arenes, such as those in (b), are used by industry during the synthesis of commercially important materials, for example: explosives, pharmaceuticals and dyes (from nitration) – see also 5.4.4(d), and polymers such as polystyrene (from alkylation) – see also 5.4.6(a).

- Details of the reaction schemes are not required.

(f) explain the relative resistance to bromination of benzene compared with cyclohexene (see also 5.2.4(d)) in terms of delocalisation of the benzene ring.

(g) describe the reactions of phenol

(i) with bases and with sodium to form salts;

(ii) with bromine to form 2,4,6-tribromophenol.

(g) explain the relative ease of bromination of phenol compared with benzene, in terms of activation of the benzene ring.

(h) state the uses of phenols in antiseptics and disinfectants.

5.4.2 Carbonyl compounds

Content

- Reactions of carbonyl compounds.
- Characteristic tests for carbonyl compounds.

Assessment outcomes

Candidates should be able to:

(a) describe the reduction of carbonyl compounds using $NaBH_4$ to form alcohols.

- *In equations, for organic reduction reactions, the symbol [H] is acceptable.*

(b) describe the mechanism for nucleophilic addition reactions of hydrogen cyanide (in the presence of potassium cyanide) with aldehydes and ketones (see also 5.4.5(c)).

- *Because of the toxic nature of hydrogen cyanide and cyanide ions, this reaction should not be performed. The reaction is included solely to illustrate nucleophilic addition.*
- *Candidates should show 'curly arrows', relevant lone pairs and dipoles in this mechanism.*

(c) describe the use of 2,4-dinitrophenylhydrazine

(i) to detect the presence of a carbonyl group in an organic compound;

(ii) to identify a carbonyl compound from the melting point of the derivative.

- *The equation for this reaction is **not** required.*

(d) describe the use of Tollens' reagent (ammoniacal silver nitrate)

(iii) to detect the presence of an aldehyde group;

(iv) to distinguish between aldehydes and ketones, explained in terms of the oxidation of aldehydes to carboxylic acids with reduction of silver ions to silver.

5.4.3 Carboxylic Acids and Esters

N3.2

Content

- Review of appropriate material from AS Chemistry – Module 2812: Chains and Rings, 5.2.5 Alcohols.
- Carboxylic acids; formation of salts.
- Esterification of carboxylic acids.
- Hydrolysis of esters.
- Formation of acyl chlorides from carboxylic acids

Assessment outcomes

Candidates should be able to:

(a) describe carboxylic acids as proton donors.

(b) describe the reactions of carboxylic acids, typified by ethanoic acid:

  (i) with aqueous alkalis to form carboxylates (salts);

  (ii) with alcohols, in the presence of an acid catalyst, to form esters (see also 5.2.5(d)).

(c) state the uses of esters in perfumes and flavourings.

(d) describe the acid and base hydrolysis of esters to form carboxylic acids and carboxylates respectively.

(e) describe the formation of acyl chlorides by reaction of **carboxylic acids** with PCl_5 or $SOCl_2$ and the use of acyl chlorides in organic synthesis (see 5.4.5(f)).

5.4.4 Nitrogen compounds

Content

- Properties of primary amines.
- Amino acids; peptide formation.
- Hydrolysis of proteins.

Assessment outcomes

Candidates should be able to:

(a) describe the preparation of amines, for example,

  (i) describe the formation of phenylamine by reduction of nitrobenzene using tin and concentrated hydrochloric acid,
  (ii) the formation of primary amines by reduction of nitriles using $LiAlH_4$ in a non-aqueous solvent such as dry ether,
  (iii) the formation of amines by substitution of halogenoalkanes with excess ethanolic ammonia (see also 5.2.6(a(ii))).

(b) describe the reactions of primary amines with acids to form salts.

(c) explain the basicity of primary amines and the relative basicities of ethylamine and phenylamine in terms of the inductive effect and the influence of the delocalised electrons in the benzene ring.

(d) describe the synthesis of an azo-dye by reaction of phenylamine with nitrous acid (HNO_2/HCl, <10°C) with the formation of a diazonium salt, followed by coupling with phenols under alkaline conditions; the use of such reactions in the formation of dyestuffs.

(e) state the general formula for an α-amino acid as $RCH(NH_2)COOH$.

(f) describe the acid-base properties of α-amino acids and the formation of zwitterions.

(g) explain the formation of a peptide linkage between α-amino acids leading to the idea that polypeptides and proteins are condensation polymers (see also Section 5.4.6(b)).

(h) describe the acid hydrolysis, for example with hot HCl(aq), of proteins and peptides to form α-amino acids.

5.4.5 Stereoisomerism and organic synthesis

C3.2, C3.3; IT3.1.	WO3.1, WO3.2, WO3.3.

Content

- Stereoisomerism.
- Organic synthesis of 2-hydroxypropanoic acid (lactic acid).
- Chirality and its importance in pharmaceuticals.

Assessment outcomes

Candidates should be able to:

(a) interpret and use the term stereoisomerism in terms of *cis-trans* and optical isomerism.

(b) explain the term chiral centre and identify any chiral centres in a molecule of given structural formula (for example, amino acids (see also 5.4.4(e)) and 2-hydroxypropanoic acid (lactic acid)).

(c) describe the two-stage synthesis of 2-hydroxypropanoic acid (lactic acid) by the addition of hydrogen cyanide to ethanal (see also 5.4.2(b)) followed by acid hydrolysis; explain the use of such reactions in synthesis by providing a route for lengthening a carbon chain.

- Because of the toxic nature of hydrogen cyanide and cyanide ions, this synthesis should **not** be performed.

(d) understand that chiral molecules prepared synthetically in the laboratory may contain a mixture of optical isomers, whereas molecules of the same compound produced naturally in living systems will often be present as one optical isomer only (for example: L-amino acids).

(e) understand that the synthesis of pharmaceuticals often requires the production of chiral drugs containing a single optical isomer, resulting in smaller doses (only half the drug is needed), reduced side effects and improved pharmacological activity.

- Candidates *will **not** be expected to memorise the structures of any pharmaceuticals but they will be expected to identify the presence of chiral centres in a given structure.*

(f) describe the use of acyl chlorides in organic synthesis, for example, the preparation of esters, carboxylic acids, and N-substituted amides.

5.4.6 Polymerisation

Content

- Review of appropriate material from AS Chemistry – Module 2812: Chains and Rings, 5.2.4 Hydrocarbons: Alkenes.
- Addition polymerisation.
- Condensation polymerisation.
- Uses of polymers.

Assessment outcomes

Candidates should be able to:

(a) describe the characteristics of addition polymerisation, typified by poly(phenylethene) (see also 5.2.4(g)–(m), 5.2.6(f)).

(b) identify that some alkenes, typified by propene, can produce addition polymers that are atactic, isotactic or syndiotactic.

(c) describe the characteristics of condensation polymerisation:

(i) in polyesters, typified by *Terylene* (from benzene-1,4-dicarboxylic acid and ethane-1,2-diol);

(ii) in polyamides, typified by nylon-6,6 (from 1-6-diaminohexane and hexane-1,6-dicarboxylic acid) and Kevlar (from benzene-1,4-diamine and benzene-1,4-dicarboxylic acid);

(iii) in polypeptides and proteins (see also Section 5.4.4(g)).

(d) suggest the type of polymerisation reaction from

(i) a given monomer or pair of monomers;

(ii) a given section of a polymer molecule.

(e) deduce the repeat unit of a polymer obtained from a given monomer or pair of monomers.

(f) identify, in a given section of polymer, the monomer(s) from which it was obtained.

(g) state the use of polyesters and polyamides as fibres in clothing.

5.4.7 *Spectroscopy*

C3.2, C3.3; IT3.1

Content

- Review of appropriate material on infra-red spectroscopy from AS Chemistry – Module 2812: Chains and Rings, 5.2.5(f).
- Mass spectrometry: molecular mass determination.
- n.m.r. spectroscopy: structure elucidation.

[In examinations, infra-red absorption data and n.m.r. chemical shift values will be provided on the *Data Sheet* (Appendix G).]

Assessment outcomes

Candidates should be able to:

(a) use a simple infra-red spectrum to identify the presence of functional groups in a molecule (limited to alcohols (O–H), carbonyl compounds (C=O), carboxylic acids (COOH) and esters (COOR) (see also 5.2.5(f)).

(b) use the molecular ion peak in a mass spectrum to determine the relative molecular mass of an organic molecule.

(c) predict, from the high resolution n.m.r. spectrum of a simple molecule containing carbon, hydrogen and/or oxygen,

(i) the different types of proton present from chemical shift values;

(ii) the relative numbers of each type of proton present from the relative peak area;

(iii) the number of protons adjacent to a given proton from the spin-spin splitting pattern, limited to splitting patterns up to a quadruplet only.

(iv) possible structures for the molecule.

(d) predict the chemical shifts and splitting patterns of the protons in a given molecule.

- *Background theory will **not** be tested on examination papers: the emphasis is on the interpretation of spectra. Thus, candidates will not be tested on why nuclear magnetic resonance takes place, the reasons for different chemical shift values or why spin-spin splitting occurs.*
- *The relative peak areas will be given on any provided spectra.*
- *For splitting patterns, the n + 1 rule can be used, where n is the number of H atoms on adjacent carbon atoms. Limited to singlet, doublet, triplet and quadruplet.*

(e) describe the use of D_2O to identify the n.m.r. signal from –OH groups.

5.5 Module 2815, Component 01: Trends and patterns

LP3.1, LP3.2, LP3.3; PS3.1, PS3.2, PS3.3.

Introduction

Module 2815, (component 01) is a half-module which, along with **one** of five optional half-modules 2815 (component 02–06), comprises Module 2815.

Preamble

In addition to the aims of the scheme, this module builds upon the chemical concepts that have been developed during AS Chemistry by extending the study of periodicity encountered within Module 2811: Foundation Chemistry. It is intended to provide students with a deeper knowledge and understanding of inorganic chemistry and the Periodic Table.

The main areas of inorganic chemistry studied include

- lattice enthalpy and Born-Haber cycles;
- periodic trends of oxides and chlorides;
- transition elements and redox chemistry.

Chemical periodicity is developed across Period 3 and trends are explained in terms of structure and bonding. Redox chemistry permeates chemistry and the earlier introductory work in AS Chemistry is developed further within the study of transition elements.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems.

Synoptic assessment

Module 2815, (component 01) together with Module 2816 (component 01) provides a context for synoptic assessment. The subject content in this component links strongly with the following sections from AS Chemistry:

Module 2811: Foundation Chemistry

- 5.1.3 Chemical Bonding and Structure.
- 5.1.4 Periodic Table: Introduction.
- 5.1.5 The Periodic Table: The Group 2 elements and their compounds.
- 5.1.6 The Periodic Table: The Group 7 elements and their compounds.

Module 2813 (component 01): How Far, How Fast?

- 5.3.1 Enthalpy changes.

Knowledge and understanding of these AS topics will be assumed and examination questions will be set that link the content of Module 2815 (component 01): Trends and Patterns with these and other areas of chemistry. For further details of the question paper and synoptic assessment, see section 4.

Recommended Prior Knowledge

Candidates should have studied AS Chemistry.

5.5.1 Lattice enthalpy

N3.1, N3.2	

Content

- Review of appropriate material from AS Chemistry – Module 2813 (component 01): How Far, How Fast?, 5.3.1 Enthalpy changes.
- Lattice enthalpy.
- Born-Haber cycles.

Assessment outcomes

Candidates should be able to:

(a) explain and use the term *lattice enthalpy* (ΔH negative, i.e. gaseous ions to the solid lattice) as a measure of ionic bond strength.

(b) construct Born-Haber cycles to calculate the lattice enthalpy of a simple ionic solid (e.g. NaCl, $MgCl_2$) using relevant energy terms (enthalpy change of formation, ionisation energy, enthalpy change of atomisation and electron affinity).

(c) explain, in qualitative terms, the effect of ionic charge and of ionic radius on the numerical magnitude of a lattice enthalpy.

(d) describe the thermal decomposition of the Group 2 carbonates ($MgCO_3$ to $BaCO_3$) and explain the trend in terms of lattice enthalpy, the polarisation of the anions and the charge density of the cations (see also 5.1.3(j), 5.1.5(f)).

(e) relate the high lattice enthalpy of MgO to its use as a refractory lining.

5.5.2 Periodic Table: Period 3

C3.3; IT3.1.	**WO3.1, WO3.2, WO3.3.**

Content

- Review of appropriate material from AS Chemistry – Module 2811: Foundation Chemistry, 5.1.4 Periodic Table: Introduction.
- Preparation of Period 3 oxides and chlorides.
- Periodic trends of oxides and chlorides.

Assessment outcomes

Candidates should be able to:

(a) describe redox reactions of Period 3 elements

(i) with oxygen to give MgO, Al_2O_3 and SO_2;

(ii) with chlorine to give NaCl, $MgCl_2$, $AlCl_3$, $SiCl_4$ and PCl_5;

(iii) with water to give NaOH and $Mg(OH)_2$.

(b) describe the action of water, if any, on the compounds in (a) and the pH of any resulting solutions.

(c) explain the trends in (a) and (b) above in terms of the structure and bonding of the oxides and chlorides involved.

5.5.3 *Periodic Table: Transition elements*

C3.3, IT3.1.	**WO3.1, WO3.2, WO3.3.**

Content

- Properties of transition elements.
- Ligands, complex ions and ligand exchange.
- Precipitation reactions.
- Redox reactions.
- Colorimetry.

Assessment outcomes

Candidates should be able to:

(a) describe a *transition element* as a d-block element forming one or more stable ions with incompletely filled d-orbitals.

(b) deduce the electronic configurations of atoms and ions of the d-block elements of Period 4 (Sc $\rightarrow$ Zn) , given the atomic number and charge.

- *Candidates should use sub-shell notation, i.e. for Fe: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$.*

(c) illustrate, using the transition elements iron and copper as appropriate,

(i) the existence of more than one oxidation state for each element in its compounds;

(ii) the formation of coloured ions;

(iii) the catalytic behaviour of the elements and/or their compounds.

(d) describe the simple precipitation reactions and the accompanying colour changes of Cu^{2+}(aq), Fe^{2+}(aq) and Fe^{3+}(aq) with aqueous sodium hydroxide to form $Cu(OH)_2$, $Fe(OH)_2$ and $Fe(OH)_3$ respectively.

(e) explain and use the terms *complex ion* and *ligand* in terms of co-ordinate bonding.

(f) describe the process of ligand substitution and the accompanying colour changes, for example in the formation of:

(i) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[CuCl_4]^{2-}$ from $[Cu(H_2O)_6]^{2+}$;

(ii) $[Fe(SCN)(H_2O)_5]^{2+}$ from $[Fe(H_2O)_6]^{3+}$.

(g) predict from data, the formula and possible shape of a complex ion, limited to tetrahedral and octahedral complexes.

(h) explain how colorimetry can be used to determine the formula of a complex ion, for example $[Fe(SCN)(H_2O)_5]^{2+}$.

(i) predict the colour of a transition element complex from its ultraviolet/visible spectrum.

(j) describe redox behaviour in transition elements, for example by Fe^{3+}/Fe^{2+} and MnO_4^-/Mn^{2+}.

(k) construct redox equations, such as those in (j) above, using relevant half-equations.

(l) perform calculations involving simple redox titrations, for example MnO_4^-/Fe^{2+} in acid solution.

5.6 Module 2815, Component 02: Biochemistry

	LP3.1, LP3.2, LP3.3.

Introduction

This is one of five optional half-modules, Components 02-06, that, along with the half-module, Component 01: Trends and Patterns, comprise Module 2815.

Preamble

Biochemistry is the study of chemical processes in living organisms. Candidates should be aware of the characteristics of living organisms and recognise that these characteristics are maintained by complex chemical reactions. The basic structure of animal cells with reference to the structure and function of sub-cellular organelles (nucleus, mitochondria, ribosomes, endoplasmic reticulum and the cell membrane) is useful background but will **not** be examined in this option. Candidates will not be expected to memorise the formulae or structures of complex substances, such as proteins, polysaccharides and nucleic acids, unless specified in this teaching module.

Candidates studying Biology will inevitably have met some of the ideas in this option, but it is important to emphasise that this component places stress on the chemical interpretation of biological processes at the molecular level.

Assessment Objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should have studied the AS Chemistry modules and Module 2814: Chains, Rings and Spectroscopy.

5.6.1 Proteins

IT3.1.

Content

- Review of appropriate material from A2 Chemistry – Module 2814 Chains, Rings and Spectroscopy, 5.4.4(e)–(h).
- Amino acids, polypeptides and proteins.
- Protein structure: primary, secondary, tertiary and quaternary structures.
- Denaturation of proteins.

Assessment Outcomes

Candidates should be able to:

(a) explain the term primary structure of proteins.

(b) describe the secondary structure of proteins: α-helix and β-pleated sheet; the stabilisation of these structures by hydrogen bonding.

(c) state the importance of the tertiary protein structure and explain its stabilisation by R groups in the amino acid residues, in terms of ionic linkages, disulphide bridges, hydrogen bonds and van der Waals' forces.

(d) describe the quaternary structure of proteins, for example: haemoglobin including the role of Fe^{2+}.

(e) explain denaturation of proteins by heavy metal ions, extremes of temperature and pH changes (see also 5.6.2(d)).

5.6.2 Enzymes

IT3.1.

Content

- Enzymes: relationship between enzymes and substrates; active sites.
- Competitive and non-competitive inhibition.
- Industrial uses of enzymes.

Assessment Outcomes

Candidates should be able to:

(a) describe the behaviour of enzymes as catalysts of high activity and specificity.

(b) explain the relationship between enzyme and substrate concentrations of biochemical systems.

(c) explain the concept of an active site in the structure of an enzyme.

(d) distinguish between inhibition of enzymes:

- (i) competitive inhibition by a similar substrate molecule competing for the active site;
- (ii) non-competitive inhibition by heavy metal ions.

(e) explain the advantages of immobilising enzymes.

(f) state the commercial and industrial uses of enzymes, typified by biological washing powders.

5.6.3 Carbohydrates

IT3.1.

Content

- Monosaccharides.
- Disaccharides.
- Polysaccharides.

Assessment Outcomes

Candidates should be able to:

(a) describe the open-chain structure of a pentose (for example: ribose) and a hexose (for example: glucose).

(b) describe the α- and β-pyranose ring structures of D-glucose.

(c) describe the structure of a disaccharide including the nature of the glycosidic link, typified by maltose and cellobiose.

(d) describe the structure of polysaccharides, for example: cellulose and starch (amylose and amylopectin):

- (i) as condensation polymers;
- (ii) in terms of their glycosidic links (to include 1α-4, 1β-4 and 1α-6 links).

(e) describe the enzyme and acid hydrolysis of the glycosidic linkage.

(f) compare the solubilities of monosaccharides and polysaccharides in water, in terms of hydrogen bonding.

(g) suggest how the structures and properties of cellulose, starch and glycogen make them suitable for their role as structural or storage polymers in plants and animals.

5.6.4 Lipids and membrane structure

IT3.1.

Content

- Biological functions of lipids.
- Triglycerides.
- Phosphoglycerides; formation of bilayers.

Assessment Outcomes

Candidates should be able to:

(a) describe the structure and function of triglyceryl esters.

(b) describe the hydrolysis of triglycerides as a source of fatty acids, for example: in soap-making.

(c) explain the solubility of triglycerides in non-polar solvents.

(d) describe the structure and function of phosphoglycerides in the formation of bimolecular layers.

(e) explain that

(i) lipids, treated simply as $(CH_2)_n$, are essentially a concentrated energy store of carbon and hydrogen;

(ii) carbohydrates, treated simply as $(CH_2O)_n$, are made up of partly oxidised carbon and hydrogen units allowing more 'instant access' to energy;

(iii) why, on complete oxidation, lipids release more energy per gramme than carbohydrates.

- *Treatment of metabolic stages is **not** required.*

5.6.5 Nucleic acids

IT3.1.

Content

- Nucleotides and nucleic acids.
- DNA and RNA; base pairing.
- DNA and genetic information.
- m-RNA and protein synthesis.

Assessment Outcomes

Candidates should be able to:

(a) describe, in simple terms, the structure of

  (i) nucleotides;

  (ii) the nucleic acids DNA and RNA (as condensation polymers of nucleotides), including base pairing and the part played by hydrogen bonding.

(b) describe the chemical and physical differences between DNA and RNA molecules including

  (i) their base pairs and sugars;

  (ii) the double helix in DNA and single strand in RNA;

  (iii) their molecular sizes.

(c) explain the role of DNA

  (i) in the replication of genetic information;

  (ii) in coding for m-RNA by transcription.

(d) describe the role of m-RNA and t-RNA in coding for proteins by translation.

5.7 Module 2815, Component 03: Environmental Chemistry

	LP3.1, LP3.2, LP3.3.

Introduction

This is one of five optional half-modules, Components 02-06 that, along with the half-module Component 01: Trends and Patterns, comprise Module 2815.

Preamble

This component is intended to provide candidates with the opportunity to study some of the chemical reactions occurring in the world around them. These can include examples of many of the types of reactions and processes that will have been encountered in the laboratory. Throughout this module, the emphasis is on the application of chemical facts and principles to processes occurring in the environment and inherent difficulties encountered in providing solutions to pollution. In the context of this component, it is felt important that candidates should appreciate this aspect, bearing in mind the increasing concern, both national and international, for protecting the environment.

Assessment Objectives

See Section 3. Candidates are expected to apply knowledge and understanding and other skills gained in this component to new situations and/or solve related problems.

Recommended Prior Knowledge

Candidates should have studied the AS Chemistry modules and Module 2816, (component 01): Unifying Concepts in Chemistry 5.11.2 How Far? The subject material builds upon the many environmental issues that permeate the AS modules, especially within Module 2812: Chains and Rings, for example: free radicals (see 5.2.2); the use of CFCs (see also 5.2.6); fuels (see also 5.2.3) and the disposal of plastics (see also 5.2.4) and within Module 2813 (component 01) How far, How Fast? depletion of ozone layer (see also 5.3.2).

5.7.1 The atmosphere

IT3.1.	

Content

- The composition of the atmosphere; the carbon cycle.
- Some chemical reactions in the atmosphere.
- The origin, importance and vulnerability of the ozone layer.
- The residence time of oxides of carbon and oxides of nitrogen.
- Pollution in the troposphere.
- The ‘Greenhouse Effect’.

Assessment Outcomes

Candidates should be able to:

(a) understand the terms troposphere and stratosphere.

(b) use the carbon cycle to describe and explain how the concentration of carbon dioxide in the troposphere depends on:

- (i) photosynthesis;
- (ii) plant and animal respiration;
- (iii) equilibrium with carbon dioxide dissolved in surface waters.

(c) use ideas of chemical equilibria (see also 5.3.3) to describe and explain how the stratospheric concentration of ozone is maintained in terms of photochemical reactions involving the 'oxygen only' model.

(d) outline the role of ozone in the absorption of ultraviolet radiation.

(e) explain how the release in the stratosphere of chlorine free-radicals from CFCs (see also 5.2.2(d), (e) and 5.2.6(f), (g)) affects the balance of the ozone and oxygen (see also 5.3.2 (i), (l)).

(f) describe, in terms of their relevant physical and chemical properties, the selection of possible alternatives to the use of CFCs.

(g) outline:

- (i) the sources of nitrogen oxides in the atmosphere;
- (ii) the effect of nitrogen monoxide on the balance of stratospheric ozone and oxygen;
- (iii) the role of free radicals in the formation of complex pollutants, typified by photochemical smog (see also 5.3.2(j));
- (iv) the effects of photochemical smog on humans, animals and plants and polymers.
- *A recall of the equations will **not** be tested.*

(h) describe how catalytic converters in car exhaust systems are effective in decreasing toxic emissions from internal combustion engines (see also 5.3.2(i)–(k)).

(i) understand the term residence time as the average time that a species exists in the atmosphere.

(j) explain that the 'Greenhouse Effect' of a given gas is dependent both on its atmospheric concentration and its ability to absorb infra-red radiation, typified by CO_2, CH_4 and CFCs.

5.7.2 The hydrosphere

Content

- The air-water interface.
- Some cations and anions in natural waters.
- Potable water.

Assessment Outcomes

Candidates should be able to:

(a) describe the effects of water temperature and gas pressure on the solubility of gases in water.

- *A qualitative treatment only is required. Henry's Law will **not** be tested.*

(b) explain the natural acidity of rainwater from dissolved carbon dioxide.

(b) explain enhanced acidity from soluble nitrogen and sulphur oxides.

(c) describe and explain the importance of dissolved oxygen in

(i) the support of aquatic life;

(ii) the decomposition of organic material.

(d) explain the role of dissolved carbon dioxide in the formation of temporary hardness in water, containing aqueous magnesium and calcium ions (see also 5.1.5(h)).

(e) describe the removal of temporary hardness from water by boiling and ion exchange, and explain the chemistry involved.

(f) outline the steps taken to produce potable water including the use of aluminium ions in the removal of very fine suspended solids (colloids).

(g) outline the removal of bacteria from water supplies by oxidation, using chlorine or ozone (see also 5.1.6(e)).

5.7.3 The lithosphere

Content

- Chemical weathering of rocks.
- Clay minerals.
- Cation exchange.
- The supply of nutrients to plants.

Assessment Outcomes

Candidates should be able to:

(a) explain the chemical processes of weathering in terms of the hydration of ions, the precipitation of carbonates and the ultimate formation of insoluble oxides.

(b) describe the structure of clay minerals in terms of 'SiO_4' tetrahedral sheets and 'AlO_6' octahedral sheets.

(c) describe the similarities of, and differences between, the layer structures of 1:1 and 2:1 clay minerals, noting the importance of hydrogen bonding in the former.

(d) explain the presence of negative charge on the surface of 2:1 silicate clays, in terms of substitution of silicon by aluminium ions, and the consequent attraction of hydrated cations.

(e) explain the process of cation exchange at the surface of silicate clays.

(f) explain the differing cation exchange capacities and tendency to crack of 1:1 and 2:1 clay minerals in terms of their structures.

(g) explain the importance of cation exchange for the supply of cationic nutrients to plants.

5.7.4 Treatment of waste

Content

- The disposal of solid domestic waste.

Assessment Outcomes

Candidates should be able to:

(a) discuss the changing composition of solid domestic waste in terms of the increased use and consequent disposal of polymers, batteries and disposable materials.

(b) describe the process of landfill as involving both aerobic and (subsequently) anaerobic decomposition.

(c) identify problems which may arise from some of the products of anaerobic decomposition, notably methane and hydrogen sulphide.

(d) outline the importance of waste incineration for

  (i) providing useful energy as heat for communities;

  (ii) reducing the bulk of waste compared with landfill and consequently reducing demand for landfill sites.

(e) understand the importance of temperature control during waste incineration to prevent release of toxic emissions into the environment (see also 5.2.4(k), (m)).

5.8 Module 2815, Component 04: Methods of Analysis and Detection

	LP3.1, LP3.2, LP3.3.

Introduction

This is one of five optional half-modules, components 02–06 that, along with the half-module Component 01: Trends and Patterns, comprise Module 2815.

Preamble

This component is designed to develop and complement the spectroscopic areas of the 'core' specification previously encountered (see Module 2812 Chains and Rings: 5.2.5(f) and Module 2814; Chains, Rings and Spectroscopy: 5.4.7) and to show how various analytical techniques may be used in combination to provide evidence of structural features in molecules. In addition, this component highlights some of the analytical methods that candidates may encounter both in further study and in many areas of employment in the broadly scientific field.

In questions all data normally associated with the appropriate spectra will be provided on the *Data Sheet* (see Appendix G) and on examination papers.

Assessment Objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this component to new situations and/or solve related problems.

Recommended Prior Knowledge

Candidates should have studied the AS Chemistry modules and A2 Chemistry – Module 2814: Chains, Rings and Spectroscopy, 5.4.7 Spectroscopy.

5.8.1 Separation techniques for analysis: chromatography and electrophoresis

Content

- Chromatography; partition and adsorption.
- Electrophoresis; separation of amino acids.
- Applications of separation techniques.

Assessment Outcomes

Candidates should be able to:

(a) describe simply, and explain qualitatively, paper, gas/liquid and thin-layer chromatography in terms of partition and adsorption.

(b) explain the terms R_f value and retention time.

(c) interpret one-way and two-way chromatograms in the identification of particular species present in a mixture.

(d) interpret gas/liquid chromatograms in terms of the percentage composition of a mixture.

(e) describe simply the process of electrophoresis.

(f) describe the separation and detection of amino acids by electrophoresis including the use of changing the pH (see also 5.4.4(f)).

(g) outline the extraction of DNA, the separation of the genetic fragments by electrophoresis and their detection by phosphorus-32 to produce a genetic fingerprint.

5.8.2 Mass spectrometry

IT3.1.

Content

- Review of appropriate material from AS Chemistry – Module 2811: Foundation Chemistry, 5.1.1 Atoms, Molecules and Stoichiometry; and from A2 Chemistry – Module 2814: Chains, Rings and Spectroscopy, 5.4.7 Spectroscopy.
- High resolution mass spectrometry.
- Mass spectrometry of molecules: mass spectra, base peak, molecular ion, (M+1) and (M+2) peaks.
- Elucidation of structure.

Assessment Outcomes

Candidates should be able to:

(a) use accurate relative molecular mass data from high resolution mass spectrometry to distinguish between molecules of similar relative molecular mass.

(b) suggest the identity of the major fragment ions in a given mass spectrum.

- *Rearrangement reactions are **not** required.*

(c) use molecular ion peaks, base peaks and fragmentation peaks to identify structures (limited to unipositive ions).

(d) use the M and (M+1) peaks from a mass spectrum to determine the number of carbon atoms in a molecule of an organic compound.

(f) use the M, (M+2) and, where appropriate, (M+4) peaks from a mass spectrum to identify organic compounds containing chlorine and bromine.

5.8.3 Atomic Emission Spectroscopy

Content

- The electromagnetic spectrum: wavelength, frequency and energy.
- Atomic emission line spectra.
- Applications of flame emission spectroscopy.

Assessment Outcomes

Candidates should be able to:

(a) convert wavelength to frequency using $c=f\lambda$.

(b) explain the processes which bring about the emission spectrum of atomic hydrogen.

(c) understand that electromagnetic radiation is quantised.

(d) calculate the energy of a quantum of electromagnetic radiation of given frequency (using $E = hf$) and relate this to the transition of an electron between energy levels.

(e) explain the convergent nature of atomic line emission spectra in terms of energy levels and use the convergence limit to calculate the ionisation energy of hydrogen.

(f) understand that the study of emission spectra of stars led to the discovery of several new elements.

(g) describe the use of flame emission spectroscopy in the quantitative determination of metal ions in biological fluids, for example: sodium in blood serum.

5.8.4 Ultraviolet/Visible Absorption Spectroscopy

Content

- Colour in organic molecules; chromophores.
- Delocalisation; increased conjugation.
- Dyes and indicators.

Assessment Outcomes

Candidates should be able to:

(a) explain that ultraviolet/visible absorption in organic molecules requires electronic transitions between energy levels in chromophores which contain a double or triple bond, a delocalised system or a lone pair of electrons.

- Detailed theory of why chromophores have absorptions of appropriate energy is not required, nor is any consideration of the molecular orbitals involved.

(b) predict whether a given organic molecule will absorb in the ultraviolet/visible region.

(c) explain, in qualitative terms, how increasing conjugation in an organic molecule decreases the gap between energy levels and hence shifts the absorption towards longer wavelength.

(d) explain the colour changes in acid-base indicators, such as methyl orange, in terms of a change in chromophore.

5.8.5 Combined Spectral Techniques

IT3.1.

Content

- Elucidation of structure using up to **three** spectra.

Assessment Outcomes

Candidates should be able to:

(a) state the regions of the electromagnetic spectrum in which absorptions occur for each branch of spectroscopy studied.

(b) bring together evidence from a number of spectra: n.m.r., i.r. and mass spectra.

Notes for guidance

All data normally associated with the appropriate spectra will be provided on the *Data Sheet* (see Appendix G) and on examination papers.

In questions candidates may be expected to:

- show knowledge and understanding of AS Chemistry – Module 2812: Chains and Rings, 5.2.5(f); A2 Chemistry – Module 2814: Chains, Rings and Spectroscopy, 5.4.7 Spectroscopy.
- explain the contribution made by each of up to **three** spectra to a possible identification of an unknown compound.
- use evidence from up to **three** spectra to suggest a probable structure for an unknown compound.
- suggest what further evidence might be required to confirm a structure suggested by a study of spectra.

In n.m.r. spectra,

- the analysis of splitting patterns will be restricted up to a quartet.
- Characteristic chemical shift values will be supplied.
- Candidates will be expected to identify aromatic protons from chemical shift values but will **not** be expected to analyse their splitting patterns.
- The compounds chosen will be limited to those containing C, H, N and O, excluding nitriles.

5.9 Module 2815, Component 05: Gases, Liquids and Solids

LP3.1, LP3.2, LP3.3.

Introduction

This is one of five optional half-modules, Components 02-06, that, along with the half-module Component 01: Trends and Patterns, comprise Module 2815.

Preamble

This component applies equilibrium concepts within the main body of the specification to the interactions between the different phases that occur in single component systems and those that apply to multi-component systems, that is mixtures/solutions involving gases, liquids and solids.

Assessment outcomes

See Section 3. Candidates are expected to apply the knowledge, understanding and other skills gained in this component to new situations and/or solve related problems.

Recommended prior knowledge

Candidates should have studied the AS Chemistry modules and Module 2816 (component 01): Unifying Concepts in Chemistry 5.11.2 How Far? The subject material particularly builds upon Module 2811: Foundation Chemistry, 5.1.3 Structure and Bonding, for example, the nature of intermolecular forces (see 5.1.3(k)–(m)) and their relationship with physical properties (see 5.1.3(p), (q)).

5.9.1 States of matter

Content

- Review of appropriate material on inter-particular forces from AS Chemistry – Module 2811: Foundation Chemistry, 5.1.3 Structure and Bonding.
- The characteristics of the three states of matter (the phases).
- The gaseous state.
- Ideal gas behaviour and deviations from it.
- The Ideal Gas Equation and its use in determining a value for relative molecular masses.

Assessment outcomes

Candidates should be able to:

(a) describe, using a kinetic-molecular model, the solid, liquid and gaseous states; melting, vaporisation and vapour pressure (see also 5.1.3(k)).

(b) state the basic assumptions of the kinetic theory as applied to an ideal gas.

(c) explain qualitatively, in terms of intermolecular forces (see also 5.1.3(k), (l)) and molecular size,

- (i) the conditions necessary for a gas to approach ideal behaviour;
- (ii) the limitations of ideality at very high pressures and very low temperatures.

(d) state and use the Ideal Gas Equation $pV = nRT$ in calculations, including the determination of the relative molecular mass of a volatile liquid.

5.9.2 Phase diagrams

Content

- Phase diagrams of: pure compounds; of solid-solid, solid-liquid and liquid-liquid solutions.
- Eutectics.
- Alloys.

Assessment outcomes

Candidates should be able to:

(a) understand that phase diagrams are graphical plots of experimentally determined results.

(b) interpret phase diagrams as curves describing the conditions of equilibrium between phases and as regions representing single phases.

(c) predict how phases may alter with changes in temperature or pressure.

(d) sketch the shape of the phase diagram for water and explain the anomalous behaviour of water (see also 5.1.3(m)).

(e) understand and use the term eutectic.

(f) interpret phase diagrams for two-component systems and predict how compositions and phases vary with changes in temperature.

(g) sketch the shape of the phase diagram for mixtures of tin and lead.

(h) state, and explain in simple terms, how the hardness and melting points of common alloys differ from those of pure metals.

(i) sketch the shape of the phase diagram for a two-component system, such as NaCl and water.

(j) sketch the shape of the solubility curve of a salt, such as NaCl in water.

5.9.3 Distribution between phases

Content

- Review of appropriate material on equilibrium constants from A2 Chemistry – Module 2816 (component 01): Unifying Concepts in Chemistry, 5.11.2 How Far?
- The solubility of gases in liquids; Henry's Law.
- Partition coefficient; solvent extraction.

Assessment outcomes

Candidates should be able to:

(a) describe and explain how the solubility of a gas in a liquid is affected by pressure, temperature and change of chemical state.

(b) state Henry's Law and apply it in simple calculations (see also 5.11.2(c), (d)).

(c) state what is meant by a partition coefficient.

(d) calculate a partition coefficient for a system in which the solute is in the same molecular state in the two solutions.

(e) explain solvent extraction.

5.9.4 Raoult's Law and distillation

Content

- Raoult's Law; its application to liquid-liquid mixtures; positive and negative deviations.
- Boiling point/composition curves; fractional distillation; azeotropic mixtures.
- Steam distillation.

Assessment outcomes

Candidates should be able to:

(a) state and apply Raoult's Law.

(b) explain qualitatively the effect of a non-volatile solute on the vapour pressure of a solvent and the freezing point and boiling point of the solution.

(c) outline, in qualitative terms, the relationships of boiling point and enthalpy change of vaporisation with intermolecular forces (see also 5.1.3(p)).

(d) interpret the boiling point/composition curves for mixtures of two miscible liquids in terms of

  (i) 'ideal' behaviour;

  (ii) positive or negative deviations from Raoult's Law, related to intermolecular attractions or bonding.

(e) understand and use the term azeotropic mixture.

(f) explain the limitations on separating two components which form an azeotropic mixture.

(g) describe the principles of fractional distillation of ideal liquid mixtures.

(h) describe a typical laboratory fractionating column.

(i) demonstrate a knowledge and understanding of the packing of fractionating columns and other means of establishing equilibrium at different temperatures between liquid and vapour.

(j) explain the concept of theoretical plates in fractionating columns.

(k) deduce the number of theoretical plates by graphical means, using given data.

(l) explain steam distillation of two immiscible liquids.

(m) demonstrate an awareness of the applications of fractional and steam distillation to the separation of the components of liquid mixtures.

- *Examples include making distilled water, the distillation of aqueous ethanol, the fractional distillation of crude oil, the steam distillation of natural products, for example: eucalyptus, citrus fruit peel, perfumes from plant material.*

5.10 Module 2815, Component 06: Transition Elements

LP3.1, LP3.2, LP3.3.

Introduction

This is one of five optional half-modules. Components 02–06 that, along with the half-module Component 01: Trends and Patterns, comprise Module 2815.

Preamble

In addition to the aims of the scheme, this component builds upon the chemical concepts that have been developed during AS Chemistry.

This component is intended to provide candidates with a deeper knowledge and understanding of inorganic chemistry:

- electrode potentials.
- transition metals: the bonding of ligands to form complex ions; stereochemistry of complex ions; origin of colour in transition metal compounds.
- transition elements: a survey of properties including redox chemistry of vanadium, chromium, cobalt and copper.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems.

Recommended Prior Knowledge

Candidates should have studied the AS Chemistry modules and A2 Chemistry – Module 2815, (component 01): Trends and Patterns, 5.5.3 Periodic Table: Transition elements.

5.10.1 Electrode potentials

Content

- Electrode potentials.
- Standard cells.
- Feasibility of reactions.

Assessment Outcomes

Candidates should be able to:

(a) define the term standard electrode (redox) potential, $E^{\ominus}$.

(b) describe the methods used to measure the standard electrode potentials of the following systems, using a reference electrode of their choice:

(i) metals or non-metals in contact with their ions in aqueous solution;

(ii) ions of the same element in different oxidation states.

(c) calculate a standard cell potential by combining two standard electrode potentials.

- *$E^{\ominus}$ data will be provided on examination papers.*

(d) use standard cell potentials to predict the feasibility of a reaction.

(e) recognise the limitations of predictions made using standard cell potentials, in terms of kinetics and changing concentration.

5.10.2 *Ligands and complexes*

Content

- Review of appropriate material from A2 Chemistry – Module 2815 (component 01): Trends and Patterns, 5.5.3 Periodic Table: Transition elements.
- Bonding in complexes.
- Stoichiometry and isomerism of complexes.

Assessment outcomes

Candidates should be able to:

(a) state what is meant by *co-ordination number* and predict the formula and charge of a complex ion, given the metal ion, its charge and the ligand.

(b) state that complexes typically show

(i) four-fold co-ordination with either a planar or tetrahedral shape;

(ii) six-fold co-ordination with an octahedral shape.

(c) describe the types of isomerism (*cis-trans* and optical) shown by complexes, including those associated with bidentate ligands.

- Examples: cis-trans: $Ni(NH_3)_2Cl_2$; optical: $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$.

(d) describe the use of cis-platin as an anti-cancer drug.

5.10.3 *Colour*

Content

- Colour in transition metal complexes.
- The role of d-orbitals.
- The effect of different ligands.

Assessment Outcomes

Candidates should be able to:

(a) describe the shape and symmetry of the d-orbitals and the splitting of d-orbital energy levels in transition metal complexes (octahedral only).

(b) explain, in terms of d-orbital splitting, why transition metal ions, containing at least one partially filled d-orbital (d^1 to d^9), form complexes that are usually coloured.

(c) explain the lack of colour in d^0 and d^{10} compounds.

(d) explain how ligand exchange may change the d-orbital splitting of complexes, resulting in a change of colour.

(e) suggest the colour of a transition metal complex from its visible spectrum.

(f) describe the use of compounds of d-block elements in pigments, for example: TiO_2 in white paint; Monastral Blue/other porphyrin complexes for dyes in paints.

5.10.4 Chemistry of Transition metals

Content

- Characteristic transition metal chemistry as illustrated by vanadium, chromium, cobalt and copper.
- Uses of these metals.

Assessment outcomes

Candidates should be able to describe and explain the chemistry of:

(a) vanadium, in respect of

(i) the occurrence and colour of its aqueous ions and compounds containing the metal in its +2, +3, +4 and +5 oxidation states.

(ii) redox reactions involving the +2, +3, +4 and +5 oxidation states and explanations in terms of $E^{\ominus}$ values;

(iii) its catalytic properties, for example as V_2O_5 in the Contact Process.

(b) chromium, in respect of

(i) the occurrence, relative stability and colour of its aqueous ions and compounds containing the metal in its +3 and +6 oxidation states;

(ii) the chromate(VI) to dichromate(VI) interconversion;

(iii) its use in stainless steel and in hardening steel.

(c) cobalt, in respect of

(i) the occurrence, relative stability and colour of its aqueous ions and compounds containing the metal in its +2 and +3 oxidation states;

(ii) the effect of ligands and/or temperature on the stability and geometry of cobalt complexes, for example: the equilibria between $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$; $[Co(NH_3)_6]^{2+}$ and $[Co(NH_3)_6]^{3+}$.

(d) copper, in respect of

(i) the occurrence, relative stability and colour of its aqueous ions and compounds containing the metal in its +1 and +2 oxidation states, including the disproportionation (and stabilisation) of Cu^+(aq);

(ii) the Cu^{2+}(aq)/I^-(aq) reaction;

(iii) its estimation in alloys such as brass by titration using $I_2/S_2O_3^{2-}$;

(iv) its use in brass, bronze, coinage metals and other alloys.

5.11 Module 2816, Component 01: Unifying Concepts in Chemistry

	LP3.1, LP3.2, LP3.3.

Preamble

In addition to the aims of the scheme, this module builds upon the chemical concepts that have been developed during AS Chemistry by extending the study of physical chemistry encountered within Module 2813 (component 01): How Far, How Fast?

Module 2816 (component 01) is intended to provide students with a quantitative study of physical chemistry:

- rate equations, orders of reaction, the rate-determining step.
- equilibrium constants, K_c and K_p.
- acid-base equilibria including pH, K_a and buffer solutions.

The material covered in this component links many areas of chemistry and serves to explain many chemical phenomena. For example, the qualitative treatment of reaction rates and equilibria encountered at AS is developed within a quantitative and graphical context.

Assessment objectives

See Section 3. Candidates are expected to apply knowledge, understanding and other skills gained in this component to new situations and/or to solve related problems.

Synoptic assessment

Module 2816 (component 01) together with Module 2815 (component 01) addresses synoptic assessment. The subject content in this component links strongly with the following sections from AS Chemistry:

Module 2811: Foundation Chemistry

- 5.1.1 Atoms, Molecules and Stoichiometry

Module 2813 (component 01): How Far, How Fast?

- 5.3.1 Enthalpy changes
- 5.3.2 Reaction rates
- 5.3.3 Chemical Equilibrium

Knowledge and understanding of these AS topics is assumed and examination questions will be set that link the content of Unifying Concepts in Chemistry to these and other areas of chemistry. For further details of the question paper and, for synoptic assessment see section 4.

Recommended Prior Knowledge

Candidates should have studied AS Chemistry.

5.11.1 How fast?

N3.1, N3.2, N3.3; IT3.2.	**WO3.1, WO3.2, WO3.3.**

Content

- Review of appropriate material from AS Chemistry – Module 2813 (component 01): How Far, How Fast?, 5.3.2 Reaction rates.
- Concentration–time and rate–concentration graphs.
- Orders; rate equations; rate constants.
- Rate-determining step.

Assessment outcomes

Candidates should be able to:

(a) explain and use the terms: rate of reaction, order, rate constant, half-life, rate-determining step.

(b) deduce, from a concentration-time graph, the rate of a reaction and the half-life of a first-order reaction.

(c) recall that the half-life of a first-order reaction is independent of the concentration.

(d) deduce, from a rate-concentration graph, the order (0,1 or 2) with respect to a reactant.

(e) calculate, using the initial rates method, the order (0,1 or 2) with respect to a reactant.

(f) construct a rate equation of the form: rate = $k[A]^m[B]^n$, for which *m* and *n* are 0, 1 or 2.

(g) calculate a rate constant from a rate equation.

(h) explain qualitatively, the effect of temperature change on a rate constant and hence the rate of a reaction.

(i) For a multi-step reaction,

  (i) given the rate-determining step, predict an expression for the rate equation;

  (ii) show that a rate equation enables a rate-determining step to be proposed;

  (iii) use a rate equation and the balanced equation for a reaction to suggest possible steps in a reaction mechanism.

  - *Integrated forms of rate equations are **not** required.*

5.11.2 How far?

C3.3; N3.1, N3.2; IT3.2, IT3.3.	**PS3.1, PS3.2, PS3.3.**

Content

- Review of appropriate material from AS Chemistry – Module 2813 (component 01): How Far, How Fast?, 5.3.3 Chemical Equilibrium.
- Mole fractions; partial pressures.
- The equilibrium constant K_c.
- The equilibrium constant K_p.

Candidates will **not** be required to solve quadratic equations.

Assessment outcomes

Candidates should be able to:

(a) understand and use the terms concentration, mole fraction and partial pressure.

(b) calculate a concentration or partial pressure present at equilibrium, given appropriate data.

(c) deduce, for homogeneous reactions, expressions for the equilibrium constants: K_c, in terms of concentrations, and K_p in terms of partial pressures.

(d) calculate the values of the equilibrium constants K_c or K_p, including determination of units, given appropriate data.

(e) recall that, for an equilibrium system,

  (i) changes in concentration and pressure have no effect on the magnitude of the equilibrium constant;

  (ii) an increase in temperature decreases the value of K_c or K_p for an exothermic reaction and increases the value of K_c or K_p for an endothermic reaction.

(f) understand that a large value of K_c or K_p indicates a high theoretical yield of products, and vice versa.

(g) appreciate that most organic reactions are in equilibrium.

5.11.3 Acids, bases and buffers

N3.1, N3.2; IT3.2.	

Content

- Review of appropriate material from AS Chemistry – Module 2813 (component 01): How Far, How Fast?, 5.3.3 Chemical Equilibrium.
- Brønsted-Lowry theory of acids and bases.
- pH and hydrogen ion concentration.
- Titration curves and indicators.
- Buffers: action, uses and calculations.

Candidates will **not** be required to solve quadratic equations.

Assessment outcomes

Candidates should be able to:

(a) describe and use the Brønsted-Lowry theory of acids and bases, to include conjugate acid-base pairs (see also 5.3.3(e)–(i)).

(b) define the terms pH, K_w, K_a and pK_a.

(c) calculate pH from [H^+(aq)] and [H^+(aq)] from pH

  (i) for strong monobasic acids and bases;

  (ii) for weak monobasic acids.

(d) For a weak acid HA, it can be assumed that

- *[H^+(aq)] = [A^-(aq)];*
- *the equilibrium acid concentration is approximately equal to the undissociated acid concentration.*

(e) using acid-base titration pH curves for strong and weak acids and bases,

  (i) recognise their shapes;

  (ii) deduce suitable indicators, from supplied pH ranges;

  (iii) explain why phenolphthalein is unsuitable for titrations involving weak bases and why methyl orange is unsuitable for titrations involving weak acids.

(f) explain the choice of suitable indicators for acid-base titrations, given the pH range of the indicator.

(g) explain what is meant by a *buffer solution* (as a system that minimises pH changes on addition of an acid or a base).

(h) explain the role of each component in a buffer solution (for example: CH_3COOH/CH_3COO^- and NH_4^+/NH_3) in the control of pH.

(i) calculate the pH of a buffer solution, for example: from the K_a value of a weak acid and the equilibrium concentrations of the conjugate acid–base pair.

(j) state the importance of buffer solutions for controlling pH in blood and shampoos.

6 Further Information and Training for Teachers

To support teachers using these specifications, OCR will make the following materials and services available:

- a full programme of In-Service Training (INSET) meetings.
- specimen question papers and mark schemes.
- past question papers and mark schemes after each examination session.
- coursework guidance materials, including a Chemistry Coursework Handbook.
- written advice on coursework proposals.
- individual feedback to each Centre on the moderation of coursework.
- a Report on the Examination, compiled by senior examining personnel, after each examination session.

If you would like further information about the specification, please contact OCR.

7 Reading List and Other Resources

Reading List

Introduction

The books referred to below may prove useful in delivering AS GCE and Advanced GCE Chemistry.

The list is not intended to be exhaustive nor does inclusion on the list constitute a recommendation of the suitability of the resource for the specification. The list below contains books that are available in late 2001. However, it is recognised that many new or revised books will be published to support this and other Chemistry specifications. Teachers will need to use their professional judgement in assessing the suitability of the material contained in this list.

It is not intended that teachers/candidates need refer to all the material quoted.

Cambridge University Press (CUP) have recently published their Cambridge Advanced Science series, which has been endorsed by OCR as providing complete coverage of the specification.

AS Chemistry Core:

Ratcliff B., Eccles H., Johnson D., Nicholson J., Raffan J., *Chemistry 1*, Cambridge University Press, 2000.

Eccles H., *Revise AS Chemistry for OCR Specification A*, Heinemann Educational Secondary Division, 2000.

Earl B. and Wilford L., *Introduction to Advanced Chemistry*, John Murray, 2000.

Hunt A., *AS Chemistry*, Hodder and Stoughton, 2000.

Lister T., Renshaw J., *Essential AS Chemistry for OCR*, Stanley Thornes 2004.

Ritchie R., *Revise AS Chemistry*, Letts Educational, 2000.

A2 Chemistry Core:

Ratcliff B., Eccles H., *Chemistry 2*, Cambridge University Press, 2001.

Ritchie R., *A2 Revise Study Guide: Chemistry*, Letts Educational, 2001.

Earl B. and Wilford L., *Further Advanced Chemistry*, John Murray, 2001.

Facer G., Do *Brilliantly at ... A2 Chemistry*, Collins, 2002.

Lister T., Renshaw J., *Essential A2 Chemistry for OCR*, Stanley Thornes 2004.

A2 Chemistry Options:

McCarthy A., *Methods of Analysis and Detection*, Cambridge University Press, 2001.

Harwood R., *Biochemistry*, Cambridge University Press, 2002.

Winfield A., *Environmental Chemistry*, Cambridge University Press, 2000.

Matthews P., *Gases, Liquids and Solids*, Cambridge University Press, 2002.

Acaster D., *Transition Elements*, Cambridge University Press, 2001.

Subject Core and Options

Atkins P., Jones L., *Chemistry Molecules, Matter and Change*, Freeman, 1997.

Conoley C. and Hills P., Collins *Advanced Science: Chemistry*, Collins Educational, 1998.

Clugston M. and Flemming R., *Advanced Chemistry*, Oxford University Press, 2000.

Freemantle M. H., *Chemistry in Action*, Thomson Learning, 2000.

Hill G., Holman J., *Chemistry in Context (5th Edition)*, Nelson Thornes, 2001.

Hunt A., *Complete A-Z Chemistry Handbook*, Hodder & Stoughton Educational, 2000.

Lewis B. and Berry M., *AS and A Level Chemistry*, Longman, 2000.

Lister T. and Renshaw J., *Chemistry for Advanced Level: Course Study Guide*, Stanley Thornes, 2000.

Lewis M., *Chemistry A-Level Through Diagrams*, Oxford University Press, 2001.

McMonagle D., *Advanced Level Study Aids – Chemistry*, John Murray, 2002.

McMurry J., *Chemistry*, Prentice Hall, 2001.

Parsonage M., *Facts and Practice for A-level: Chemistry*, Oxford University Press, 2001.

Ramsden E.N. *A Level Chemistry,* Stanley Thornes, 2000

Ritchie R. and Sadler J., *A Level Exam Practice: Chemistry*, Letts Educational Ltd, 2001.

Ryan L., *Advanced Chemistry for You,* Nelson Thornes, 2000.

Salters' *Advanced Chemistry: Chemical Ideas*, Heinemann Educational Secondary Division, 2000.

Salters' *Advanced Chemistry: Chemical Storylines*, Heinemann Educational Secondary Division, 2000.

Salters' *Advanced Chemistry: Activities and Assessment Pack*, Heinemann Educational Secondary Division, 2000.

Salters' *Advanced Chemistry: Teacher's and Technician's Guide*, Heinemann Educational Secondary Division, 2000.

Vokins M., *Nuffield Advanced Chemistry: Students' Book*, Longman, 2000.

Vokins M., *Nuffield A Level Chemistry: Teacher's Guide*, Longman, 2000.

Calculations

Clark J., *Calculations in A Level Chemistry*, Longman, 2000.

Ramsden E.N., *Calculations for A-level Chemistry*, Stanley Thornes, 2001.

Barwick V., Prichard E*, Introducing Measurement Uncertainty*, Laboratory of the Government Chemist, 2003.

Prichard E., *Introduction to Measurement Terminology*, Laboratory of the Government Chemist, 2004.

Data Books

Chemistry: Book of Data, Nuffield-Chelsea Curriculum Trust, Longman, 1984.

General Interest

Atkins P., *Atkins Molecules*, Cambridge University Press, 2004

Emsley J., *Molecules at an Exhibition*, Oxford Paperbacks, 1999.

Emsley J., *Nature's Building Blocks - An A-Z Guide to the Elements*, Oxford University Press, 2001.

Collins Gem Chemical Elements, Collins, 2001.

The age of the molecule, Royal Society of Chemistry, 2000

Sharp D.W.A. (Editor), *The Penguin Dictionary of Chemistry*, Penguin Books, 1990.

Lister T., *Cutting Edge Chemistry*, Royal Society of Chemistry, 2000.

CD Roms for Chemistry

Chemistry Set
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Interactive Periodic Table
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Royal Society of Chemistry
1. Spectroscopy for Schools and Colleges
2. Practical Chemistry for Schools and Colleges.
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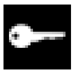
Stanley Thornes *Essential A2 Chemistry for OCR* Teacher CD-ROM

Appendix A

Key Skills

These specifications provide opportunities for the development of the Key Skills of *Communication, Application of Number, Information Technology, Working With Others, Improving Own Learning and Performance* and *Problem Solving* as required by the QCA Subject Criteria for Chemistry (1999).

Through classwork, coursework and preparation for external assessment, candidates may produce evidence for Key Skills at Level 3. However, the extent to which this evidence fulfils the requirements of the QCA Key Skills specifications at this level will be dependent on the style of teaching and learning adopted for each module. In some cases, the work produced may meet the evidence requirements of the Key Skills specifications at a higher or lower level.

Throughout section 5 the symbol  is used in the margin to highlight where Key Skills development opportunities are signposted. The following abbreviations are used to represent the above Key Skills:

C = Communication

N = Application of Number

IT = Information Technology

WO = Working with Others

LP = Improving Own Learning and Performance

PS = Problem Solving

These abbreviations are taken from the QCA Key Skills specifications for use in programmes starting from September 2000. References in section 5 and Appendix A , for example **IT3.1**, show the Key Skill (IT), the level (3) and subsection (1).

Centres are encouraged to consider the OCR Key Skills scheme to provide certification of Key Skills for their students.

Detailed opportunities for generating Key Skills evidence through this specification are posted on the OCR website, www.ocr.org.uk.

Key Skills Coverage

For each module, the following matrix indicates those Key Skills for which opportunities for at least some coverage of the relevant Key Skills unit exist.

Module	Communication	Application of number	IT	Working with Others	Learning Performance	Problem Solving
	Level 3	Level 3	Level 3	Level 3	Level 3	Level 3
2811	✓	✓	✓	✓	✓	✓
2812	✓	✓	✓	✓	✓	✓
2813	✓	✓	✓	✓	✓	✓
2814	✓	✓	✓	✓	✓	
2815	✓	✓	✓	✓	✓	✓
2816	✓	✓	✓	✓	✓	✓

Appendix B

Notes for Guidance on Coursework Assessment and Submission

This Appendix is intended to provide guidance for teachers in assessing experimental and investigative skills, but should not exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. It is not expected that all of the practical work undertaken by candidates would be appropriate for assessment.

For examples of suitable tasks for assessing practical skills, and for examples of possible individual studies, teachers should refer to the Chemistry Coursework Handbook. Copies can be ordered from the OCR Publications Department.

The experimental and investigative skills to be assessed are:

P Planning;

I Implementing;

A Analysing Evidence and Drawing Conclusions;

E Evaluating Evidence and Procedures.

It is expected that candidates will have had opportunities to acquire experience and develop the relevant skills before assessment takes place.

The skills may be assessed at any time during the course using suitable practical activities based on laboratory work, related to or part of the content of the teaching course. The context(s) for the assessment of the coursework for the AS Component 02 should be drawn from the content of the AS modules, 2811: Foundation Chemistry, 2812: Chains and Rings and 2813 (component 01): How Far, How Fast? The context(s) for the assessment of the coursework for the A2 2816 (component 02) should be drawn from the content of the A2 modules, 2814: Chains, Rings and Spectroscopy, 2815: Trends and Patterns/Options and 2816 (component 01): Unifying Concepts in Chemistry in which the level of demand of the related scientific knowledge and understanding is higher.

In AS GCE and in A2 the skills may be assessed in the context of separate practical exercises, although more than one skill may be assessed in any one exercise. They may also be assessed all together in the context of a single 'whole investigation' in which the task is set by the teacher, or using individual investigations in which each candidate pursues his or her own choice of assignment.

Skills **P** and **A** are marked out of 8 and Skills **I** and **E** are marked out of 7. Thus, for each candidate entered for 2813 (component 02), and for 2816 (component 02), Centres are required to award **one** mark for each of Skills **P**, **I**, **A** and **E**. Hence the maximum raw mark available for each component is 30. These marks are then doubled so that the final marks submitted are out of 60.

When a skill has been assessed on more than one occasion, in AS or in A2, the better or best mark for that skill should be submitted. However, Centres are recommended **not** to assess the skills on more than two occasions in each of AS GCE and A2 since this may take up time which might better be devoted to other aspects of the specification. In each of AS and A2 the time required for the internal assessment of experimental and investigative skills is normally expected to be between 5 and 10 hours.

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

The Demand of an Activity

The demand of an activity is an important feature of the assessment. From the bottom to the top of the mark range in a skill area the activity should involve increasing demands of associated scientific knowledge and understanding, manipulation, precision and accuracy and complexity.

The difference in standard of AS and A2 is a product of the level of demand of the related scientific knowledge and understanding and the complexity and level of demand of the tasks set. In A2, candidates are required to apply knowledge, understanding and skills from the AS and A2 parts of the Advanced GCE specification in planning experimental work and in the evaluation of data (synoptic assessment). Details of the way in which tasks can be differentiated are given in Section 4.2 and further guidance on setting appropriate tasks is given in the Coursework Handbook published separately.

Teachers should appreciate that the choice of an activity which is comparatively undemanding (primarily in terms of the level of the scientific knowledge and understanding which can be linked to the activity and in the range/complexity of the equipment/techniques used) may prevent access to the highest marks.

Teachers should be aware of this feature of the assessment so that, when considering the award of higher marks, the activity should require a sophisticated approach and/or complex treatment. Higher marks must not be awarded for work which is simplistic or trivial.

One of the factors that determines the demand of an activity is the level of guidance given to candidates. The use of a highly structured worksheet, for example, will reduce the number of decisions and judgements required by the candidate and so will limit the range of marks available.

Marking Candidates' Work

A similar set of mark descriptors is used for AS and A2 (see Appendix C). The descriptors should be used to make a judgement as to which mark best fits a candidate's performance.

The descriptors have been written to provide clear continuity from the assessment of Sc1 for GCSE. This should ensure an effective continuation of the development of candidates' skills from GCSE to AS GCE and Advanced GCE in Chemistry.

The mark descriptors within a skill area have been written to be hierarchical. Thus, in marking a piece of work, the descriptors for the lowest defined mark level should be considered first and only if there is a good match should the descriptors for the next level up be considered.

Therefore, if a teacher is considering the award of a high mark for a piece of work, the work must have demonstrated a good match to all the lower mark descriptors.

For each skill the scheme allows the award of intermediate marks (between the defined mark levels). An intermediate mark may be awarded when the work of a candidate exceeds the requirements of a defined mark level but does not meet the requirements of the next higher defined mark level sufficiently to justify its award. Thus, an intermediate mark could be awarded if the work meets only one of the two descriptors at the higher defined mark level, provides a partial match to both or provides a complete match to one and a partial match to the other.

In Skills **P** and **A**, a mark above the highest defined mark level should be awarded for work which meets all the requirements of the descriptors for the highest defined mark level and is judged to be of exceptional merit in terms of originality, depth, flair or the use of novel or innovative methods.

A mark of zero should be awarded where there has been an attempt to address the skill but the work does not meet the requirements of the lowest defined mark level.

The marks awarded should be based on both the final written work and the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of any guidance needed by, or given to, the candidate.

In defining the various mark descriptors it is recognised that practical tasks vary widely, both in the experimental procedures used, and in the nature of the observations and measurements which may be made by the candidate. The mark descriptors for each defined level are intended to provide guidance to teachers on how to recognise levels of achievement. It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular defined level **must** be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements.

Synoptic Assessment

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the specification. Assessment Objective AO4 relates specifically to synoptic assessment and marks from the A2 Coursework Component (F2) contribute to the assessment of AO4 .

During experimental and investigative work, synoptic assessment

- allows candidates to apply knowledge and understanding of principles and concepts of chemistry from different parts of the specification in planning experimental work and in the analysis and evaluation of data;
- allows candidates to apply skills and techniques learned during the course.

All practical work assessed internally by centres for the A2 unit 2816 (component 02) should draw on the range of experience that the candidate acquired during the AS and A2 courses. It is particularly important that an exercise used to evaluate planning skills should involve an element of research which goes beyond the repetition of an experiment that simply reflects the use of ideas or techniques met within the module, currently being studied. Likewise an assessment that involves analysing evidence and drawing conclusions must require a candidate to use knowledge and understanding acquired outside the confines of a standard experiment recently practised. During the process of moderation, evidence will be sought that such breadth has been achieved.

The assessment descriptors for the skills of Planning (**P**) and Analysing Evidence and Drawing Conclusions (**A**), include statements that relate specifically to synoptic assessment. These are shown in bold and should be applied only when assessing A2 work. Thus, in A2, a candidate will not be able to achieve more than 2 marks in each of Skills **P** and **A** without demonstrating aspects of synoptic assessment. Candidates should also bring to the assessment of Skill **I** (Implementing) their experience of practical and investigative work from throughout the course. In Skill **E** (Evaluating Evidence and Procedures) aspects of Skills **P** and **A** are evaluated. Overall, in A2, approximately 15 of the 30 available marks can thus be identified as contributing to an assessment of AO4 (synoptic assessment).

Quality of Written Communication

Coursework must include an assessment of candidates' quality of written communication. At Level 3 candidates are required to:

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

The mark descriptors for Skills **P** and **A** have been written to include these aspects and these skills carry an additional mark each in recognition of this.

Annotation of Candidates' Work

Each piece of assessed coursework must be annotated to show how the marks have been awarded in relation to the relevant skills.

The writing of comments on candidates' work can provide a means of dialogue and feedback between teacher and candidate and a means of communication between teachers during internal standardisation of coursework. The main purpose of annotating candidates'

coursework should be, however, to provide a means of communication between teacher and the Moderator, showing where marks have been awarded and why. The sample of work which is submitted for moderation **must** show how the marks have been awarded in relation to the marking criteria.

Annotations should be made at appropriate points in the margins of the text. The annotations should indicate both where achievement for a particular skill has been recognised and the mark awarded. It is suggested that the minimum that is necessary is that the 'shorthand' mark descriptors (for example, P.5a, I.3b) should be written at the point on the script where it is judged that the work has met the descriptors concerned.

For Skill **I** Implementing, more detail is necessary and the Moderator will require evidence concerning candidates' use of practical techniques and safe working practice. This evidence could take the form of checklists or written notes.

Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for AS and Advanced GCE this is likely to be the education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters.

Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of *Safety in Science Education* (see below). For members, the CLEAPSS guide, *Managing Risk Assessment in Science* offers detailed advice.

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

Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X;

Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2;

Hazcards, 1995, CLEAPSS School Science Service*;

Laboratory Handbook, 1988-97, CLEAPSS School Science Service*;

Topics in Safety, 2nd edition, 1988, ASE ISBN 0 86357 104 2;

Safety Reprints, 1996 edition, ASE ISBN 0 86357 246 4.

Hazardous Chemicals, A Manual for Science Education, 1997, SSERC Limited ISBN 0 9531776 0 2

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

(Other publications have sometimes been suggested, e.g. the DES *Microbiology, an HMI Guide for Schools and FE,* but this is now out of print).

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting the CLEAPSS School Science Service (or, in Scotland, SSERC).

When candidates are planning their own practical activities, whether in project work or more routine situations, the teacher or lecturer has a duty to check the plans before practical work starts and to monitor the activity as it proceeds.

Support Material

For examples of suitable tasks for assessing practical skills during AS and A2, and for examples of possible individual studies, teachers should refer to the Chemistry Coursework Handbook. Copies can be ordered from the OCR Publications Department.

The handbook also contains

- detailed mark schemes that clearly demonstrate the different standards required for AS and A2 coursework;
- details of how synoptic assessment can be achieved within A2 coursework;
- a list of activities that may allow candidates to be assessed via a single, more extended, investigation for their assessed coursework.

AS and A2 Summary Grids outlining the practical tasks included in this publication are shown below.

AS - Exemplar Summary Grid

Practical task	Skill P	Skill I	Skill A	Skill E
Which equation is correct?	✓			
To determine the concentration of a lime water solution.	✓		✓	
Determination of the relative atomic mass of lithium.		✓	✓	✓
Hydrolysis of halogenoalkanes.	✓			
To determine the enthalpy change of a reaction.			✓	✓
The oxidation of ethanol.		✓		

A2 - Exemplar Summary Grid

Practical task	Skill P	Skill I	Skill A	Skill E
Identification of an organic unknown.	✓		✓	
Preparation of the pharmaceutical, antefebrin.		✓		
The estimation of iron(II) and iron (III) in a mixture containing both.	✓		✓	
The preparation of ions containing vanadium in two oxidation states.		✓		
Preparation of tin (IV) iodide.		✓		
The determination of an equilibrium constant.			✓	✓
The determination of a rate equation.	✓		✓	✓

Appendix C

Mark Descriptors for Experimental and Investigative Skills

In defining the various mark descriptors, it is recognised that practical tasks vary widely, both in the experimental procedures used and in the nature of the observations and measurements which may be made by the candidate. The mark descriptors within each defined level are intended to provide guidance to teachers on how to recognise levels of achievement.

It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular level **must** be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements.

For examples of suitable tasks for assessing practical skills, and for examples of possible individual studies, teachers should refer to the Chemistry Coursework Handbook. Copies can be ordered from the OCR Publications Department.

Skill P – Planning		Total 8
Mark	**Descriptor**	**The candidate:**
0		
1	P.1a	develops a question or problem in simple terms and plans a fair test or an appropriate practical procedure, making a prediction where relevant.
	P.1b	chooses appropriate equipment.
2		
3	P.3a	develops a question or problem using scientific knowledge and understanding **drawn from more than one area of the specification**; identifies the key factors to vary, control or take account of.
	P.3b	decides on a suitable number and range of observations and/or measurements to be made.
4		
5	P.5a	uses detailed scientific knowledge and understanding **drawn from more than one module of the specification** and information from preliminary work or a secondary source to plan an appropriate strategy, taking into account the need for safe working and justifying any prediction made.
	P.5b	describes a strategy, including choice of equipment, which takes into account the need to produce precise and reliable evidence; produces a clear account and uses specialist vocabulary appropriately.
6		
7	P.7a	retrieves and evaluates information from a variety of sources, and uses it to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specification**; uses spelling, punctuation and grammar accurately.
	P.7b	justifies the strategy developed, including the choice of equipment, in terms of the need for precision and reliability.
8		

The statements in bold represent additional requirements when assessing Unit 2816 Component 02 work; they are not to be used for Unit 2813 Component 02.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Skill I- Implementing		Total 7
Mark	**Descriptor**	**The candidate:**
0		
1	**I.1a**	demonstrates competence in simple techniques and an awareness of the need for safe working.
	I.1b	makes and records observations and/or measurements which are adequate for the activity.
2		
3	**I.3a**	demonstrates competence in practised techniques and is able to manipulate materials and equipment with precision.
	I.3b	makes systematic and accurate observations and/or measurements which are recorded clearly and accurately.
4		
5	**I.5a**	demonstrates competence and confidence in the use of practical techniques; adopts safe working practices throughout.
	I.5b	makes observations and/or measurements with precision and skill; records observations and/or measurements in an appropriate format.
6		
7	**I.7a**	demonstrates skilful and proficient use of all techniques and equipment.
	I.7b	makes and records all observations and/or measurements in appropriate detail and to the degree of precision permitted by the techniques or apparatus.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. Descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Skill A - Analysing Evidence and Drawing Conclusions		Total 8
Mark	**Descriptor**	
0		The candidate:
1	**A.1a**	carries out some simple processing of the evidence collected from experimental work.
	A.1b	where appropriate, identifies trends or patterns in the evidence and draws simple conclusions.
2		
3	**A.3a**	processes and presents evidence gathered from experimental work including, where appropriate, the use of appropriate graphical and/or numerical techniques.
	A.3b	links conclusions drawn from processed evidence with the associated scientific knowledge and understanding **drawn from more than one area of the specification**.
4		
5	**A.5a**	carries out detailed processing of evidence and analysis including, where appropriate, the use of advanced numerical techniques such as statistics, the plotting of intercepts or the calculation of gradients.
	A.5b	draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding **drawn from more than one module of the specification**; produces a clear account which uses specialist vocabulary appropriately.
6		
7	**A.7a**	where appropriate, uses detailed scientific knowledge and understanding **drawn from different parts of the AS and A2 specification** to make deductions from the processed evidence, with due regard to nomenclature, terminology and the use of significant figures (where relevant).
	A.7b	draws conclusions which are well structured, appropriate, comprehensive, and concise and which are coherently linked to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specification**; uses spelling, punctuation and grammar accurately.
8		

The statements in bold represent additional requirements when assessing Unit 2816 Component 02 work; they are not to be used for Unit 2813 Component 02.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. Descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Skill E - Evaluating Evidence and Procedure		Total 7
Mark	**Descriptor**	
0		The candidate:
1	**E.1a**	makes relevant comments on the suitability of the experimental procedures.
	E.1b	recognises any anomalous results.
2		
3	**E.3a**	recognises how limitations in the experimental procedures and/or strategy may result in sources of error.
	E.3b	comments on the accuracy of the observations and/or measurements, suggesting reasons for any anomalous results.
4		
5	**E.5a**	indicates the significant limitations of the experimental procedures and/or strategy and suggests how they could be improved.
	E.5b	comments on the reliability of the evidence and evaluates the main sources of error.
6		
7	**E.7a**	justifies proposed improvements to the experimental procedures and/or strategy in terms of increasing the reliability of the evidence and minimising significant sources of error.
	E.7b	assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.

Both statements at a defined level must be satisfied in order that the mark for this level is awarded. Descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

Appendix D

Notes for Guidance on Practical Examinations

Experimental Skills: AS

Unit 2813, Component 03: Practical Examination 1

The questions in this paper is set in the same general context as that used for the preliminary planning exercise (see Section 4.2), External Assessment (Practical Examination option).

The questions in the practical paper may include the following exercises.

(a) A volumetric analysis problem, based on one set of titrations.

A knowledge of volumetric determinations involving acids and alkalis will be assumed.

(b) An experiment that may involve

- the direct or indirect determination of the enthalpy change for a reaction;
- reacting molar ratios;
- a formula determination;
- reaction rates (candidates will **not** be expected to determinate the order of a reaction or a rate constant);
- an observational problem in which the candidate will be asked to investigate, by specified experiments, an unknown substance or mixture.

Such experiments depend on the use of usual laboratory apparatus (see below).

Candidates may also be required to carry out simple calculations as detailed in the specification.

Systematic analysis and knowledge of traditional methods of separation will **not** be required but it will be assumed that candidates will be familiar with:

- the tests for the anions: chloride, bromide, iodide and carbonate;
- the tests for unsaturation (bromine), the presence of an ester (fruity smell), the presence of a primary or secondary alcohol (oxidation with $Cr_2O_7^{2-}/H^+$).

Exercises involving organic substances and ions not on the list above may be set but candidates will only be required to make observations and draw general conclusions. Any additional information required by candidates will be supplied on the examination paper.

Further details of the practical techniques required and the expected accuracy, are given later in this appendix.

Experimental Skills: A2

Unit 2816, Component 03: Practical Examination 2

One of the questions in this paper will be set in the same general context as that used for the preliminary planning exercise (see section 4.2), External Assessment (Practical Examination option).

The questions in the practical paper may include the following exercises.

(a) A volumetric analysis problem, based on one set of titrations.

A knowledge of the following volumetric determinations will be assumed:

- an acid/base titration;
- iron(II), by potassium manganate(VII).

Titrations involving other reagents may be set but full instructions and other necessary information would be provided.

(b) An experiment that may involve the determination of some physical quantity, for example

- the determination of a rate constant or the order of a reaction;
- the direct or indirect determination of the enthalpy change for a reaction.

Such experiments depend on the use of usual laboratory apparatus (see later in this appendix).

Candidates may also be required to carry out simple calculations as detailed in the specification.

(c) An observational problem in which the candidate will be asked to investigate, by specified experiments, an unknown substance or mixture.

Systematic analysis and a knowledge of traditional methods of separation will not be required but it will be assumed that candidates will be familiar with:

- the tests for the anions: chloride, bromide, iodide and carbonate;
- the test for unsaturation (bromine), an aldehyde (Tollens' reagent), the presence of an ester (fruity smell), the presence of a primary or secondary alcohol (oxidation with $Cr_2O_7^{2-}/H^+$).

Exercises involving organic substances and ions not on the list above may be set but candidates will only be required to make observations and draw general conclusions.

Further details of the practical techniques required and the expected accuracy, given later in this appendix.

Practical Techniques

The following notes are intended to give schools and colleges and their candidates an indication of the accuracy that is expected in quantitative exercises and general instructions for qualitative exercises.

(a) Candidates should normally record burette readings to the nearest 0.05 cm^3 and they should ensure that they have carried out a sufficient number of titrations, for example: in an experiment with a good end-point, two titres within 0.10 cm^3.

(b) Candidates should normally record:

- weighing to the nearest 0.01 g,
- temperature readings estimated to the nearest 0.5 °C (from a thermometer graduated to 1 °C),
- times to the nearest second.

(c) In observational exercises candidates should use approximately 1 cm depth of solution (1-2 cm^3) for each test and add reagents slowly, ensuring good mixing, until no further change is seen. Candidates should indicate at what stage a change occurs, writing any deductions alongside the observation on which they are based. Answers should include details of colour changes and precipitates formed and the names and chemical tests for any gases evolved in observational exercises, equations are not required.

Marks for deductions or conclusions can only be gained if the appropriate observations are recorded.

Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for AS and Advanced GCE this is likely to be the education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters.

Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful micro-organisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of *Safety in Science Education* (see below). For members, the CLEAPSS guide, *Managing Risk Assessment in Science* offers detailed advice.

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Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting the CLEAPSS School Science Service (or, in Scotland, SSERC).

When candidates are planning their own practical activities, whether in project work or more routine situations, the teacher or lecturer has a duty to check the plans before practical work starts and to monitor the activity as it proceeds.

Apparatus List

This list given below has been drawn up in order to give guidance to schools and colleges concerning the apparatus that is expected to be generally available for examination purposes. The list is not intended to be exhaustive: in particular, items (such as Bunsen burners, tripods, glass-tubing) that are commonly regarded as standard equipment in a chemical laboratory are not included. Unless otherwise stated, the rate of allocation is "per candidate".

Two burettes, 50 cm^3

Two pipettes, 25 cm^3

One pipette, 10 cm^3

Dropping pipette

One pipette filler

Conical flasks: 3 within range 150 cm^3 to 250 cm^3

Volumetric flask, 250 cm^3

Measuring cylinders, 25 cm^3 and 50 cm^3

Wash bottle

Two filter funnels

Porcelain crucible, approximately 15 cm^3, with lid

Evaporating basin, at least 30 cm^3

Beakers, squat form with lip: 100 cm^3, 250 cm^3

Thermometers: –10 °C to +110 °C at 1 °C;

–5 °C to +50 °C at 0.2 °C

Plastic beaker or any other suitable alternative

Clocks (or wall-clock) to measure to an accuracy of about 1 s. (Where clocks are specified, candidates may use their own wrist watches if they prefer.)

Balance, single-pan, direct reading, 0.01 g or better (1 per 8-12 candidates).

Thermometer Suppliers for -5 to 50°C (x 0.2)

Beecroft
Northfield Road
S60 1RR
Tel: 01709 377881
E-mail: sales@beecroft-science.co.uk
Cat. No. NT67, -5 to 50°C (x 0.2)

Analytical Supplies
Duffield Road
Little Eaton
Eaton
DE21 5DR
Tel: 01332 831671
E-mail: sales@asl-supplies.co.uk
Cat No. THE302, -5 to 50°C (x 0.2)

Philip Harris
Novara House
Excelsior Road
Ashby Park
Ashby de la Zouch
Leicestershire
LE65 1NG
Tel: 0870 6000 193
E-mail: orders@philipharris.co.uk
Cat No. A 86101, -5 to 105°C (x 0.2)

Appendix E

Mathematical Requirements

In order to be able to develop the knowledge, understanding and skills in section 5, candidates need to have been taught and to have acquired competence in the areas of mathematics set out below.

Arithmetic and Computation

For AS GCE and Advanced GCE in Chemistry, 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 $\log_{10}x$.

For A2 units only, candidates should also be able to:

- **use calculators to find and use x^n, $1/x$, e^x.**

Handling Data

For AS and Advanced GCE in Chemistry, candidates should be able to:

- use an appropriate number of significant figures;
- find arithmetic means and medians;
- construct and interpret bar charts, pie charts and histograms;
- use a technique for smoothing a set of data;
- understand the use of scatter plots to identify a relationship between two variables;
- interpret and use logarithmic scales.

Algebra

For AS and Advanced GCE in Chemistry, candidates should be able to:

- understand and use the following symbols: $<$, $>$, Δ, $\approx$, $\propto$;
- understand and 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;
- use logarithms in relation to quantities which range over several orders of magnitude.

Geometry

For AS and Advanced GCE in Chemistry, candidates should be able to:

- appreciate angles and shapes in regular 2-D and 3-D structures;
- visualise and represent 2-D and 3-D forms including two dimensional representations of 3-D objects;
- understand the symmetry of 2-D shapes.

For A2 units only, candidates should also be able to:

- **understand the symmetry of 3-D shapes.**

Graphs

For AS and Advanced GCE in Chemistry, 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;
- understand that $y = mx + c$ represents a linear relationship;
- determine the slope and intercept of a linear graph;

For A2 units only, candidates should also be able to:

- **draw and use the slope of a tangent to a curve as a measure of rate of change.**

Appendix F

Glossary of Terms used in Question Papers

It is hoped that the glossary will prove helpful to candidates as a guide, although it is not exhaustive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context. They should also note that the number of marks allocated for any part of a question is a guide to the depth of treatment required for the answer.

(a) *Define* (*the term[s]*)... is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, being required.

(b) *Explain* / *What is meant by*... normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

(c) *State* ... implies a concise answer with little or no supporting argument, for example, a numerical answer that can be obtained by 'inspection'.

(d) *List* ... requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.

(e) *Describe* ... requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended should be interpreted in the light of the indicated mark value.

(f) *Discuss* ... requires candidates to give a critical account of the points involved in the topic.

(g) *Deduce* / *Predict* ... implies that candidates are not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question. Predict also implies a concise answer with no supporting statement required.

(h) *Outline* … implies brevity, i.e. restricting the answer to giving essential detail only.

(i) *Suggest* ... is used in two main contexts. It may either imply that there is no unique answer or that candidates are expected to apply their general knowledge to a 'novel' situation, one that formally may not be 'in the syllabus'.

(j) *Calculate* ... is used when a numerical answer is required. In general, working should be shown.

(k) *Measure* ... implies that the quantity concerned can be directly obtained from a suitable measuring instrument, for example, mass using a balance, or volume using a burette.

(l) *Determine* ... often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, for example, an energy change from $mc\Delta T$.

(m) *Show* ... is used when an algebraic deduction has to be made to prove a given equation. It is important that the terms being used by candidates are stated explicitly.

(n) *Estimate* ... implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

(o) *Sketch* ... when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, for example, passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

(p) *Sketch* ... when applied to diagrams, implies that a simple, freehand drawing is acceptable. Nevertheless, care should be taken over proportions and the clear exposition of important details.

Special Note

Units, significant figures. Candidates should be aware that misuse of units and/or significant figures is liable to be penalised. Candidates are expected to quote units wherever necessary and to quote answers to an appropriate number of significant figures. The number of significant figures used in a numerical problem should be used as a guide to candidates.

Appendix G

Data Sheet

Data Sheet for Chemistry

GCE Advanced Level and AS

Chemistry 3882, 7882

Units 2811 –2816

These data are for the use of candidates following Chemistry 3882 or 7882.

Clean copies of this sheet must be issued to candidates in the examination room, and must be given up to the invigilator at the end of the examination.

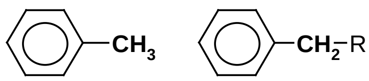
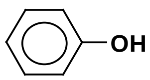
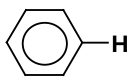
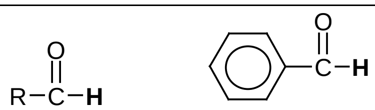
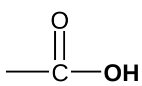
Copies of this sheet may be used for teaching

Characteristic infra-red absorptions in organic molecules

Bond	Location	Wavenumber
C–O	alcohols, esters	1000 – 1300 cm^{-1}
C=O	aldehydes, ketones, carboxylic acids, esters	1680 – 1750 cm^{-1}
O–H	hydrogen bonded in carboxylic acids	2500 – 3300 cm^{-1} (broad)
N–H	primary amines	3100 – 3500 cm^{-1}
O–H	hydrogen bonded in alcohols,	3230 – 3550 cm^{-1}
O–H	free	3580 – 3670 cm^{-1}

Chemical shifts for some types of protons in n.m.r. spectra

- Chemical shifts are for hydrogen relative to TMS (tetramethylsilane)
- Chemical shifts are typical values and can vary slightly depending on the solvent, concentration and substituents.

Type Of Proton	Chemical Shift, δ
R–$\mathbf{CH_3}$	0.7–1.6
R–CH_2–R	1.2–1.4
R_3**CH**	1.6–2.0
	2.0–2.9
	2.3–2.7
–O–$\mathbf{CH_3}$ –O–$\mathbf{CH_2}$–R	3.3–4.3
R–**OH**	3.5–5.5
	6.5–7.0
	7.1–7.7
	9.5–10
	11.0–11.7

The Periodic Table of the Elements

Key

relative atomic mass
atomic symbol
name
atomic number

Group

1	2											3	4	5	6	7	0
							1.0 H hydrogen 1										4.0 He helium 2
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12											27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulphur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	– Tc technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54
133 Cs caesium 55	137 Ba barium 56	139 La lanthanum 57 *	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	– Po polonium 84	– At astatine 85	– Rn radon 86
– Fr francium 87	– Ra radium 88	– Ac actinium 89 **	– Rf rutherfordium 104	– Db dubnium 105	– Sg seaborgium 106	– Bh bohrium 107	– Hs hassium 108	– Mt meitnerium 109	– Unn ununnilium 110	– Uuu unununium 111	– Uub ununbium 112		– Uuq ununquadium 114		– Uuh ununhexium 116		– Uuo ununoctium 118

lanthanides *	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	– Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
actinides **	– Th thorium 90	– Pa protactinium 91	– U uranium 92	– Np neptunium 93	– Pu plutonium 94	– Am americium 95	– Cm curium 96	– Bk berkelium 97	– Cf californium 98	– Es einsteinium 99	– Fm fermium 100	– Md mendelevium 101	– No nobelium 102	– Lr lawrencium 103