

Specification

GCE Chemistry

Pearson Edexcel Level 3 Advanced Subsidiary GCE in
Chemistry (8CH01)
First examination 2014

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(9CH01)
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Issue 5

About this specification

The Edexcel Advanced Subsidiary/Advanced Level GCE in Chemistry is designed for use in school and colleges and it is part of a suite of GCE qualifications offered by Edexcel.

Key features of the specification

A practical specification

Studying the GCE in Chemistry should be a practical experience for students. This specification contains practical activities embedded within each unit, to reflect the nature of chemistry. This will increase students' enjoyment and understanding of chemistry together with providing them with the skills needed to study science at higher levels.

The practical skills assessment at Advanced Subsidiary and Advanced Level reflect the types of practical activities that students would be familiar with as part of their teaching and learning. These are designed to be assessed alongside the teaching of the units. However, they are flexible and can be taken at any point during the Advanced Subsidiary or Advanced Level course.

Glossary of terms

A glossary of terms is provided in the support materials.

Why choose this specification?

Edexcel's GCE Chemistry specification is a motivating specification.

The specification enables motivating contemporary chemistry contexts to be included in the teaching and learning programme. It is designed to motivate both teachers and students, to encourage more students to study chemistry and to encourage teachers to update the content that they deliver.

Students will study aspects of chemistry that are often in the media and affect their lives. It is important that students have the necessary knowledge and understanding to explain many different aspects of contemporary chemistry. These areas include:

- climate change
- green chemistry
- pharmaceuticals
- chemistry research.

These contexts are given as examples within the units so they can be updated or expanded upon by teachers over the lifetime of this qualification.

The content of this specification includes the fundamental key concepts of chemistry needed for progression into higher education and employment. However, it has been streamlined to allow students enough time to study the units in depth. This ensures that the teaching and learning experience is enjoyable.

Supporting you

Edexcel aims to provide comprehensive support for our qualifications. We have, therefore, published our own dedicated suite of resources for teachers and students written by qualification experts. We also endorse a wide range of materials from other publishers to give you a choice of approach.

Specification updates

This specification is Issue 5 and is valid for examination from Summer 2014. If there are any significant changes to the specification Edexcel will write to centres to let them know. Changes will also be posted on our website. For more information on our wide range of support and services for this qualification please visit www.edexcel.com/or our GCE website www.edexcel.com/gce2008.

Contents

A	Specification at a glance	4
B	Specification overview	11
	Summary of assessment requirements	11
	Assessment objectives and weightings	14
	Relationship of assessment objectives to units	15
	Qualification summary	15
C	Chemistry unit content	19
	Course structure	20
	Unit 1 The Core Principles of Chemistry	21
	Unit 2 Application of Core Principles of Chemistry	33
	Unit 3 Chemistry Laboratory Skills I	47
	Unit 4 General Principles of Chemistry I – Rates, Equilibria and Further Organic Chemistry	51
	Unit 5 General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry	65
	Unit 6 Chemistry Laboratory Skills II	77
D	Assessment and additional information	83
	Assessment information	83
	Additional information	88

E	Resources, support and training	91
	Resources to support the specification	91
	Edexcel's own published resources	91
	Edexcel publications	91
	Additional resources endorsed by Edexcel	92
	Edexcel support services	93
	Training	94
F	Appendices	95
	Appendix 1 Performance descriptions	97
	Appendix 2 Wider curriculum	103
	Appendix 3 Codes	105
	Appendix 4 How Science Works – mapping and expansion on specification content	107
	Appendix 5 Mathematical requirements mapping	119
	Appendix 6 The periodic table of the elements	121
	Appendix 7 Mapping of internal assessment activities to the units	123
	Appendix 8 Further resources and support	125

A Specification at a glance

AS Unit 1: The Core Principles of Chemistry

*Unit code 6CH01

- Externally assessed
- Availability: June

40%
of the
total AS
marks

20% of
the total
GCE
marks

Content summary:

This unit provides opportunities for students to develop the basic chemical skills of formulae writing, equation writing and calculating chemical quantities. The study of energetics in chemistry is of theoretical and practical importance. In this unit students learn to define, measure and calculate enthalpy changes. They will see how a study of enthalpy changes can help chemists to understand chemical bonding. The study of atomic structure introduces s, p, and d orbitals and shows how a more detailed understanding of electron configurations can account for the arrangement of elements in the periodic table. The unit introduces the three types of strong chemical bonding (ionic, covalent and metallic). Organic chemistry is also introduced with students studying alkanes and alkenes.

Assessment:

Examination of 1 hour 30 minutes in two sections.

Section A: objective test questions.

Section B: mixture of short-answer and extended answer questions.

See *Appendix 3* for a description of this code and all other codes relevant to this qualification.

AS Unit 2: Application of Core Principles of Chemistry

*Unit code 6CH02

- Externally assessed
- Availability: June

**40%
of the
total AS
marks****20% of
the total
GCE
marks****Content summary:**

This unit develops the treatment of chemical bonding by introducing intermediate types of bonding and by exploring the nature and effects of intermolecular forces. Study of the periodic table is extended to cover the chemistry of groups 2 and 7. Ideas about redox reactions are applied, in particular, to the reactions of halogens and their compounds. The unit develops a largely qualitative understanding of the ways in which chemists can control the rate, direction and extent of chemical change. Organic chemistry in this unit covers alcohols and halogenoalkanes. The treatment is extended to explore the mechanisms of selected examples. Students have to use formulae and balance equations and have an understanding of chemical quantities. Aspects of green chemistry and climate change are also studied.

Assessment:

Examination of 1 hour 30 minutes in three sections.

Section A: objective test questions.

Section B: mixture of short-answer and extended answer questions.

Section C: contemporary context questions.

AS Unit 3: Chemistry Laboratory Skills I

*Unit code 6CH03

- Internally assessed
- Availability: June

**20%
of the
total AS
marks****10% of
the total
GCE
marks****Content summary:**

This unit contains practical assessments that cover the content of Units 1 and 2. There is no specific content for this unit. The practical assessments cover the areas of physical, organic and inorganic chemistry. The types of practicals that students must complete are qualitative observations, quantitative measurements and preparations.

Assessment:

Three separate activities testing students' laboratory skills in three different ways. The three activities must cover the areas of physical, organic and inorganic chemistry.

A2

**Unit 4: General Principles of Chemistry I –
Rates, Equilibria and Further Organic Chemistry**

*Unit code 6CH04

- Externally assessed
- Availability: June

**40%
of the
total A2
marks****20% of
the total
GCE
marks****Content summary:**

In this unit students make a quantitative study of chemical kinetics and take further their study of organic reaction mechanisms. The topics of entropy and equilibria show how chemists are able to predict quantitatively the direction and extent of chemical change. The organic chemistry in this unit covers carbonyl compounds, plus carboxylic acids and their derivatives. Students are required to apply their knowledge gained in Units 1 and 2 to all aspects of this unit. This includes nomenclature, ideas of isomerism, bond polarity and bond enthalpy, reagents and reaction conditions, reaction types and mechanisms. Students are also expected to use formulae and balance equations and calculate chemical quantities.

Assessment:

Examination of 1 hour 40 minutes in three sections.

Section A: objective test questions.

Section B: mixture of short-answer and extended answer questions.

Section C: data questions, with use of a data booklet.

A2

**Unit 5: General Principles of Chemistry II –
Transition Metals and Organic Nitrogen Chemistry**

*Unit code 6CH05

- Externally assessed
- Availability: June

**40%
of the
total A2
marks****20% of
the total
GCE
marks****Content summary:**

In this unit the study of electrode potentials builds on the study of redox in Unit 2, including the concept of oxidation number and the use of redox half equations. Students will study further chemistry related to redox and transition metals. The further organic chemistry section of this unit focuses on arenes and organic nitrogen compounds such as amines, amides, amino acids and proteins. Students are expected to use the knowledge and understanding of organic chemistry that they have gained over the whole GCE in Chemistry when covering the organic synthesis section. This unit draws on all other units within the GCE in Chemistry and students are expected to use their prior knowledge when learning about these areas. Students will again encounter ideas of isomerism, bond polarity and bond enthalpy, reagents and reaction conditions, reaction types and mechanisms. Students are also expected to use formulae and balance equations and calculate chemical quantities.

Assessment:

Examination of 1 hour 40 minutes in three sections.

Section A: objective test questions

Section B: mixture of short-answer and extended answer questions.

Section C: contemporary context questions.

A2 Unit 6: Chemistry Laboratory Skills II

*Unit code 6CH06

- Internally assessed
- Availability: June

**20%
of the
total A2
marks****10% of
the total
GCE
marks****Content summary:**

This unit contains practical assessments that cover the content of Units 4 and 5. There is no specific content for this unit. The practical assessments cover the areas of physical, organic and inorganic chemistry. The types of practicals that students must complete are qualitative observations, quantitative measurements and preparations. There is the opportunity for students to undertake a multi-stage experiment, which includes the quantitative measurement and preparation in a longer assessment.

Assessment:

Students' laboratory skills are tested in three different ways, through a choice of activities and pathways. The three activities must cover the areas of physical, organic and inorganic chemistry.

Pathway 1 — as in AS but with practicals covering areas of Units 4 and 5.

Pathway 2 — activity b as in AS, but tasks c and d are together in a multi-stage experiment.

B Specification overview

Summary of assessment requirements

Unit number and unit title	Level	Assessment information	Number of marks allocated in the unit
Unit 1: The Core Principles of Chemistry	AS	The examination will be 1 hour 30 minutes and contain Sections A and B. Section A is an objective test section, and Section B contains a mixture of short-answer and extended answer questions. Section B will include questions on the analysis and evaluation of practical work. Quality of written communication will be assessed in this examination in Section B.	80
Unit 2: Application of Core Principles of Chemistry	AS	The examination will be 1 hour 30 minutes and contain Sections A, B and C. Section A is an objective test section, and Section B contains a mixture of short-answer and extended answer questions. Section C will contain questions on contemporary contexts. This may contain stimulus materials on a scenario that students must read in order to answer the questions. Quality of written communication will be assessed in this examination in either Section B or C. Questions on the analysis and evaluation of practical work will also be included in either Section B or C.	80
Unit 3: Chemistry Laboratory Skills I	AS	<p>Students' laboratory skills will be tested in four different ways, there will be a general practical competence (GPC) check and three separate activities which make up this assessment unit. The four activities must cover the areas of physical, organic and inorganic chemistry.</p> <p>Activities 'b, c and d' include practical activities where the teacher uses Edexcel devised practical activity sheets and mark schemes (if marked by the teacher). Teachers have the option of marking these activities or having them marked by Edexcel.</p> <p>Activity a: General Practical Competence (GPC)</p> <p>This will confirm that students have completed a range of practicals over the whole year and developed their laboratory skills. Students must have carried out at least five practicals in class. The practicals that the students complete must cover the three areas of physical, organic and inorganic chemistry. Verification of completion is required as well as the core practical code (or title), field and dates the practicals were carried out.</p> <p>Activity b: Qualitative observation. Students must complete one qualitative observation, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.</p> <p>Activity c: Quantitative measurement. Students must complete one quantitative measurement, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.</p>	40

B Specification overview

Unit number and unit title	Level	Assessment information	Number of marks allocated in the unit
		<p>Activity d: Preparation. Students must complete one preparation (making a chemical), from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 12.</p> <p>These activities must all be carried out under controlled conditions. Students will be allowed to write up their practical reports in a separate lesson, but their materials must be collected at the end of the session and handed back at the beginning of the next session. Students are not permitted to work on their practical sheets out of the lesson. Students' work must be individual and they may not work with other students in groups.</p> <p>The practical sheets for activities b, c and d are confidential and must not be shown to students prior to their completion of them. They will be available on a secure Edexcel website for teachers to download in preparation for delivery.</p>	
Unit 4: General Principles of Chemistry I – Rates, Equilibria and Further Organic Chemistry	A2	The examination will be 1 hour 40 minutes and contain Sections A, B and C. Section A is an objective test section, and Section B contains a mixture of short-answer and extended answer questions. Section C will contain data questions and will require the use of a data booklet. The longer timing of the examination reflects the style of the Section C questions. Students will be able to show their full ability in Sections B and C as these contain areas where they will be stretched and challenged. They will be provided with data from a laboratory experiment and asked a series of questions on it. Quality of written communication will be assessed in this examination in either Section B or C.	90
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry	A2	The examination will be 1 hour 40 minutes and contain Sections A, B and C. Section A is an objective test section, and Section B contains a mixture of short-answer and extended answer questions. Questions on the analysis and evaluation of practical work will also be included in Section B. Section C will contain questions on contemporary contexts. This may contain stimulus materials on a scenario that students must read in order to answer the questions. The longer timing of the examination is to reflect the style of the Section C questions. Students will be able to show their full ability in Sections B and C as these contain areas where they will be stretched and challenged. Quality of written communication will be assessed in this examination in either Section B or C.	90
Unit 6: Chemistry Laboratory Skills II	A2	As with AS Unit 3 students' laboratory skills will be tested in four different ways. However there is a choice in how these can be delivered. The laboratory skills assessment must cover the areas of physical, organic and inorganic chemistry.	40

Unit number and unit title	Level	Assessment information	Number of marks allocated in the unit
		<p>All students will have to complete activities a and b as detailed below, as in AS.</p> <p>Activities 'b, c and d' include practical activities where the teacher uses Edexcel devised practical activity sheets and mark schemes (if marked by the teacher). Teachers have the option of marking these activities or having them marked by Edexcel.</p> <p>Activity a: General Practical Competence (GPC)</p> <p>This will confirm that students have completed a range of practicals over the whole year and developed their laboratory skills. Students must have carried out at least five practicals in class. The practicals that the students complete must cover the three areas of physical, organic and inorganic chemistry. Verification of completion is required as well as the core practical code (or title), field and dates the practicals were carried out.</p> <p>Activity b: Qualitative observation. Students must complete one qualitative observation, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.</p> <p>Students then have a choice of completing either pathway 1 or pathway 2 as detailed below.</p> <p>Pathway 1: Students complete activities c and d, as in AS, as described below.</p> <p>Activity c: Quantitative measurement. Students must complete one quantitative measurement, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.</p> <p>Activity d: Preparation. Students must complete one preparation (making a chemical), from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 12.</p> <p>Pathway 2: Students could complete a multi-stage experiment, which comprises a quantitative measurement and a preparation. This covers the same criteria as activities c and d, but gives students experience of a longer and different style practical activity. The activity must be chosen from the selection provided by Edexcel. It will include a student sheet, teacher and technician notes and a mark scheme. This activity is marked out of 26.</p> <p>All of these activities must be carried out under controlled conditions. Students will be allowed to write up their practical reports in a separate lesson, but their materials must be collected at the end of the session and handed back at the beginning of the next session. Students are not permitted to work on their practical sheets out of the lesson. Students' work must be individual and they may not work with other students in groups.</p> <p>The practical sheets for activities b, c, d and the multi-stage experiment are confidential and must not be shown to students prior to their completion of them. They will be available on a secure Edexcel website for teachers to download in preparation for delivery.</p>	

Information for international centres

A 100 per cent examination option is available **ONLY** to international centres wishing to take GCE Chemistry. This will take the form of alternative written papers for Units 3 and 6.

This option is **not** available for home centres.

International private centres, including all centres entering candidates via the British Council, are not permitted to enter candidates for internal assessment and therefore must take the alternative written papers.

For further details please refer to the Edexcel international website www.edexcel.com/international.

Assessment objectives and weightings

AO1: Knowledge and understanding of science and of How Science Works

Candidates should be able to:

- recognise, recall and show understanding of scientific knowledge
- select, organise and communicate relevant information in a variety of forms.

AO2: Application of knowledge and understanding of science and of How Science Works

Candidates should be able to:

- analyse and evaluate scientific knowledge and processes
- apply scientific knowledge and processes to unfamiliar situations including those related to issues
- assess the validity, reliability and credibility of scientific information.

AO3: How Science Works

Candidates should be able to:

- demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

		% in AS	% in A2	% in GCE
AO1	Knowledge and understanding of science and of <i>How Science Works</i>	38.4%	25%	31.7%
AO2	Application of knowledge and understanding of science and of <i>How Science Works</i>	38.4%	43%	40.7%
AO3	<i>How Science Works</i>	23.2%	32%	27.6%
TOTAL		100%	100%	100%

Relationship of assessment objectives to units

Unit number	Assessment objective			
	AO1	AO2	AO3	Total for AO1, AO2 and AO3
Unit 1	10%	8%	2%	20%
Unit 2	8%	10%	2%	20%
Unit 3	1.2%	1.2%	7.6%	10%
Unit 4	5.3%	9.4%	5.3%	20%
Unit 5	6%	10.9%	3.1%	20%
Unit 6	1.2%	1.2%	7.6%	10%
Total for Advanced Level GCE	31.7%	40.7%	27.6%	100%

Qualification summary

Subject criteria

The General Certificate of Education is part of the Level 3 provision. This specification is based on the Advanced Subsidiary GCE and Advanced Level GCE subject criteria for chemistry which are prescribed by the regulatory authorities and are mandatory for all awarding bodies.

The GCE in Chemistry has been designed to build on the knowledge and skills set out in the GCSE Science criteria, and provide further opportunities for students to consider the applications and implications of chemistry and the development of scientific ideas.

The GCE in Chemistry criteria includes *How Science Works*, which is explained below in more detail. It also includes experimental and investigative skills, mathematical requirements and key skills.

Aims

The aims of the Edexcel Advanced Subsidiary GCE and Advanced Level GCE in Chemistry are to develop:

- students' interest in, and enthusiasm, for chemistry, including developing an interest in further study and careers in chemistry
- an appreciation of how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society
- a deeper understanding of the skills, knowledge and understanding of *How Science Works*
- essential knowledge and understanding of different areas of the subject and how they relate to each other.

How Science Works

This Edexcel Advanced Subsidiary GCE and Advanced Level GCE specification requires students to develop the skills, knowledge and understanding of *How Science Works*, which are described as follows:

- use theories, models and ideas to develop and modify scientific explanations
- use knowledge and understanding to pose scientific questions, define scientific problems and present scientific arguments and ideas
- use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems
- carry out experimental and investigative activities, including appropriate risk management, in a range of contexts
- analyse and interpret data to provide evidence, recognising correlations and causal relationships
- evaluate methodology, evidence and data and resolve conflicting evidence
- appreciate the tentative nature of scientific knowledge
- communicate information and ideas in appropriate ways using appropriate terminology
- consider the applications and implications of science and appreciate their associated benefits and risks
- consider ethical issues in the treatment of humans, other organisms and the environment

- appreciate the role of the scientific community in validating new knowledge and ensuring integrity
- appreciate the ways in which society uses science to inform decision making.

These statements have been embedded within the specification and will be assessed both in the examinations and as part of the internal assessment. A more detailed mapping of where these statements are found within the units can be found in *Appendix 4*. This also contains a further expansion on the specification points which address these *How Science Works* statements.

Experimental and investigative skills

This Edexcel Advanced Subsidiary GCE and Advanced Level GCE specification requires students to develop a range of experimental and investigative skills. These are highlighted in the previous *How Science Works* section.

Core practicals that all students must carry out have been listed within the unit specification, at both AS and A2 level. Many of these will be standard GCE practicals. This ensures that all students cover a variety of different practicals and have developed their experimental and investigative skills. The examinations can then contain questions of a more practical nature, such as analysis and evaluation of practical work, discussion of errors, safety procedures and risk assessments.

The GCE in Chemistry criteria assessment objective 3 (AO3): *How Science Works*, states that students should be able to:

- demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

These points have been embedded within the specification and the internal and external assessments, both at AS and A2 level.

With all laboratory practicals it is essential that centres carry out a detailed risk assessment before allowing students to carry out the practical. For further information on risk assessments and chemical hazards please refer to the CLEAPSS website (www.cleapss.org.uk).

C Chemistry unit content

Unit 1 The Core Principles of Chemistry 21

Unit 2 Application of Core Principles of Chemistry 33

Unit 3 Chemistry Laboratory Skills I 47

Unit 4 General Principles of Chemistry I – Rates, Equilibria and Further Organic Chemistry 51

Unit 5 General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry 65

Unit 6 Chemistry Laboratory Skills II 77

Course structure

- Edexcel's GCE in Chemistry comprises six units and contains an Advanced Subsidiary subset of three AS units.
- The Advanced Subsidiary GCE is the first half of the GCE course and consists of Units 1, 2 and 3. It may be awarded as a discrete qualification or contribute 50 per cent of the total Advanced Level GCE marks.
- The full Advanced Level GCE award consists of the three AS units (Units 1, 2 and 3), plus three A2 units (Units 4, 5 and 6) which make up the other 50 per cent of the Advanced GCE. Students wishing to take the full Advanced Level GCE must, therefore, complete all six units.
- The structure of this qualification allows teachers to construct a course of study which can be taught and assessed either as:
 - ◆ distinct modules of teaching and learning with related units of assessment taken at appropriate stages during the course; or
 - ◆ a linear course which is assessed in its entirety at the end.

1.1 Unit description

Chemical ideas

This unit provides opportunities for students to develop the basic chemical skills of formulae writing, equation writing and calculating chemical quantities.

The study of energetics in chemistry is of theoretical and practical importance. In this unit students learn to define, measure and calculate enthalpy changes. They will see how a study of enthalpy changes can help chemists to understand chemical bonding.

The study of atomic structure introduces s, p, and d orbitals and shows how a more detailed understanding of electron configurations can account for the arrangement of elements in the periodic table.

The unit introduces the three types of strong chemical bonding (ionic, covalent and metallic).

Organic chemistry is also introduced, with students studying alkanes and alkenes.

How chemists work

Practical work measuring energy changes helps students to understand the ideas of uncertainty in measurements and evaluate their results in terms of systematic and random errors.

The study of atomic structure gives some insight into the types of evidence which scientists use to study electrons in atoms. This leads to an appreciation of one of the central features of chemistry which is the explanation of the properties of elements and the patterns in the periodic table in terms of atomic structure.

The role of instrumentation in analytical chemistry is illustrated by mass spectrometry.

Students are introduced to some of the evidence which will help them to understand the different kinds of chemical bonding.

Chemists set up theoretical models and gain insights by comparing real and ideal properties of chemicals. This is illustrated in the unit by the ionic model and the comparison of lattice energies calculated from theory with those determined with the help of Born-Haber cycles.

Throughout the unit students see the importance of chemical data and learn to select data from databases and use it to look for patterns and calculate other quantities.

The introduction to organic chemistry shows how chemists work safely with potentially hazardous chemicals by managing risks.

Chemistry in action

The uses of mass spectrometry illustrate the importance of sensitive methods of analysis in areas such as space research, medical research and diagnosis, in detecting drugs in sport and in environmental monitoring.

In this unit students learn how chemical insights can help to make the use of polymeric and other materials more sustainable. This involves analysis of the uses of energy, raw materials and other resources at each stage of the life cycle of products.

Core practicals

The following specification points are core practicals within this unit that students must complete:

- 1.3j – CP1
- 1.3k – CP2
- 1.4f – CP3

These practicals can be used to meet the requirements of Activity a: General Practical Competence (GPC) in the assessment of Unit 3. They may also appear in the written examination for Unit 1. The core practical codes (eg CP1, CP2 etc) should be used when completing the record card for each student.

Use of examples**Examples in practicals**

Where 'eg' follows a type of experiment in the specification students are not expected to have carried out that specific experiment. However, they should be able to use data from that or similar experiments.

For instance in this unit, *1.4f ii Energetics*, the specification states:

simple enthalpy of combustion experiments using, eg a series of alcohols in a spirit burner.

Students will be expected to have carried out simple enthalpy of combustion reactions, but they may or may not have carried out these using alcohol in spirit burners.

In the unit test students could be given experimental data for this, or any other enthalpy of combustion reaction, and be expected to analyse and evaluate this data.

Examples in unit content

Where 'eg' follows a concept students are not expected to have been taught the particular example given in the specification. They should be able to illustrate their answer with an example of their choice.

For instance in this unit, *1.6.1f Ionic bonding*, the specification states:

recall trends in ionic radii down a group and for a set of isoelectronic ions, eg N^{3-} to Al^{3+} .

Students will be expected to recall the trends in ionic radii down a group, and for a set of isoelectronic ions, but they may or may not have done this from N^{3-} to Al^{3+} .

In the unit test students could be asked to recall the trends in ionic radii down a group. They could be asked this in reference to any group in the periodic table, either the one listed as an example or another group.

1.2 Assessment information

Unit 1 examination The examination will be 1 hour 30 minutes and have 80 marks. It will contain two Sections, A and B.

Section A is an objective test section which will aim to cover a large proportion of the specification for this unit.

Section B contains a mixture of short-answer and extended answer questions. This will include questions on the analysis and evaluation of practical work.

Quality of written communication will be assessed in this examination in Section B.

1.3 Formulae, equations and amounts of substance

Application of ideas from this topic will be applied to all other units.

During this topic there will be the opportunity to carry out a number of internal assessment activities. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- a demonstrate an understanding of the terms atom, element, ion, molecule, compound, empirical and molecular formulae
- b write balanced equations (full and ionic) for simple reactions, including the use of state symbols
- c demonstrate an understanding of the terms relative atomic mass, amount of substance, molar mass and parts per million (ppm), eg gases in the atmosphere, exhausts, water pollution
- d calculate the amount of substance in a solution of known concentration (excluding titration calculations at this stage), eg use data from the concentrations of the various species in blood samples to perform calculations in mol dm^{-3}
- e use chemical equations to calculate reacting masses and vice versa using the concepts of amount of substance and molar mass
- f use chemical equations to calculate volumes of gases and vice versa using the concepts of amount of substance and molar volume of gases, eg calculation of the mass or volume of CO_2 produced by combustion of a hydrocarbon (given a molar volume for the gas)
- g use chemical equations and experimental results to deduce percentage yields and atom economies in laboratory and industrial processes and understand why they are important
- h demonstrate an understanding of, and be able to perform, calculations using the Avogadro constant
- i analyse and evaluate the results obtained from finding a formula or confirming an equation by experiment, eg the reaction of lithium with water and deducing the equation from the amounts in moles of lithium and hydrogen
- j make a salt and calculate the percentage yield of product, eg preparation of a double salt (ammonium iron(II) sulfate from iron, ammonia and sulfuric acid)
- k carry out and interpret the results of simple test tube reactions, such as displacements, reactions of acids, precipitations, to relate the observations to the state symbols used in equations and to practise writing full and ionic equations.

1.4 Energetics

During this topic there will be the opportunity to carry out an internal assessment activity. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- a demonstrate an understanding of the term enthalpy change, ΔH
- b construct simple enthalpy level diagrams showing the enthalpy change
- c recall the sign of ΔH for exothermic and endothermic reactions, eg illustrated by the use of exo- and endothermic reactions in hot and cold packs
- d recall the definition of standard enthalpy changes of reaction, formation, combustion, neutralization and atomization and use experimental data to calculate energy transferred in a reaction and hence the enthalpy change of the reaction. This will be limited to experiments where substances are mixed in an insulated container, and combustion experiments
- e recall Hess's Law and apply it to calculating enthalpy changes of reaction from data provided, selected from a table of data or obtained from experiments and understand why standard data is necessary to carry out calculations of this type
- f evaluate the results obtained from experiments using the expression:
energy transferred in joules = mass x specific heat capacity x temperature change
and comment on sources of error and assumptions made in the experiments. The following types of experiments should be performed:
 - i experiments in which substances are mixed in an insulated container and the temperature rise measured
 - ii simple enthalpy of combustion experiments using, eg a series of alcohols in a spirit burner
 - iii plan and carry out an experiment where the enthalpy change cannot be measured directly, eg the enthalpy change for the decomposition of calcium carbonate using the enthalpy changes of reaction of calcium carbonate and calcium oxide with hydrochloric acid
- g demonstrate an understanding of the terms bond enthalpy and mean bond enthalpy, and use bond enthalpies in Hess cycle calculations and recognise their limitations. Understand that bond enthalpy data gives some indication about which bond will break first in a reaction, how easy or difficult it is and therefore how rapidly a reaction will take place at room temperature.

1.5 Atomic structure and the periodic table

Students will be assessed on their ability to:

- a recall the definitions of relative atomic mass, relative isotopic mass and relative molecular mass and understand that they are measured relative to $1/12^{\text{th}}$ the mass of a ^{12}C atom
- b demonstrate an understanding of the basic principles of a mass spectrometer and interpret data from a mass spectrometer to:
 - i deduce the isotopic composition of a sample of an element, eg polonium
 - ii deduce the relative atomic mass of an element
 - iii measure the relative molecular mass of a compound
- c describe some uses of mass spectrometers, eg in radioactive dating, in space research, in sport to detect use of anabolic steroids, in the pharmaceutical industry to provide an identifier for compounds synthesised for possible identification as drugs
- d recall and understand the definition of ionization energies of gaseous atoms and that they are endothermic processes
- e recall that ideas about electronic structure developed from:
 - i an understanding that successive ionization energies provide evidence for the existence of quantum shells and the group to which the element belongs
 - ii an understanding that the first ionization energy of successive elements provides evidence for electron sub-shells
- f describe the shapes of electron density plots (or maps) for s and p orbitals
- g predict the electronic structure and configuration of atoms of the elements from hydrogen to krypton inclusive using $1s \dots$ notation and electron-in-boxes notation (recall electrons populate orbits singly before pairing up)
- h demonstrate an understanding that electronic structure determines the chemical properties of an element
- i recall that the periodic table is divided into blocks, such as s, p and d

- j represent data, in a graphical form, for elements 1 to 36 and use this to explain the meaning of the term 'periodic property'
- k explain trends in the following properties of the element from periods 2 and 3 of the periodic table:
 - i melting temperature of the elements based on given data using the structure and the bonding between the atoms or molecules of the element
 - ii ionization energy based on given data or recall of the shape of the plots of ionization energy versus atomic number using ideas of electronic structure and the way that electron energy levels vary across the period.

1.6 Bonding

Students will be assessed on their ability to:

- 1 **Ionic bonding**
 - a recall and interpret evidence for the existence of ions, limited to physical properties of ionic compounds, electron density maps and the migration of ions, eg electrolysis of aqueous copper chromate(VI)
 - b describe the formation of ions in terms of electron loss or gain
 - c draw electron configuration diagrams of cations and anions using dots or crosses to represent electrons
 - d describe ionic crystals as giant lattices of ions
 - e describe ionic bonding as the result of strong net electrostatic attraction between ions
 - f recall trends in ionic radii down a group and for a set of isoelectronic ions, eg N^{3-} to Al^{3+}
 - g recall the stages involved in the formation of a solid ionic crystal from its elements and that this leads to a measure value for the lattice energy (students will not be expected to draw the full Born-Haber cycles)

- h test the ionic model for ionic bonding of a particular compound by comparison of lattice energies obtained from the experimental values used in Born-Haber cycles, with provided values calculated from electrostatic theory
- i explain the meaning of the term polarization as applied to ions
- j demonstrate an understanding that the polarizing power of a cation depends on its radius and charge, and the polarizability of an anion depends on its size
- k demonstrate an understanding that polarization of anions by cations leads to some covalency in an ionic bond, based on evidence from the Born-Haber cycle
- l use values calculated for standard heats of formation based on Born-Haber cycles to explain why particular ionic compounds exist, eg the relative stability of MgCl_2 over MgCl or MgCl_3 and NaCl over NaCl_2 .

2 Covalent bonding

- a demonstrate an understanding that covalent bonding is strong and arises from the electrostatic attraction between the nucleus and the electrons which are between the nuclei, based on the evidence:
 - i the physical properties of giant atomic structures
 - ii electron density maps for simple molecules
- b draw electron configuration diagrams for simple covalently bonded molecules, including those with multiple bonds and dative covalent bonds, using dots or crosses to represent electrons.

3 Metallic bonding

- a demonstrate an understanding that metals consist of giant lattices of metal ions in a sea of delocalised electrons
- b describe metallic bonding as the strong attraction between metal ions and the sea of delocalised electrons
- c use the models in 1.6.3a and 1.6.3b to interpret simple properties of metals, eg conductivity and melting temperatures.

1.7 Introductory organic chemistry

Related topics in *Units 2, 4 and 5* will assume knowledge of this material.

During this topic there will be the opportunity to carry out an internal assessment activity. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- 1 Introduction
 - a demonstrate an understanding that there are series of organic compounds characterised by a general formula and one or more functional groups
 - b apply the rules of IUPAC nomenclature to compounds relevant to this specification and draw these compounds, as they are encountered in the specification, using structural, displayed and skeletal formulae
 - c appreciate the difference between hazard and risk
 - d demonstrate an understanding of the hazards associated with organic compounds and why it is necessary to carry out risk assessments when dealing with potentially hazardous materials. Suggest ways by which risks can be reduced and reactions can be carried out safely by:
 - i working on a smaller scale
 - ii taking specific precautions or using alternative techniques depending on the properties of the substances involved
 - iii carrying out the reaction using an alternative method that involves less hazardous substances.

2 Alkanes

- state the general formula of alkanes and understand that they are saturated hydrocarbons which contain single bonds only
- explain the existence of structural isomers using alkanes (up to C₅) as examples
- know that alkanes are used as fuels and obtained from the fractional distillation, cracking and reformation of crude oil
- discuss the reasons for developing alternative fuels in terms of sustainability and reducing emissions, including the emission of CO₂ and its relationship to climate change
- describe the reactions of alkanes in terms of combustion and substitution by chlorine showing the mechanism of free radical substitution in terms of initiation, propagation and termination, and using curly half-arrows in the mechanism to show the formation of free radicals in the initiation step using a single dot to represent the unpaired electron.

3 Alkenes

- state the general formula of alkenes and understand that they are unsaturated hydrocarbons with a carbon-carbon double bond which consists of a σ and a π bond
- explain E-Z isomerism (geometric/cis-trans isomerism) in terms of restricted rotation around a C=C double bond and the nature of the substituents on the carbon atoms
- demonstrate an understanding the E-Z naming system and why it is necessary to use this when the *cis*- and *trans*- naming system breaks down
- describe the addition reactions of alkenes, limited to:
 - the addition of hydrogen with a nickel catalyst to form an alkane
 - the addition of halogens to produce di-substituted halogenoalkanes
 - the addition of hydrogen halides to produce mono-substituted halogenoalkanes
 - oxidation of the double bond by potassium manganate(VII) to produce a diol

- e describe the mechanism (including diagrams), giving evidence where possible, of:
 - i the electrophilic addition of bromine and hydrogen bromide to ethene
 - ii the electrophilic addition of hydrogen bromide to propene
- f describe the test for the presence of C=C using bromine water and understand that the product is the addition of OH and Br
- g describe the addition polymerization of alkenes and identify the repeat unit given the monomer, and vice versa
- h interpret given information about the uses of energy and resources over the life cycle of polymer products to show how the use of renewable resources, recycling and energy recovery can contribute to the more sustainable use of materials.

2.1 Unit description

Chemical ideas

This unit develops the treatment of chemical bonding by introducing intermediate types of bonding and by exploring the nature and effects of intermolecular forces.

Study of the periodic table is extended to cover the chemistry of groups 2 and 7. Ideas about redox reactions are applied in particular to the reactions of halogens and their compounds.

The unit develops a largely qualitative understanding of the ways in which chemists can control the rate, direction and extent of chemical change.

Organic chemistry in this unit covers alcohols and halogenoalkanes. The treatment is extended to explore the mechanisms of selected examples.

Students have to use formulae and balance equations and have an understanding of chemical quantities.

How chemists work

Electron-pair repulsion theory shows how chemists can make generalisations and use them to make predictions.

Chemists rationalise a great deal of information about chemical changes by using theory to categorise reagents and types of chemical change. This is illustrated by the use of inorganic and organic examples in this unit.

The use of models in chemistry is illustrated by the way in which the Maxwell-Boltzmann distribution and collision theory can account for the effects of temperature on the rates of chemical reactions.

The unit shows how chemists can study chemical changes on an atomic scale and propose mechanisms to account for their observations.

Chemistry in action

This unit shows the contribution that chemistry can make to a more sustainable economy by redeveloping manufacturing processes to make them more efficient, less hazardous and less polluting.

Insight into the mechanisms of chemical reactions can help to account for the damaging effects of some chemicals on the natural environment.

The study of spectroscopy gives further examples of the importance of accurate and sensitive methods of analysis which can be applied to study chemical changes but also to detect drugs such as alcohol.

The unit deals with issues regarding the environment, such as climate change, the effect of greenhouse gases, carbon footprints and other aspects of green chemistry. It ensures that students understand the underlying chemistry and can investigate ways to combat these issues.

Core practicals

The following specification points are core practicals within this unit that students must complete:

2.4d – CP4
2.5c – CP5
2.7.1g – CP6
2.7.2b – CP7
2.7.2c – CP8
2.7.2d – CP9
2.8f – CP10
2.10.1d – CP11
2.10.2c – CP12
2.10.2e – CP13

These practicals can be used to meet the requirements of Activity a: General Practical Competence (GPC) in the assessment of Unit 3. They may also appear in the written examination for Unit 2. The core practical codes (eg CP1, CP2 etc) should be used when completing the record card for each student.

Use of examples**Examples in practicals**

Where 'eg' follows a type of experiment in the specification students are not expected to have carried out that specific experiment. However, they should be able to use data from that or similar experiments.

For instance in this unit, *2.7g ii Properties down group 2*, the specification states:

simple acid-base titrations using a range of indicators, acids and alkalis, to calculate solution concentrations in g dm^{-3} and mol dm^{-3} , eg measuring the residual alkali present after skinning fruit with potassium hydroxide.

Students will be expected to have carried out simple acid-base titrations, but they may or may not have done this to measure the residual alkali present after skinning fruit.

In the unit test students could be given experimental data for this or any other acid-base titration, and be expected to analyse and evaluate this data.

Examples in unit content

Where 'eg' follows a concept students are not expected to have been taught the particular example given in the specification. They should be able to illustrate their answer with an example of their choice.

For instance in this unit, *2.10.2f Halogenoalkanes*, the specification states:

discuss the uses of halogenoalkanes, eg as fire retardants and modern refrigerants.

Students will be expected to discuss the use of halogenoalkanes, but they may or may not have looked at their use as fire retardants or refrigerants.

In the unit test students could be asked to discuss some of the uses of halogenoalkanes. This could be those listed as examples or other uses.

2.2 Assessment information

Unit 2 examination The examination will be 1 hour 30 minutes and have 80 marks. It will contain three Sections: A, B and C.

Section A is an objective test section which will aim to cover a large proportion of the specification for this unit.

Section B contains a mixture of short-answer and extended answer questions.

Section C will contain extended answer questions on contemporary contexts. This may contain stimulus materials on a scenario that students must read in order to answer the questions. It will focus on the chemistry behind the contexts and will not be a comprehension exercise.

Quality of written communication will be assessed in this examination, in either Section B or C. Questions on the analysis and evaluation of practical work will also be included in either Section B or C.

2.3 Shapes of molecules and ions

Students will be assessed on their ability to:

- demonstrate an understanding of the use of electron-pair repulsion theory to interpret and predict the shapes of simple molecules and ions
- recall and explain the shapes of BeCl_2 , BCl_3 , CH_4 , NH_3 , NH_4^+ , H_2O , CO_2 , gaseous PCl_5 and SF_6 and the simple organic molecules listed in Units 1 and 2
- apply the electron-pair repulsion theory to predict the shapes of molecules and ions analogous to those in 2.3b
- demonstrate an understanding of the terms bond length and bond angle and predict approximate bond angles in simple molecules and ions
- discuss the different structures formed by carbon atoms, including graphite, diamond, fullerenes and carbon nanotubes, and the applications of these, eg the potential to use nanotubes as vehicles to carry drugs into cells.

2.4 Intermediate bonding and bond polarity

Students will be assessed on their ability to:

- a explain the meaning of the term electronegativity as applied to atoms in a covalent bond
- b recall that ionic and covalent bonding are the extremes of a continuum of bonding type and explain this in terms of electronegativity differences leading to bond polarity in bonds and molecules, and to ionic bonding if the electronegativity is large enough
- c distinguish between polar bonds and polar molecules and be able to predict whether or not a given molecule is likely to be polar
- d carry out experiments to determine the effect of an electrostatic force on jets of liquids and use the results to determine whether the molecules are polar or non-polar.

2.5 Intermolecular forces

Students will be assessed on their ability to:

- a demonstrate an understanding of the nature of intermolecular forces resulting from interactions between permanent dipoles, instantaneous dipoles and induced dipoles (London forces) and from the formation of hydrogen bonds
- b relate the physical properties of materials to the types of intermolecular force present, eg:
 - i the trends in boiling and melting temperatures of alkanes with increasing chain length
 - ii the effect of branching in the carbon chain on the boiling and melting temperatures of alkanes
 - iii the relatively low volatility (higher boiling temperatures) of alcohols compared to alkanes with a similar number of electrons
 - iv the trends in boiling temperatures of the hydrogen halides HF to HI
- c carry out experiments to study the solubility of simple molecules in different solvents

- d interpret given information about solvents and solubility to explain the choice of solvents in given contexts, discussing the factors that determine the solubility including:
 - i the solubility of ionic compounds in water in terms of the hydration of the ions
 - ii the water solubility of simple alcohols in terms of hydrogen bonding
 - iii the insolubility of compounds that cannot form hydrogen bonds with water molecules, eg polar molecules such as halogenoalkanes
 - iv the solubility in non-aqueous solvents of compounds which have similar intermolecular forces to those in the solvent.

2.6 Redox

Students will be assessed on their ability to:

- a demonstrate an understanding of:
 - i oxidation number — the rules for assigning oxidation numbers
 - ii oxidation and reduction as electron transfer
 - iii oxidation and reduction in terms of oxidation number changes
 - iv how oxidation number is a useful concept in terms of the classification of reactions as redox and as disproportionation
- b write ionic half-equations and use them to construct full ionic equations.

2.7 The periodic table — groups 2 and 7

During this topic there will be the opportunity to carry out a number of internal assessment activities. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- 1 Properties down group 2**
- a explain the trend in the first ionization energy down group 2
 - b recall the reaction of the elements in group 2 with oxygen, chlorine and water
 - c recall the reactions of the oxides of group 2 elements with water and dilute acid, and their hydroxides with dilute acid
 - d recall the trends in solubility of the hydroxides and sulfates of group 2 elements
 - e recall the trends in thermal stability of the nitrates and the carbonates of the elements in groups 1 and 2 and explain these in terms of size and charge of the cations involved
 - f recall the characteristic flame colours formed by group 1 and 2 compounds and explain their origin in terms of electron transitions
 - g describe and carry out the following:
 - i experiments to study the thermal decomposition of group 1 and 2 nitrates and carbonates
 - ii flame tests on compounds of group 1 and 2
 - iii simple acid-base titrations using a range of indicators, acids and alkalis, to calculate solution concentrations in g dm^{-3} and mol dm^{-3} , eg measuring the residual alkali present after skinning fruit with potassium hydroxide
 - h demonstrate an understanding of how to minimise the sources of measurement uncertainty in volumetric analysis and estimate the overall uncertainty in the calculated result.
- 2 Inorganic chemistry of group 7 (limited to chlorine, bromine and iodine)**
- a recall the characteristic physical properties of the elements limited to the appearance of solutions of the elements in water and hydrocarbon solvents
 - b describe and carry out the following chemical reactions of halogens:
 - i oxidation reactions with metal and non-metallic elements and ions such as iron(II) and iron(III) ions in solution
 - ii disproportionation reactions with cold and hot alkali, eg hot potassium hydroxide with iodine to produce potassium iodate(V)

- c carry out an iodine/thiosulfate titration, including calculation of the results and evaluation of the procedures involved, eg determination of the purity of potassium iodate(V) by liberation of iodine and titration with standard sodium thiosulfate solution
- d describe and carry out the following reactions:
 - i potassium halides with concentrated sulfuric acid, halogens and silver nitrate solution
 - ii silver halides with sunlight and their solubilities in aqueous ammonia solution
 - iii hydrogen halides with ammonia and with water (to produce acids)
- e make predictions about fluorine and astatine and their compounds based on the trends in the physical and chemical properties of halogens.

2.8 Kinetics

Students will be assessed on their ability to:

- a recall the factors that influence the rate of chemical reaction, including concentration, temperature, pressure, surface area and catalysts
- b explain the changes in rate based on a qualitative understanding of collision theory
- c use, in a qualitative way, the Maxwell-Boltzmann model of the distribution of molecular energies to relate changes of concentration and temperature to the alteration in the rate of a reaction
- d demonstrate an understanding of the concept of activation energy and its qualitative relationship to the effect of temperature changes on the rate of reaction
- e demonstrate an understanding of the role of catalysts in providing alternative reaction routes of lower activation energy and draw the reaction profile of a catalysed reaction including the energy level of the intermediate formed with the catalyst
- f carry out simple experiments to demonstrate the factors that influence the rate of chemical reactions, eg the decomposition of hydrogen peroxide.

2.9 Chemical equilibria

Students will be assessed on their ability to:

- a demonstrate an understanding that chemical equilibria are dynamic
- b deduce the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium, eg extraction of methane from methane hydrate
- c interpret the results of simple experiments to demonstrate the effect of a change of temperature, pressure and concentration on a system at equilibrium, eg
 - i iodine(I) chloride reacting with chlorine to form iodine(III) chloride, or
 - ii $\text{N}_2\text{O}_4 \rightleftharpoons \text{NO}_2$.

2.10 Organic chemistry

Related topics in *Units 4* and *5* will assume knowledge of this material.

During this topic there will be the opportunity to carry out a number of internal assessment activities. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- 1 Alcohols
 - a give examples of, and recognise, molecules that contain the alcohol functional group.
 - b demonstrate an understanding of the nomenclature and corresponding structural, displayed and skeletal formulae of alcohols, and classify them as primary, secondary or tertiary

- c describe the following chemistry of alcohols:
 - i combustion
 - ii reaction with sodium
 - iii substitution reactions to form halogenoalkanes, including reaction with PCl_5 and its use as a qualitative test for the presence of the $-\text{OH}$ group
 - iv oxidation using potassium dichromate(VI) in dilute sulfuric acid on primary alcohols to produce aldehydes and carboxylic acids and on secondary alcohols to produce ketones
- d demonstrate an understanding of, and practise, the preparation of an organic liquid (reflux and distillation), eg oxidation of alcohols.

2 Halogenoalkanes

- a demonstrate an understanding of the nomenclature and corresponding structural, displayed and skeletal formulae for halogenoalkanes, including the distinction between primary, secondary and tertiary structures
- b interpret given data and observations comparing the reactions and reactivity of primary, secondary and tertiary compounds
- c carry out the preparation of an halogenoalkane from an alcohol and explain why a metal halide and concentrated sulfuric acid should not be used when making a bromoalkane or an iodoalkane
- d describe the typical behaviour of halogenoalkanes. This will be limited to treatment with:
 - i aqueous alkali, eg KOH (aq)
 - ii alcoholic potassium hydroxide
 - iii water containing dissolved silver nitrate
 - iv alcoholic ammonia
- e carry out the reactions described in 2.10.2d i, ii, iii
- f discuss the uses of halogenoalkanes, eg as fire retardants and modern refrigerants.

2.11 Mechanisms

Students will be assessed on their ability to:

- a classify reactions (including those in Unit 1) as addition, elimination, substitution, oxidation, reduction, hydrolysis or polymerization
- b demonstrate an understanding of the concept of a reaction mechanism and that bond breaking can be homolytic or heterolytic and that the resulting species are either free radicals, electrophiles or nucleophiles
- c give definitions of the terms free radical, electrophile and nucleophile
- d demonstrate an understanding of why it is helpful to classify reagents
- e demonstrate an understanding of the link between bond polarity and the type of reaction mechanism a compound will undergo
- f describe the mechanisms of the substitution reactions of halogenoalkanes and recall those in 1.7.2e and 1.7.3e
- g demonstrate an understanding of how oxygen, O_2 , and ozone, O_3 , absorb UV radiation and explain the part played by emission of oxides of nitrogen, from aircraft, in the depletion of the ozone layer, including the free radical mechanism for the reaction and the fact that oxides act as catalysts.

2.12 Mass spectra and IR

Students will be assessed on their ability to:

- a interpret fragment ion peaks in the mass spectra of simple organic compounds, eg the difference between propanal and propanone
- b use infrared spectra, or data from infrared spectra, to deduce functional groups present in organic compounds and predict infrared absorptions, given wavenumber data, due to familiar functional groups. This will be limited to:
 - i C–H stretching absorptions in alkanes, alkenes and aldehydes
 - ii O–H stretching absorption in alcohols and carboxylic acids
 - iii N–H stretching absorption in amines
 - iv C=O stretching absorption in aldehydes and ketones
 - v C–X stretching absorption in halogenoalkanes
 - vi as an analytical tool to show the change in functional groups during the oxidation of an alcohol to a carbonyl
- c demonstrate an understanding that only molecules which change their polarity as they vibrate can absorb infrared radiation
- d demonstrate an understanding that H₂O, CO₂, CH₄ and NO molecules absorb IR radiation and are greenhouse gases, whilst O₂ and N₂ are not.

2.13 Green chemistry

Students will be assessed on their ability to:

- a demonstrate an understanding that the processes in the chemical industry are being reinvented to make them more sustainable ('greener') by:
 - i changing to renewable resources
 - ii finding alternatives to very hazardous chemicals
 - iii discovering catalysts for reactions with higher atom economies, eg the development of methods used to produce ethanoic acid based on catalysts of cobalt, rhodium and iridium
 - iv making more efficient use of energy, eg the use of microwave energy to heat reactions in the pharmaceutical industry
 - v reducing waste and preventing pollution of the environment
- b discuss the relative effects of different greenhouse gases as absorbers of IR and hence on global warming
- c discuss the difference between anthropogenic and natural climate change over hundreds of thousands of years
- d demonstrate understanding of the terms 'carbon neutrality' and 'carbon footprint'
- e apply the concept of carbon neutrality to different fuels, such as petrol, bio-ethanol and hydrogen
- f discuss and explain, including the mechanisms for the reactions, the science community's reasons for recommending that CFCs are no longer used due to their damaging effect on the ozone layer.

3.1 Unit description

This unit contains practical assessments that cover the content of Units 1 and 2. There is no specific content for this unit.

Students' laboratory skills will be tested in four different ways, so there will be four separate activities **a**, **b**, **c** and **d**, which make up this assessment unit. Activity **a** must cover the three areas of physical, organic and inorganic chemistry. However, over activities **b**, **c** and **d** two of these must be covered. The types of practicals that students must complete for activities **b**, **c** and **d** are qualitative observations, quantitative measurements and preparations.

Edexcel will provide a selection of assessed practical sheets for activities **b**, **c** and **d**. Students can either complete just one assessed practical sheet for each activity, or they can complete more than one for each activity and submit the best mark. The total mark for this unit is 40 marks.

Section 'b, c and d' include practical activities (40 marks) where the teacher uses Edexcel devised practical activity sheets and mark schemes.

Teachers have the option of marking these activities or having them marked by Edexcel.

3.2 Assessment information

Controlled conditions

These activities must all be carried out under controlled conditions. Students will be allowed to write up their practical reports in a separate lesson, but their materials must be collected at the end of the session and handed back at the beginning of the next session. Students are not permitted to work on their practical sheets out of the lesson. Students' work must be individual and they may not work with other students in groups.

Assessed practical sheets

The practical sheets for activities **b**, **c** and **d** are confidential and must not be shown to students prior to their completion of them. They will be available on a secure Edexcel website for teachers to download in preparation for delivery.

Activities**Activity a: General Practical Competence (GPC)**

This will confirm that the students have completed a range of practicals over the whole year and developed their laboratory skills. Students must have carried out at least five practicals in class. By completing these practicals students will be able to:

- follow and interpret experimental instructions, covering the full range of laboratory exercises set throughout the course, with minimal help from the teacher
- always work with interest and enthusiasm in the laboratory completing most laboratory exercises in the time allocated
- manipulate apparatus, use chemicals, carry out all common laboratory procedures and use data logging (where appropriate) with the highest level of skill that may be reasonably expected at this level
- work sensibly and safely in the laboratory paying due regard to health and safety requirements without the need for reminders from the teacher
- gain accurate and consistent results in quantitative exercises, make most of the expected observations in qualitative exercises and obtain products in preparations of high yield and purity.

Verification of completion of these practicals is required as well as the core practical code, or title of an alternative practical, field of chemistry and dates on which the practicals were carried out. There will be no separate mark awarded for these practical activities.

Activity b: Qualitative observation

Students must complete one qualitative observation, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.

Activity c: Quantitative measurement

Students must complete one quantitative measurement, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.

Activity d: Preparation

Students must complete one preparation (making a chemical), from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 12.

3.3 Tasks for activity b

Tasks for activity b — qualitative observation for the AS are as follows. These tasks will change each year. Please see *section 3.6* for further details.

Activity code	Title	Unit
ASB1	Observation exercise on three inorganic compounds — 1	Unit 2, Topic 2.7: The periodic table — groups 2 and 7
ASB2	Observation exercise on three inorganic compounds — 2	Unit 2, Topic 2.7: The periodic table — groups 2 and 7
ASB3	Observation exercise on three organic compounds	Unit 1, Topic 1.7: Introductory organic chemistry Unit 2, Topic 2.10: Organic chemistry
ASB4	Observation exercise on two organic compounds	Unit 2, Topic 2.10: Organic chemistry

3.4 Tasks for activity c

Tasks for activity c — quantitative measurement for the AS are as follows.

Activity code	Title	Unit
ASC1	Acid-base titration — finding the molar mass of a solid acid	Unit 1, Topic 1.3: Formulae, equations and amounts of substance Unit 2, Topic 2.7: The periodic table — groups 2 and 7
ASC2	Finding the enthalpy change for the reaction between an acid and a base	Unit 1, Topic 1.4: Energetics
ASC3	Sodium thiosulfate(V)-iodine titration	Unit 2, Topic 2.7: The periodic table — groups 2 and 7
ASC4	Hess's Law	Unit 1, Topic 1.4: Energetics

3.5 Tasks for activity d

Tasks for activity d – preparation for the AS are as follows.

Activity code	Title	Unit
ASD1	Preparation of a double salt	Unit 1, Topic 1.3: Formulae, equations and amounts of substance
ASD2	Preparation of a salt	Unit 1, Topic 1.3: Formulae, equations and amounts of substance
ASD3	Preparation of an organic compound	Unit 2, Topic 2.10: Organic chemistry

3.6 Availability of activity sheets

The activity sheets for activities **b**, **c** and **d** will be available to download from the Edexcel website. They are securely stored so a password is required to access them. These activity sheets are confidential and must not be distributed to students prior to them carrying out the task.

The tasks for activity b – qualitative observation will change each year. The tasks listed in *section 3.3* (ASB1, ASB2, ASB3 and ASB4) are only valid from September 2008 to August 2009. New tasks will be available for each following year, on the Edexcel website, as secure files. The new files will have different codes (eg ASB5) to make them easily identifiable.

4.1 Unit description

Chemical ideas

In this unit students make a quantitative study of chemical kinetics and take further their study of organic reaction mechanisms.

The topics of entropy and equilibria show how chemists are able to predict quantitatively the direction and extent of chemical change.

The organic chemistry in this unit covers carbonyl compounds, plus carboxylic acids and their derivatives.

Students are required to apply their knowledge gained in Units 1 and 2, to all aspects of this unit. This includes nomenclature, ideas of isomerism, bond polarity and bond enthalpy, reagents and reaction conditions, reaction types and mechanisms. Students are also expected to use formulae and balance equations and calculate chemical quantities.

How chemists work

Through practical work, students will learn about the methods used to measure reaction rates. They will collect data, analyse it and interpret the results. They then see how a knowledge of rate equations and other evidence can enable chemists to propose models to describe the mechanisms of reactions.

The study of entropy introduces students to the methods of thermodynamics and shows how chemists use formal, quantitative and abstract thinking to answer fundamental questions about the stability of chemicals and the direction of chemical change.

The unit tests the equilibrium law by showing the degree to which it can accurately predict changes during acid-base reactions, notably the changes to pH during titrations.

The historical development of theories explaining acids and bases shows how scientific ideas change as a result of new evidence and fresh thinking.

Chemistry in action

This unit shows how the principles of kinetics and thermodynamics can help to achieve optimal conditions for the manufacture of chemicals.

The study of buffer solutions shows the varied importance of equilibrium systems in living cells, in medicines, in foods and in the natural environment.

The two broad areas of application of chemistry are synthesis and analysis. In this unit synthesis is illustrated by reactions of carbonyl compounds (notably with cyanide ions) and the production of esters for use as solvents, flavourings and perfumes. The main analytical technique featured is nmr including coverage of magnetic resonance imaging.

Core practicals

The following specification points are core practicals within this unit that students must complete:

- 4.3c – CP14
- 4.3e – CP15
- 4.4g – CP16
- 4.8.2c – CP17
- 4.8.3d – CP18
- 4.8.4b – CP19
- 4.8.4c – CP20

These practicals can be used to meet the requirements of Activity a: General Practical Competence (GPC) in the assessment of Unit 6. They may also appear in the written examination for Unit 4. The core practical codes (eg CP1, CP2 etc) should be used when completing the record card for each student.

Use of examples**Examples in practicals**

Where 'eg' follows a type of experiment in the specification students are not expected to have carried out that specific experiment. However they should be able to use data from that or similar experiments.

For instance in this unit, *4.3g How fast? – rates*, the specification states:

Investigate the activation energy of a reaction eg oxidation of iodide ions by iodate(V).

Students will be expected to have investigated the activation energy of a reaction, but they may or may not have done this by the oxidation of iodide ions by iodate(V).

In the unit test students could be given experimental data for this or any other reaction, and be expected to use this data to evaluate or estimate the activation energy.

Examples in unit content

Where 'eg' follows a concept students are not expected to have been taught the particular example given in the specification. They should be able to illustrate their answer with an example of their choice.

For instance in this unit, *4.7m Acid/base equilibria*, the specification states:

explain the importance of buffer solutions in biological environments, eg buffers in cells and in blood (H_2CO_3/HCO_3^-) and buffers in foods to prevent deterioration due to pH change (caused by bacterial or fungal activity).

Students will be expected to explain the importance of buffer solutions in biological systems, but they may or may not have looked at buffers in cells and blood, or in food.

In the unit test students could be asked to illustrate the importance of buffer solutions with a biological example that they select themselves. This could be one listed as an example or it could be another example.

4.2 Assessment information

Unit 4 examination The examination will be 1 hour 40 minutes and have 90 marks. It will contain three Sections, A, B and C.

Section A is an objective test section which will aim to cover a large proportion of the specification for this unit.

Section B contains a mixture of short-answer and extended answer questions.

Section C will contain data questions and will require students to select the necessary data from the data booklet. They will be provided with data from a laboratory experiment and asked a series of questions on it. The longer timing of the examination reflects the style of the questions for Section C.

Students will be able to show their full ability in Sections B and C as these will contain areas where they will be stretched and challenged.

Quality of written communication will be assessed in this examination, in either Section B or C. The data booklet can be used throughout the examination for this unit.

4.3 How fast? – rates

Knowledge of the concepts introduced in *Unit 2, Topic 2.8: Kinetics* will be assumed and extended in this topic.

During this topic there will be the opportunity to carry out a number of internal assessment activities. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- demonstrate an understanding of the terms 'rate of reaction', 'rate equation', 'order of reaction', 'rate constant', 'half-life', 'rate-determining step', 'activation energy', 'heterogeneous and homogenous catalyst'
- select and describe a suitable experimental technique to obtain rate data for a given reaction, eg colorimetry, mass change and volume of gas evolved
- investigate reactions which produce data that can be used to calculate the rate of the reaction, its half-life from concentration or volume against time graphs, eg a clock reaction
- present and interpret the results of kinetic measurements in graphical form, including concentration-time and rate-concentration graphs

- e investigate the reaction of iodine with propanone in acid to obtain data for the order with respect to the reactants and the hydrogen ion and make predictions about molecules/ions involved in the rate-determining step and possible mechanism (details of the actual mechanism can be discussed at a later stage in this topic)
- f deduce from experimental data for reactions with zero, first and second order kinetics:
 - i half-life (the relationship between half-life and rate constant will be given if required)
 - ii order of reaction
 - iii rate equation
 - iv rate-determining step related to reaction mechanisms
 - v activation energy (by graphical methods only; the Arrhenius equation will be given if needed)
- g investigate the activation energy of a reaction, eg oxidation of iodide ions by iodate(V)
- h apply a knowledge of the rate equations for the hydrolysis of halogenoalkanes to deduce the mechanisms for primary and tertiary halogenoalkane hydrolysis and to deduce the mechanism for the reaction between propanone and iodine
- i demonstrate that the mechanisms proposed for the hydrolysis of halogenoalkanes are consistent with the experimentally determined orders of reactions, and that a proposed mechanism for the reaction between propanone and iodine is consistent with the data from the experiment in 4.3e
- j use kinetic data as evidence for S_N1 or S_N2 mechanisms in the nucleophilic substitution reactions of halogenoalkanes.

4.4 How far? – entropy

Students will be assessed on their ability to:

- a demonstrate an understanding that, since endothermic reactions can occur spontaneously at room temperature, enthalpy changes alone do not control whether reactions occur
- b demonstrate an understanding of entropy in terms of the random dispersal of molecules and of energy quanta between molecules

- c demonstrate an understanding that the entropy of a substance increases with temperature, that entropy increases as solid → liquid → gas and that perfect crystals at zero kelvin have zero entropy
- d demonstrate an understanding that the standard entropy of a substance depends mainly on its physical state but also on its complexity
- e demonstrate an understanding that reactions occur due to chance collisions, and that one possible ordered arrangement, eg in a crystalline solid, can be rearranged into many possible disordered arrangements, eg in a solution, so the probability of disorder is greater than order
- f interpret the natural direction of change as being in the direction of increasing total entropy (positive entropy change), eg gases spread spontaneously through a room
- g carry out experiments and relate the results to disorder and enthalpy changes including:
- dissolving a solid, eg adding ammonium nitrate crystals to water
 - gas evolution, eg reacting ethanoic acid with ammonium carbonate
 - exothermic reaction producing a solid, eg burning magnesium ribbon in air
 - endothermic reaction of two solids, eg mixing solid barium hydroxide, $\text{Ba(OH)}_2 \cdot 8\text{H}_2\text{O}$ with solid ammonium chloride
- h demonstrate an understanding that the entropy change in any reaction is made up of the entropy change in the system added to the entropy change in the surroundings, summarised by the expression:
- $$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$$
- i calculate the entropy change in the system for a reaction, ΔS_{system} , given entropy data
- j use the expression $\Delta S_{\text{surroundings}} = \frac{-\Delta H}{T}$ to calculate the entropy change in the surroundings and hence ΔS_{total}

- k demonstrate an understanding that the feasibility of a reaction depends on the balance between ΔS_{system} and $\Delta S_{\text{surroundings}}$ and that at higher temperatures the magnitude of $\Delta S_{\text{surroundings}}$ decreases and its contribution to ΔS_{total} is less. Reactions can occur as long as ΔS_{total} is positive even if one of the other entropy changes is negative
- l demonstrate an understanding of and distinguish between the concepts of thermodynamic stability and kinetic inertness
- m calculate ΔS_{system} and $\Delta S_{\text{surroundings}}$ for the reactions in 4.4g to show that endothermic reactions can occur spontaneously at room temperature
- n define the term enthalpy of hydration of an ion and use it and lattice energy to calculate the enthalpy of solution of an ionic compound
- o demonstrate an understanding of the factors that affect the values of enthalpy of hydration and the lattice energy of an ionic compound
- p use entropy and enthalpy of solution values to predict the solubility of ionic compounds.

4.5 Equilibria

Knowledge of the concepts introduced in *Unit 2, Topic 2.9: Chemical equilibria* will be assumed and extended in this topic.

Students will be assessed on their ability to:

- a demonstrate an understanding of the term 'dynamic equilibrium' as applied to states of matter, solutions and chemical reactions
- b recall that many important industrial reactions are reversible
- c use practical data to establish the idea that a relationship exists between the equilibrium concentrations of reactants and products which produces the equilibrium constant for a particular reaction, eg data on the hydrogen-iodine equilibrium

- d calculate a value for the equilibrium constant for a reaction based on data from experiment, eg the reaction of ethanol and ethanoic acid (this can be used as an example of the use of ICT to present and analyse data), the equilibrium $\text{Fe}^{2+}(\text{aq}) + \text{Ag}^+(\text{aq}) \rightleftharpoons \text{Fe}^{3+}(\text{aq}) + \text{Ag}(\text{s})$ or the distribution of ammonia or iodine between two immiscible solvents
- e construct expressions for K_c and K_p for homogeneous and heterogeneous systems, in terms of equilibrium concentrations or equilibrium partial pressures, perform simple calculations on K_c and K_p and work out the units of the equilibrium constants
- f demonstrate an understanding that when ΔS_{total} increases the magnitude of the equilibrium constant increases since $\Delta S = R \ln K$
- g apply knowledge of the value of equilibrium constants to predict the extent to which a reaction takes place
- h relate the effect of a change in temperature on the value of ΔS_{total}

4.6 Application of rates and equilibrium

Students will be assessed on their ability to:

- a demonstrate an understanding of how, if at all, and why a change in temperature, pressure or the presence of a catalyst affects the equilibrium constant and the equilibrium composition and recall the effects of changes of temperature and pressure on rate, eg the thermal decomposition of ammonium chloride, or the effect of temperature and pressure changes in the system $2\text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4$
- b use information on enthalpy change and entropy to justify the conditions used to obtain economic yields in industrial processes, and understand that in reality industrial processes cannot be in equilibrium since the products are removed, eg in the Haber process temperature affects the equilibrium yield and rate whereas pressure affects only the equilibrium yield (knowledge of industrial conditions are not required)
- c demonstrate an understanding of the steps taken in industry to maximise the atom economy of the process, eg recycling unreacted reagents or using an alternative reaction

- d demonstrate an understanding of the importance of being able to control reactions, through knowledge of equilibrium constants and entropy changes, the importance of controlling reactions to produce adequate yields under safe, economically viable conditions and why some reactions 'go' and some will never occur.

4.7 Acid/base equilibria

During this topic there will be the opportunity to carry out an internal assessment activity. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- a demonstrate an understanding that the theory about acidity developed in the 19th and 20th centuries from a substance with a sour taste to a substance which produces an excess of hydrogen ions in solution (Arrhenius theory) to the Brønsted-Lowry theory
- b demonstrate an understanding that a Brønsted-Lowry acid is a proton donor and a base a proton acceptor and that acid-base equilibria involve transfer of protons
- c demonstrate understanding of the Brønsted-Lowry theory of acid-base behaviour, and use it to identify conjugate acid-base pairs
- d define the terms pH, K_a and K_w , pK_a and pK_w , and be able to carry out calculations relating the pH of strong acids and bases to their concentrations in mol dm⁻³
- e demonstrate an understanding that weak acids and bases are only slightly dissociated in aqueous solution, and apply the equilibrium law to deduce the expressions for the equilibrium constants K_a and K_w

- f analyse the results obtained from the following experiments:
 - i measuring the pH of a variety of substances, eg equimolar solutions of strong and weak acids, strong and weak bases and salts
 - ii comparing the pH of a strong acid and a weak acid after dilution 10, 100 and 1000 times
- g analyse and evaluate the results obtained from experiments to determine K_a for a weak acid by measuring the pH of a solution containing a known mass of acid, and discuss the assumptions made in this calculation
- h calculate the pH of a solution of a weak acid based on data for concentration and K_a , and discuss the assumptions made in this calculation
- i measure the pH change during titrations and draw titration curves using different combinations of strong and weak monobasic acids and bases
- j use data about indicators, together with titration curves, to select a suitable indicator and the use of titrations in analysis
- k explain the action of buffer solutions and carry out calculations on the pH of buffer solutions, eg making buffer solutions and comparing the effect of adding acid or alkali on the pH of the buffer
- l use titration curves to show the buffer action and to determine K_a from the pH at the point where half the acid is neutralised
- m explain the importance of buffer solutions in biological environments, eg buffers in cells and in blood ($\text{H}_2\text{CO}_3/\text{HCO}_3^-$) and in foods to prevent deterioration due to pH change (caused by bacterial or fungal activity).

4.8 Further organic chemistry

Related topics in *Unit 5* will assume knowledge of this material.

During this topic there will be the opportunity to carry out an internal assessment activity. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:**1 Chirality**

- a recall the meaning of structural and E-Z isomerism (geometric/cis-trans isomerism)
- b demonstrate an understanding of the existence of optical isomerism resulting from chiral centre(s) in a molecule with asymmetric carbon atom(s) and understand optical isomers as object and non-superimposable mirror images
- c recall optical activity as the ability of a single optical isomer to rotate the plane of polarization of plane-polarized monochromatic light in molecules containing a single chiral centre and understand the nature of a racemic mixture
- d use data on optical activity of reactants and products as evidence for proposed mechanisms, as in S_N1 and S_N2 and addition to carbonyl compounds.

2 Carbonyl compounds

- a give examples of molecules that contain the aldehyde or ketone functional group
- b explain the physical properties of aldehydes and ketones relating this to the lack of hydrogen bonding between molecules and their solubility in water in terms of hydrogen bonding with the water
- c describe and carry out, where appropriate, the reactions of carbonyl compounds. This will be limited to:
 - i oxidation with Fehling's or Benedict's solution, Tollens' reagent and acidified dichromate(VI) ions
 - ii reduction with lithium tetrahydridoaluminate (lithium aluminium hydride) in dry ether
 - iii nucleophilic addition of HCN in the presence of KCN, using curly arrows, relevant lone pairs, dipoles and evidence of optical activity to show the mechanism
 - iv the reaction with 2,4-dinitrophenylhydrazine and its use to detect the presence of a carbonyl group and to identify a carbonyl compound given data of the melting temperatures of derivatives
 - v iodine in the presence of alkali.

3 Carboxylic acids

- a give some examples of molecules that contain the carboxylic acid functional group
- b explain the physical properties of carboxylic acids in relation to their boiling temperatures and solubility due to hydrogen bonding
- c describe the preparation of carboxylic acids to include oxidation of alcohols and carbonyl compounds and the hydrolysis of nitriles
- d describe and carry out, where appropriate, the reactions of carboxylic acids. This will be limited to:
 - i reduction with lithium tetrahydridoaluminate (lithium aluminium hydride) in dry ether (ethoxyethane)
 - ii neutralization to produce salts, eg to determine the amount of citric acid in fruit
 - iii phosphorus(V) chloride (phosphorus pentachloride)
 - iv reactions with alcohols in the presence of an acid catalyst, eg the preparation of ethyl ethanoate as a solvent or as pineapple flavouring.

4 Carboxylic acid derivatives

- a demonstrate an understanding that these include acyl chlorides and esters and recognise their respective functional groups, giving examples of molecules containing these functional groups
- b describe and carry out, where appropriate, the reactions of acyl chlorides limited to their reaction with:
 - i water
 - ii alcohols
 - iii concentrated ammonia
 - iv amines
- c describe and carry out, where appropriate, the reactions of esters. This will be limited to:
 - i their hydrolysis with an acid
 - ii their hydrolysis with a base, eg to form soaps
 - iii their reaction with alcohols and acids to explain the process of trans-esterification and recall how it is applied to the manufacture of bio-diesel (as a potentially greener fuel) and low-fat spreads (replacing the hydrogenation of vegetable oils to produce margarine)
- d demonstrate an understanding of the importance of the formation of polyesters and describe their formation by condensation polymerization of ethane-1,2-diol and benzene-1,4-dicarboxylic acid.

4.9 Spectroscopy and chromatography

Knowledge of the concepts introduced in *Unit 2, Topic 2.12: Mass Spectra and IR* will be assumed and extended in this topic.

Students will be assessed on their ability to:

- a explain the effect of different types of radiation on molecules and how the principles of this are used in chemical analysis and in reactions, limited to:
 - i infrared in analysis
 - ii microwaves for heating
 - iii radio waves in nmr
 - iv ultraviolet in initiation of reactions
- b explain the use of high resolution nmr spectra to identify the structure of a molecule:
 - i based on the different types of proton present from chemical shift values
 - ii by using the spin-spin coupling pattern to identify the number of protons adjacent to a given proton
 - iii the effect of radio waves on proton spin in nmr, limited to ^1H nuclei
 - iv the use of magnetic resonance imaging as a non-invasive technique, eg scanning for brain disorders, or the use of nmr to check the purity of a compound in the pharmaceutical industry
- c demonstrate an understanding of the use of IR spectra to follow the progress of a reaction involving change of functional groups, eg in the chemical industry to determine the extent of the reaction
- d interpret simple mass spectra to suggest possible structures of a simple compound from the m/e of the molecular ion and fragmentation patterns
- e describe the principles of gas chromatography and HPLC as used as methods of separation of mixtures, prior to further analysis (theory of R_f values not required), and also to determine if substances are present in industrial chemical processes.

5.1 Unit description

Chemical ideas

In this unit the study of electrode potentials builds on the study of redox in Unit 2, including the concept of oxidation number and the use of redox half equations.

Students will study further chemistry related to redox and transition metals.

The organic chemistry section of this unit focuses on arenes and organic nitrogen compounds such as amines, amides, amino acids and proteins. Students are expected to use the knowledge and understanding of organic chemistry that they have gained over the whole GCE in Chemistry when covering the organic synthesis section.

This unit draws on all other units within the GCE in Chemistry and students are expected to use their prior knowledge when learning about these areas. Students will again encounter ideas of isomerism, bond polarity and bond enthalpy, reagents and reaction conditions, reaction types and mechanisms. Students are also expected to use formulae and balance equations and calculate chemical quantities.

How chemists work

The study of chemical cells provides an opportunity to illustrate the impact on scientific thinking when it emerges that ideas developed in different contexts can be shown to be related to a major explanatory principle. In this unit, cell emfs and equilibrium constants are shown to be related to the fundamental criterion for the feasibility of a chemical reaction: the total entropy change.

The explanatory power of the energy-level model for electronic structures is further illustrated by showing how it can help to account for the existence and properties of transition metals. In this context there are opportunities to show the limitations of the models used at this level and to indicate the need for more sophisticated explanations.

Study of the structure of benzene is another example that shows how scientific models develop in response to new evidence. This links to further investigations of the models that chemists use to describe the mechanisms of organic reactions.

The study of catalysts touches on a 'frontier' area for current chemical research and development which is of theoretical and practical importance. This provides an opportunity to show how the scientific community reports and validates new knowledge.

Students have further opportunities to carry out quantitative analysis, to interpret complex data and assess the outcomes in terms of the principles of valid measurement. The topic of organic synthesis illustrates a selection of the techniques that chemists have developed to carry out reactions and purify products efficiently and safely.

Core practicals

The following specification points are core practicals within this unit that students must complete:

5.3.1d – CP21
5.3.1g – CP22
5.3.2g – CP23
5.3.2j – CP24
5.4.1d – CP25
5.4.1e – CP26
5.4.2b – CP27
5.4.2d – CP28
5.4.2i – CP29
5.4.3f – CP30

These practicals can be used to meet the requirements of Activity a: General Practical Competence (GPC) in the assessment of Unit 6. They may also appear in the written examination for Unit 5. The core practical codes (eg CP1, CP2 etc) should be used when completing the record card for each student.

Use of examples

Examples in practicals

Where 'eg' follows a type of experiment in the specification students are not expected to have carried out that specific experiment. However they should be able to use data from that or similar experiments.

For instance in this unit, *5.3.1h i Application of redox equilibria*, the specification states:

understand the procedures of the redox titrations below (i and ii) and carry out a redox titration with one:

i potassium manganate(VII), eg the estimation of iron in iron tablets.

Students will be expected to have carried out a redox titration with potassium manganate(VII), but they may or may not have done this to estimate the amount of iron in iron tablets.

In the unit test students could be given experimental data for a potassium manganate(VII) titration, in any context, and be expected to analyse and evaluate this data.

Examples in unit content

Where 'eg' follows a concept students are not expected to have been taught the particular example given in the specification. They should be able to illustrate their answer with an example of their choice.

For instance in this unit, *5.4.2h Organic nitrogen compounds: amines, amides, amino acids and proteins*, the specification states:

comment on the physical properties of polyamides and the solubility in water of the addition polymer poly(ethenol) in terms of hydrogen bonding, eg soluble laundry bags or liquid detergent capsules (liquid tabs).

Students will be expected to comment on the physical properties of polyamides and the solubility of poly(ethenol) in terms of hydrogen bonding, but they may or may not have looked at soluble laundry bags or liquid tabs.

In the unit test students could be asked to comment on the physical properties of this polyamide and the solubility of the addition polymer in terms of hydrogen bonding. This could be in the context of soluble laundry bags, or in another completely different context.

5.2 Assessment information

Unit 5 examination The examination will be 1 hour 40 minutes and have 90 marks. It will contain three Sections: A, B and C.

Section A is an objective test section which will aim to cover a large proportion of the specification for this unit.

Section B contains a mixture of short-answer and extended answer questions. Questions on the analysis and evaluation of practical work will also be included in Section B.

Section C will contain extended answer questions on contemporary contexts. This may contain stimulus materials on a scenario that students must read in order to answer the questions. It will focus on the chemistry behind the contexts and will not be a comprehension exercise. The longer timing of the examination reflects the style of the question for Section C.

Students will be able to show their full ability in Sections B and C as these contain areas where they will be stretched and challenged.

Quality of written communication will be assessed in this examination in either Section B or C. The data booklet can be used throughout the examination for this unit.

5.3 Redox and the chemistry of the transition metals

During this topic there will be the opportunity to carry out a number of internal assessment activities. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

- 1 **Application of redox equilibria**
 - a demonstrate an understanding of the terms 'oxidation number', 'redox', 'half-reactions' and use these to interpret reactions involving electron transfer
 - b relate changes in oxidation number to reaction stoichiometry
 - c recall the definition of standard electrode potential and standard hydrogen electrode and understand the need for a reference electrode
 - d set up some simple cells and calculate values of $E_{\text{cell}}^{\ominus}$ from standard electrode potential values and use them to predict the thermodynamic feasibility and extent of reactions
 - e demonstrate an understanding that E_{cell} is directly proportional to the total entropy change and to $\ln K$ for a reaction
 - f demonstrate an understanding of why the predictions in 5.3.1d may not be borne out in practice due to kinetic effects and non-standard conditions

- g carry out and evaluate the results of an experiment involving the use of standard electrode potentials to predict the feasibility of a reaction, eg interchange of the oxidation states of vanadium or manganese
- h demonstrate an understanding of the procedures of the redox titrations below (i and ii) and carry out a redox titration with one:
 - i potassium manganate(VII), eg the estimation of iron in iron tablets
 - ii sodium thiosulfate and iodine, eg estimation of percentage of copper in an alloy
- i discuss the uncertainty of measurements and their implications for the validity of the final results
- j discuss the use of hydrogen and alcohol fuel cells as energy sources, including the source of the hydrogen and alcohol, eg used in space exploration, in electric cars
- k demonstrate an understanding of the principles of modern breathalysers based on an ethanol fuel cell and compare this to methods based on the use of IR and to the reduction of chromium compounds.

2 Transition metals and their chemistry

- a describe transition metals as those elements which form one or more stable ions which have incompletely filled d orbitals
- b derive the electronic configuration of the atoms of the d- block elements (Sc to Zn) and their simple ions from their atomic number
- c discuss the evidence for the electronic configurations of the elements Sc to Zn based on successive ionization energies
- d recall that transition elements in general:
 - i show variable oxidation number in their compounds, eg redox reactions of vanadium
 - ii form coloured ions in solution
 - iii form complex ions involving monodentate and bidentate ligands
 - iv can act as catalysts both as the elements and as their compounds

- e recall the shapes of complex ions limited to linear $[\text{CuCl}_2]^-$, planar $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$, tetrahedral $[\text{CrCl}_4]^-$ and octahedral $[\text{Cr}(\text{NH}_3)_6]^{3+}$, $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ and other aqua complexes
- f use the chemistries of chromium and copper to illustrate and explain some properties of transition metals as follows:
- the formation of a range of compounds in which they are present in different oxidation states
 - the presence of dative covalent bonding in complex ions, including the aqua-ions
 - the colour or lack of colour of aqueous ions and other complex ions, resulting from the splitting of the energy levels of the d orbitals by ligands
 - simple ligand exchange reactions
 - relate relative stability of complex ions to the entropy changes of ligand exchange reactions involving polydentate ligands (qualitatively only), eg EDTA
 - relate disproportionation reactions to standard electrode potentials and hence to E_{cell}^\ominus
- g carry out experiments to:
- investigate ligand exchange in copper complexes
 - study the redox chemistry of chromium in oxidation states Cr(VI), Cr(III) and Cr(II)
 - prepare a sample of a complex, eg chromium(II) ethanoate
- h recall that transition metals and their compounds are important as catalysts and that their activity may be associated with variable oxidation states of the elements or surface activity, eg catalytic converters in car exhausts
- i explain why the development of new catalysts is a priority area for chemical research today and, in this context, explain how the scientific community reports and validates new discoveries and explanations, eg the development of new catalysts for making ethanoic acid from methanol and carbon monoxide with a high atom economy (green chemistry)

- j carry out and interpret the reactions of transition metal ions with aqueous sodium hydroxide and aqueous ammonia, both in excess, limited to reactions with aqueous solutions of Cr(III), Mn(II), Fe(II), Fe(III), Ni(II), Cu(II), Zn(II)
- k write ionic equations to show the difference between amphoteric behaviour and ligand exchange in the reactions in 5.3.2g
- l discuss the uses of transition metals and/or their compounds, eg in polychromic sun glasses, chemotherapy drugs.

5.4 Organic chemistry – arenes, nitrogen compounds and synthesis

Knowledge of the common uses of organic compounds mentioned in this topic is expected.

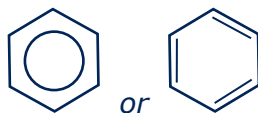
During this topic there will be the opportunity to carry out a number of internal assessment activities. Please see *Appendix 7* for more details.

Students will be assessed on their ability to:

1 Arenes: benzene

- a use thermochemical, x-ray diffraction and infrared data as evidence for the structure and stability of the benzene ring

Students may represent the structure of benzene as



as appropriate in equations and mechanisms

- b describe the following reactions of benzene, limited to:
- combustion to form a smoky flame
- treatment with:
- bromine
 - concentrated nitric and sulfuric acids
 - fuming sulfuric acid
 - halogenoalkanes and acyl chlorides with aluminium chloride as catalyst (Friedel-Crafts reaction)
 - addition reactions with hydrogen
- c describe the mechanism of the electrophilic substitution reactions of benzene in halogenation, nitration and Friedel-Crafts reactions including the formation of the electrophile
- d carry out the reactions in 5.4.1b where appropriate (using methylbenzene or methoxybenzene)
- e carry out the reaction of phenol with bromine water and dilute nitric acid and use these results to illustrate the activation of the benzene ring.

2 Organic nitrogen compounds: amines, amides, amino acids and proteins

- a give examples of:
 - i molecules that contain amine and amide functional groups
 - ii amino acids
- b describe and carry out, where appropriate (using butylamine and phenylamine), reactions to investigate the typical behaviour of primary amines. This will be limited to:
 - i characteristic smell
 - ii miscibility with water as a result of hydrogen bonding and the alkaline nature of the resulting solution
 - iii formation of salts
 - iv complex ion formation with copper(II) ions
 - v treatment with ethanoyl chloride and halogenoalkanes, eg making paracetamol
- c describe the reduction of aromatic nitro-compounds using tin and concentrated hydrochloric acid to form amines
- d describe and carry out, where appropriate, the reaction of aromatic amines with nitrous acid to form benzenediazonium ions followed by a coupling reaction with phenol to form a dye
- e recall the synthesis of amides using acyl chlorides
- f describe:
 - i condensation polymerization for the formation of polyesters such as terylene and polyamides such as nylon and Kevlar
 - ii addition polymerization including poly(propenamide) and poly(ethenol)
- g draw the structural formulae of the repeat units of the polymers in 5.4.2f
- h comment on the physical properties of polyamides and the solubility in water of the addition polymer poly(ethenol) in terms of hydrogen bonding, eg soluble laundry bags or liquid detergent capsules (liquid tabs)

- i describe and carry out, where appropriate, experiments to investigate the characteristic behaviour of amino acids. This is limited to:
 - i acidity and basicity and the formation of zwitterions
 - ii separation and identification by chromatography
 - iii effect of aqueous solutions on plane-polarised monochromatic light
 - iv formation of peptide groups in proteins by condensation polymerization
 - v reaction with ninhydrin.

3 Organic synthesis

- a give examples to illustrate the importance of organic synthesis in research for the production of useful products
- b explain why sensitive methods of chemical analysis are important when planning and monitoring organic syntheses
- c deduce the empirical formulae, molecular formulae and structural formulae from data drawn from combustion analysis, elemental percentage composition, characteristic reactions of functional groups, infrared spectra, mass spectra and nuclear magnetic resonance
- d use knowledge of organic chemistry contained in this specifications to solve problems such as:
 - i predicting the properties of unfamiliar compounds containing one or more of the functional groups included in the specification, and explain these predictions
 - ii planning reaction schemes of up to four steps, recalling familiar reactions and using unfamiliar reactions given sufficient information
 - iii selecting suitable practical procedures for carrying out reactions involving compounds with functional groups included in the specification
 - iv identifying appropriate control measures to reduce risk during a synthesis based upon data of hazards
 - v understanding why, in the synthesis of stereo-specific drugs, it is important to understand the mechanism of the reaction and how this can help to plan the synthesis

- e explain why the pharmaceutical industry has adopted combinatorial chemistry in drug research, including passing reactants over reagents on polymer supports
- f describe and carry out, where appropriate, the preparation of a compound, eg cholesteryl benzoate (a liquid crystal) and of methyl 3-nitrobenzoate, requiring some of the following techniques:
 - i refluxing
 - ii purification by washing, eg with water and sodium carbonate solution
 - iii solvent extraction
 - iv recrystallization
 - v drying
 - vi distillation
 - vii steam distillation
 - viii melting temperature determination
 - ix boiling temperature determination.

6.1 Unit description

This unit contains practical assessments that cover the content of Units 4 and 5. There is no specific content for this unit.

As with AS Unit 3 students' laboratory skills will be tested in four different ways. However there is a choice in how these can be delivered.

Activity **a** must be cover the three areas of physical, organic and inorganic chemistry. However, over activities **b**, **c** and **d** two of these areas must be covered. The types of practicals that students must complete for activities **b**, **c** and **d** are qualitative observations, quantitative measurements and preparations.

For this unit there is the opportunity for students to undertake a multi-stage experiment, which includes quantitative measurement and preparation in a longer assessment.

Edexcel will provide a selection of assessed practical sheets for activities **b**, **c** and **d** and the multi-stage experiment. Students can either complete just one assessed practical sheet for each activity, or they can complete more than one for each activity and submit the best mark. The total mark for this unit is 40.

Section 'b, c and d' include practical activities (40 marks) where the teacher uses Edexcel devised practical activity sheets and mark schemes.

Teachers have the option of marking these activities or having them marked by Edexcel.

6.2 Assessment information

Choice of pathways

In this unit students must complete activities **a** and **b** as in Unit 3 in the AS internal assessment. However, for activities **c** and **d** there will be a choice of pathways they can follow. They can follow **pathway 1** with activities **c** and **d** assessed separately, as in AS. Or they can follow **pathway 2**, which assesses activities **c** and **d** together in a multi-stage experiment.

Controlled conditions

All these activities must be carried out under controlled conditions. Students will be allowed to write up their practical reports in a separate lesson, but their materials must be collected at the end of the session and handed back at the beginning of the next session. Students are not permitted to work on their practical sheets out of the lesson. Students work must be individual and they may not work with other students in groups.

Assessed practical sheets

The practical sheets for activities **b**, **c**, **d** and the multi-stage experiment are confidential and must not be shown to students prior to their completion of them. They will be available on a secure Edexcel website for teachers to download in preparation for delivery.

Activities**Activity a: General Practical Competence (GPC)**

This will confirm that the students have completed a range of practicals over the whole year and developed their laboratory skills. Students must have carried out at least five practicals in class.

Students will have to complete practical activities as part of Units 1 and 2. By completing these practicals students will be able to:

- follow and interpret experimental instructions, covering the full range of laboratory exercises set throughout the course, with minimal help from the teacher
- always work with interest and enthusiasm in the laboratory completing most laboratory exercises in the time allocated
- manipulate apparatus, use chemicals, carry out all common laboratory procedures and use data logging (where appropriate) with the highest level of skill that may be reasonably expected at this level
- work sensibly and safely in the laboratory paying due regard to health and safety requirements without the need for reminders from the teacher
- gain accurate and consistent results in quantitative exercises, make most of the expected observations in qualitative exercises and obtain products in preparations of high yield and purity.

There will be no separate mark awarded for these practical activities.

Verification of completion of these practicals is required as well as the core practical code, or title of an alternative practical, field of chemistry and dates on which the practicals were carried out.

Activity b: Qualitative observation

Students must complete one qualitative observation, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.

Pathway 1

Activity c: Quantitative measurement

Students must complete one quantitative measurement, from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 14.

Activity d: Preparation

Students must complete one preparation (making a chemical), from the selection provided by Edexcel. This activity will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 12.

Pathway 2

Multi-stage experiment

Students could complete a multi-stage experiment, comprising of a quantitative measurement and a preparation. This will cover the same criteria as activities **c** and **d**, but allow students experience of a longer and different practical activity. This activity must be chosen from the selection provided by Edexcel. It will include a student sheet, teacher and technician notes and a mark scheme. The activity is marked out of 26.

6.3 Tasks for activity b

Tasks available for activity b — qualitative observation for the A2 are as follows. These tasks will change each year. Please see *section 6.7* for further details.

Activity code	Title	Unit
A2B1	Observation exercise on two inorganic compounds	Unit 5, Topic 5.3: Redox and the chemistry of the transition metals
A2B2	Observation exercise on three transition metal ions	Unit 5, Topic 5.3: Redox and the chemistry of the transition metals
A2B3	Observation exercise on two inorganic salt solutions	Unit 5, Topic 5.3: Redox and the chemistry of the transition metals
A2B4	Observation exercise on three organic compounds	Unit 4, Topic 4.8: Further organic chemistry

6.4 Tasks for activity c

Tasks available for activity c — quantitative measurement for the A2 are as follows.

Activity code	Title	Unit
A2C1	pH titration — finding the K_a value of a weak acid	Unit 4, Topic 4.7: Acid/base equilibria
A2C2	Following the rate of a reaction	Unit 4, Topic 4.3: How fast? — rates
A2C3	Potassium manganate(VII) titration	Unit 5, Topic 5.3: Redox and the chemistry of the transition metals
A2C4	Finding the activation energy of a reaction	Unit 4, Topic 4.3: How fast? — rates

6.5 Tasks for activity d

Tasks available for activity d — preparation for the A2 are as follows.

Activity code	Title	Unit
A2D1	Preparation of aspirin	Unit 5, Topic 5.4: Organic chemistry — arenes, nitrogen compounds and synthesis
A2D2	Preparation of a transition metal complex salt	Unit 5, Topic 5.3: Redox and the chemistry of the transition metals
A2D3	Preparation of an ester	Unit 5, Topic 5.4: Organic chemistry — arenes, nitrogen compounds and synthesis

6.6 Task for the multi-stage experiment (c+d)

Task available for the multi-stage experiment (c+d) for the A2 are as follows.

Activity code	Title	Unit
A2M1	The synthesis of aspirin in two stages	Unit 5, Topic 5.4: Organic chemistry — arenes, nitrogen compounds and synthesis

6.7 Activity sheets

The activity sheets for activities **b**, **c** and **d** will be available to download from the Edexcel website. These are securely stored so a password is required to access them. They are confidential and must not be distributed to students prior to them carrying out the task.

The tasks for activity b — qualitative observation will change each year. The tasks listed in *section 6.3* (A2B1, A2B2, A2B3 and A2B4) are only valid from September 2009 to August 2010. New tasks will be available for each following year, on the Edexcel website, as secure files. The new files will have different codes (eg A2B5) to make them easily identifiable.

Administration of internal assessment

-
- 1 Internal standardisation** Teachers choosing the option of marking the internal assessment work must show clearly how the marks have been awarded in relation to the assessment criteria. If more than one teacher in a centre is marking students' work, there must be a process of internal standardisation to ensure that there is consistent application of the assessment criteria.
-
- 2 Authentication** All candidates must sign an authentication statement. Statements relating to work not sampled should be held securely in your centre. Those which relate to sampled candidates must be attached to the work and sent to the moderator. In accordance with a revision to the current Code of Practice, any candidate unable to provide an authentication statement will receive zero credit for the component. Where credit has been awarded by a centre-assessor to sampled work without an accompanying authentication statement, the moderator will inform Edexcel and the mark will be adjusted to zero.
-
- 3 Further information** For more information on annotation, authentication, mark submission and moderation procedures, please refer to the *Edexcel Information Manual* document, which is available on the Edexcel website.
- For up-to-date advice on teacher involvement, malpractice and plagiarism, please refer to the latest *Joint Council for Qualifications (JCQ) Instructions for Conducting Coursework* document. This document is available on the JCQ website: www.jcq.org.uk.
- For additional information on malpractice, please refer to the latest *Joint Council for Qualifications (JCQ) Suspected Malpractice in Examinations and Assessments: Policies and Procedures* document, available on the JCQ website.

D Assessment and additional information

Assessment information

Assessment requirements	For a summary of assessment requirements and assessment objectives, see <i>Section B, Specification overview</i> .
Entering candidates for this qualification	Details of how to enter candidates for the examinations for this qualification can be found in Edexcel's Information Manual, copies of which are sent to all examinations officers. The information can also be found on Edexcel's website: www.edexcel.com .
Resitting of units	<p>There is no limit to the number of times that a student may retake a unit prior to claiming certification for the qualification. The best available result for each contributing unit will count towards the final grade.</p> <p>After certification all unit results may be reused to count towards a new award. Students may re-enter for certification only if they have retaken at least one unit.</p> <p>Results of units held in the Edexcel unit bank have a shelf life limited only by the shelf life of this specification.</p>
Awarding and reporting	<p>The grading, awarding and certification of this qualification will comply with the requirements of the current GCSE/GCE Code of Practice, which is published by the Office of Qualifications and Examinations Regulation (Ofqual). The AS qualification will be graded and certificated on a five-grade scale from A to E. The full GCE Advanced level will be graded on a six-point scale A* to E. Individual unit results will be reported.</p> <p>A pass in an Advanced Subsidiary subject is indicated by one of the five grades A, B, C, D, E of which grade A is the highest and grade E the lowest. A pass in an Advanced GCE subject is indicated by one of the six grades A*, A, B, C, D, E of which Grade A* is the highest and Grade E the lowest. To be awarded an A* students will need to achieve an A on the full GCE Advanced level qualification and an A* aggregate of the A2 units. Students whose level of achievement is below the minimum judged by Edexcel to be of sufficient standard to be recorded on a certificate will receive an unclassified U result.</p>

Performance descriptions

Performance descriptions give the minimum acceptable level for a grade. See *Appendix 1* for the performance descriptions for this subject.

Unit results

The minimum uniform marks required for each grade for each unit:

Unit 1

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	96	84	72	60	48

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–47.

Unit 2

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	96	84	72	60	48

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–47.

Unit 3

Unit grade	A	B	C	D	E
Maximum uniform mark = 60	48	42	36	30	24

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–23.

Unit 4

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	96	84	72	60	48

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–47.

Unit 5

Unit grade	A	B	C	D	E
Maximum uniform mark = 120	96	84	72	60	48

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–47.

Unit 6

Unit grade	A	B	C	D	E
Maximum uniform mark = 60	48	42	36	30	24

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–23.

Qualification results

The minimum uniform marks required for each grade:

Advanced Subsidiary Cash-in code 8CH01

Qualification grade	A	B	C	D	E
Maximum uniform mark = 300	240	210	180	150	120

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–119.

Advanced GCE Cash-in code 9CH01

Qualification grade	A	B	C	D	E
Maximum uniform mark = 600	480	420	360	300	240

Candidates who do not achieve the standard required for a Grade E will receive a uniform mark in the range 0–239.

Language of assessment

Assessment of this specification will be available in English only. Assessment materials will be published in English only and all work submitted for examination and moderation must be produced in English.

Quality of written communication

Students will be assessed on their ability to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate.

In GCE Chemistry the quality of written communication will cover all of these, with students selecting the most relevant way of communicating their information, to a particular context. Quality of written communication will be assessed in all units.

Assessment objectives and weighting

		% in AS	% in A2	% in GCE
AO1	Knowledge and understanding of <i>How Science Works</i>	38.4%	25%	31.7%
AO2	Application of knowledge and understanding of <i>How Science Works</i>	38.4%	43%	40.7%
AO3	How Science Works	23.2%	32%	27.6%
	TOTAL	100%	100%	100%

Synoptic assessment

In synoptic assessment the focus should be on the quality of assessment to ensure that it encourages the development of an understanding of the subject.

Synopticity requires students to connect knowledge, understanding and skills acquired in different parts of the Advanced Level GCE course.

Synoptic assessment in the context of chemistry requires students to apply knowledge and understanding gained from other units to solve a problem. For example, problems related to organic chemistry in *Unit 5* require all of the knowledge and understanding the students have developed throughout the other AS and A2 topics.

In the examinations at A2 there will be three sections. Sections B and C will contain extended answer questions where students can demonstrate the scientific knowledge they have developed over the whole GCE in Chemistry. These sections will address the synoptic assessment of the GCE in Chemistry. In addition there will be specific questions in Section C of the examinations for *Units 4* and *5* which will address synopticity. In *Unit 4* students will have to answer data questions, using knowledge and understanding gained from the AS units and *Unit 4*. In *Unit 5* students will have to answer contextualised questions on the areas of *Unit 5*, drawing on their knowledge and understanding gained throughout the whole GCE in Chemistry.

Stretch and challenge

Students can be stretched and challenged in A2 units through the use of different assessment strategies, for example:

- having using a variety of stems in the questions used — for example analyse, evaluate, discuss, compare
- ensuring connectivity between sections of questions
- having a requirement for extended writing
- using a wide range of question types to address different skills — for example open-ended questions, case studies
- improvement of synoptic assessment.

As discussed in the synoptic assessment section above, in the A2 examinations Sections B and C will stretch and challenge students.

Section B will contain short and extended answer questions and Section C will contain either data or contextualised questions, to allow students to show their full range of understanding of specific areas of chemistry.

In these sections questions may be on the following areas:

- data analysis and evaluation, from laboratory experiments
- application of chemistry to contemporary contexts, through stimulus material.

Students will then have the opportunity to demonstrate the range of their abilities in responding to these questions.

Both of these sections will therefore differentiate between A*, A and B grade students.

Additional information

Malpractice and plagiarism

For up-to-date advice on malpractice and plagiarism, please refer to the latest *Joint Council for Qualifications (JCQ) Instructions for Conducting Coursework* document. This document is available on the JCQ website: www.jcq.org.uk.

For additional information on malpractice, please refer to the latest *Joint Council for Qualifications (JCQ) Suspected Malpractice in Examinations And Assessments: Policies and Procedures* document, available on the JCQ website.

Access arrangements and special requirements

Edexcel's policy on access arrangements and special considerations for GCE, GCSE, and Entry Level is designed to ensure equal access to qualifications for all students (in compliance with the Equality Act 2010) without compromising the assessment of skills, knowledge, understanding or competence.

Please see the Joint Council for Qualifications (JCQ) website (www.jcq.org.uk) for their policy on access arrangements, reasonable adjustments and special considerations.

Please see our website (www.edexcel.com) for:

- the forms to submit for requests for access arrangements and special considerations
- dates to submit the forms.

Requests for access arrangements and special considerations must be addressed to:

Special Requirements
Edexcel
One90 High Holborn
London WC1V 7BH

Equality Act 2010

Please see our website (www.edexcel.com) for information on the Equality Act 2010.

Prior learning and progression**Prior learning**

Students who would benefit most from studying a GCE in Chemistry are likely to have a Level 2 qualification such as a GCSE in Additional Science at grades A*–C or GCSE Chemistry at Grades A* to C.

Progression

This qualification supports progression into further education, training or employment, such as bachelor degrees in Chemistry, or chemistry related degrees, or employment within the science sector.

Combinations of entry

There are no forbidden combinations.

Student recruitment

Edexcel's access policy concerning recruitment to our qualifications is that:

- they must be available to anyone who is capable of reaching the required standard
- they must be free from barriers that restrict access and progression
- equal opportunities exist for all students.

The wider curriculum

This qualification provides opportunities for developing an understanding of moral, ethical, social and cultural issues, together with an awareness of environmental issues, health and safety considerations, and European developments consistent with relevant international agreements appropriate as applied to chemistry. *Appendix 2: Wider curriculum* maps the opportunities available.

E Resources, support and training

Resources to support the specification

In addition to the resources available in the *Getting Started* book, Edexcel produces a wide range of other resources to support this specification.

Edexcel's own published resources

Edexcel aims to provide comprehensive support for our qualifications. We have therefore published our own dedicated suite of resources for teachers and students written by qualification experts. The resources include:

- AS Students' Book
- A2 Students' Book
- AS ActiveTeach CD ROM
- A2 ActiveTeach CD ROM
- AS Teacher Support Pack
- A2 Teacher Support Pack.

For more information on our complete range of products and services for the GCE in Chemistry, visit www.edexcel.com/gce2008.

Edexcel publications

You can order further copies of the specification and SAMs documents from:

Edexcel Publications
Adamsway
Mansfield
Notts NG18 4FN

Email: publication.orders@edexcel.com
Website: www.edexcel.com

Additional resources endorsed by Edexcel

Edexcel also endorses additional materials written to support this qualification.

Any resources bearing the 'Endorsed by Edexcel' logo have been through a rigorous quality assurance process to ensure complete and accurate support for the specification. For up-to-date information about endorsed resources, please visit www.edexcel.com/endorsed.

Please note that while resources are checked at the time of publication, materials may be withdrawn from circulation and website locations may change.

The resources listed are intended to be a guide for teachers and not a comprehensive list. Further suggestions can be found in *Appendix 8*.

Please see www.edexcel.com/gce2008 for up-to-date information.

Edexcel support services

Edexcel support services

Edexcel has a wide range of support services to help you implement this qualification successfully.

ResultsPlus – ResultsPlus is an application launched by Edexcel to help subject teachers, senior management teams, and students by providing detailed analysis of examination performance. Reports that compare performance between subjects, classes, your centre and similar centres can be generated in 'one-click'. Skills maps that show performance according to the specification topic being tested are available for some subjects. For further information about which subjects will be analysed through ResultsPlus, and for information on how to access and use the service, please visit www.edexcel.com/resultsplus

Ask the Expert – to make it easier for our teachers to ask us subject specific questions we have provided the **Ask the Expert** Service. This easy-to-use web query form will allow you to ask any question about the delivery or teaching of Edexcel qualifications. You'll get a personal response, from one of our administrative or teaching experts, sent to the email address you provide. You can access this service at www.edexcel.com/ask

Support for Students

Learning flourishes when students take an active interest in their education; when they have all the information they need to make the right decisions about their futures. With the help of feedback from students and their teachers, we've developed a website for students that will help them:

- understand subject specifications
- access past papers and mark schemes
- learn about other students' experiences at university, on their travels and when entering the workplace.

We're committed to regularly updating and improving our online services for students. The most valuable service we can provide is helping schools and colleges unlock the potential of their learners. www.edexcel.com/students

Training

A programme of professional development and training courses, covering various aspects of the specification and examination, will be arranged by Edexcel each year on a regional basis. Full details can be obtained from:

Training from Edexcel
Edexcel
One90 High Holborn
London WC1V 7BH

Email: trainingbookings@pearson.com
Website: www.edexcel.com/training

F Appendices

Appendix 1 Performance descriptions	97
Appendix 2 Wider curriculum	103
Appendix 3 Codes	105
Appendix 4 How Science Works – mapping and expansion on specification content	107
Appendix 5 Mathematical requirements mapping	119
Appendix 6 The periodic table of the elements	121
Appendix 7 Mapping of internal assessment activities to the units	123
Appendix 8 Further resources and support	125

Introduction

Performance descriptions have been created for all GCE subjects. They describe the learning outcomes and levels of attainment likely to be demonstrated by a representative candidate performing at the A/B and E/U boundaries for AS and A2.

In practice most candidates will show uneven profiles across the attainments listed, with strengths in some areas compensating in the award process for weaknesses or omissions elsewhere. Performance descriptions illustrate expectations at the A/B and E/U boundaries of the AS and A2 as a whole; they have not been written at unit level.

Grade A/B and E/U boundaries should be set using professional judgement. The judgement should reflect the quality of candidates' work, informed by the available technical and statistical evidence. Performance descriptions are designed to assist examiners in exercising their professional judgement. They should be interpreted and applied in the context of individual specifications and their associated units. However, performance descriptions are not designed to define the content of specifications and units.

The requirement for all AS and A level specifications to assess candidates' quality of written communication will be met through one or more of the assessment objectives.

The performance descriptions have been produced by the regulatory authorities in collaboration with the awarding bodies.

AS performance descriptions for Chemistry

Assessment objectives	Assessment objective 1 Knowledge and understanding of science and of How science works Candidates should be able to: <ul style="list-style-type: none"> ■ recognise, recall and show understanding of scientific knowledge ■ select, organise and communicate relevant information in a variety of forms. 	Assessment objective 2 Application of knowledge and understanding of science and of How science works Candidates should be able to: <ul style="list-style-type: none"> ■ analyse and evaluate scientific knowledge and processes ■ apply scientific knowledge and processes to unfamiliar situations including those related to issues ■ assess the validity, reliability and credibility of scientific information. 	Assessment objective 3 How science works Candidates should be able to: <ul style="list-style-type: none"> ■ demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods ■ make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy ■ analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary performance descriptions	Candidates characteristically: a demonstrate knowledge and understanding of most principles, concepts and facts and from the AS specification b select relevant information from the AS specification c organise and present information clearly in appropriate forms d write equations for most straightforward reactions using scientific terminology.	Candidates characteristically: a apply principles and concepts in familiar and new contexts involving only a few steps in the argument b describe significant trends and patterns shown by data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly c comment critically on statements, conclusions or data d carry out accurately most structured calculations specified for AS e use a range of chemical equations f translate successfully data presented as prose, diagrams, drawings, tables or graphs from one form to another.	Candidates characteristically: a devise and plan experimental and investigative activities, selecting appropriate techniques b demonstrate safe and skilful practical techniques c make observations and measurements with appropriate precision and record these methodically d interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

E/U boundary performance descriptions	Assessment objective 1 Candidates characteristically: a demonstrate knowledge and understanding of some principles and facts from the AS specification b select some relevant information from the AS specification c present information using basic terminology from the AS specification d write equations for some straightforward reactions.	Assessment objective 2 Candidates characteristically: a apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument b describe some trends or patterns shown by data presented in tabular or graphical form c identify, when directed, inconsistencies in conclusions or data d carry out some steps within calculations e use simple chemical equations f translate data successfully from one form to another, in some contexts	Assessment objective 3 Candidates characteristically: a devise and plan some aspects of experimental and investigative activities b demonstrate safe practical techniques c make observations and measurements and record them d interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 performance descriptions for Chemistry

Assessment objectives	Assessment objective 1 Knowledge and understanding of science and of How science works Candidates should be able to: <ul style="list-style-type: none"> ■ recognise, recall and show understanding of scientific knowledge ■ select, organise and communicate relevant information in a variety of forms. 	Assessment objective 2 Application of knowledge and understanding of science and of How science works Candidates should be able to: <ul style="list-style-type: none"> ■ analyse and evaluate scientific knowledge and processes ■ apply scientific knowledge and processes to unfamiliar situations including those related to issues ■ assess the validity, reliability and credibility of scientific information. 	Assessment objective 3 How science works Candidates should be able to: <ul style="list-style-type: none"> ■ demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods ■ make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy ■ analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary performance descriptions	Candidates characteristically: a demonstrate detailed knowledge and understanding of most principles, concepts and facts from the A2 specification b select relevant information from the A2 specification c organise and present information clearly in appropriate forms using scientific terminology d write equations for most chemical reactions.	Candidates characteristically: a apply principles and concepts in familiar and new contexts involving several steps in the argument b describe significant trends and patterns shown by complex data presented in tabular or graphical form; interpret phenomena with few errors; and present arguments and evaluations clearly c evaluate critically the statements, conclusions or data d carry out accurately complex calculations specified for A level e use chemical equations in a range of contexts f translate successfully data presented as prose, diagrams, drawings, tables or graphs, from one form to another g select a wide range of facts, principles and concepts from both AS and A2 specifications h link together appropriate facts principles and concepts from different areas of the specification.	Candidates characteristically: a devise and plan experimental and investigative activities, selecting appropriate techniques b demonstrate safe and skilful practical techniques c make observations and measurements with appropriate precision and record these methodically d interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

E/U boundary performance descriptions	Assessment objective 1 Candidates characteristically: a demonstrate knowledge and understanding of some principles and facts from the A2 specification b select some relevant information from the A2 specification c present information using basic terminology from the A2 specification d write equations for some chemical reactions.	Assessment objective 2 Candidates characteristically: a apply given principles or concepts in familiar and new contexts involving a few steps in the argument b describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form c identify, when directed, inconsistencies in conclusions or data d carry out some steps within calculations e use some chemical equations f translate data successfully from one form to another, in some contexts g select some facts, principles and concepts from both AS and A2 specifications h put together some facts, principles and concepts from different areas of the specification.	Assessment objective 3 Candidates characteristically: a devise and plan some aspects of experimental and investigative activities b demonstrate safe practical techniques c make observations and measurements and record them d interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

Signposting

Issue	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Moral	✓	✓		✓	✓	
Ethical	✓	✓		✓	✓	
Social	✓	✓		✓	✓	
Cultural	✓	✓		✓	✓	
Citizenship	✓	✓		✓	✓	
Environmental	✓	✓	✓	✓	✓	✓
European initiatives	✓	✓	✓	✓	✓	✓
Health and safety	✓	✓	✓	✓	✓	✓

Development suggestions

Issue	AS/A2 units	Opportunities for development or internal assessment
Moral	1, 2, 4, 5	Unit 2 — introduces a major moral issue in chemistry — green chemistry.
Ethical	1, 2, 4, 5	Unit 4 — bio-diesel is used instead of fossil fuels to reduce pollution and climate change.
Social	1, 2, 4, 5	Unit 5 — catalytic converters to reduce exhaust fumes and smog in cities.
Cultural	1, 2, 4, 5	Unit 1 — developing alternative fuels and reducing emissions of CO ₂ , in different countries and their environmental policies.
Citizenship	1, 2, 4, 5	Unit 2 — green chemistry, which is a concern across all areas of chemistry.
Environmental	1, 2, 3, 4, 5, 6	Across all units — waste management. Unit 2 — green chemistry, pollution, climate change and methods of production of chemicals.
European initiatives	1, 2, 3, 4, 5, 6	Across all units — use IUPAC nomenclature.
Health and safety	1, 2, 3, 4, 5, 6	Across all units — carry out practical activities after using the appropriate risk assessments and safety procedures.

Type of code	Use of code	Code number
National classification codes	Every qualification is assigned to a national classification code indicating the subject area to which it belongs. Centres should be aware that students 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.	1110
National Qualifications Framework (NQF) codes	Each qualification title is allocated a National Qualifications Framework (NQF) code. The National Qualifications Framework (NQF) code is known as a Qualification Number (QN). This is the code that features in the DfE Section 96, and on the LARA as being eligible for 16–18 and 19+ funding, and is to be used for all qualification funding purposes. The QN is the number that will appear on the student's final certification documentation.	The QNs for the qualifications in this publication are: AS — 500/2540/5 Advanced GCE — 500/2426/7
Unit codes	Each unit is assigned a unit code. This unit code is used as an entry code to indicate that a student wishes to take the assessment for that unit. Centres will need to use the entry codes only when entering students for their examination.	Unit 1 6CH01 Unit 2 6CH02 Unit 3 6CH03 Unit 4 6CH04 Unit 5 6CH05 Unit 6 6CH06
Cash-in codes	The cash-in code is used as an entry code to aggregate the student's unit scores to obtain the overall grade for the qualification. Centres will need to use the entry codes only when entering students for their qualification.	AS — 8CH01 Advanced GCE — 9CH01
Entry codes	The entry codes are used to: 1 enter a student for the assessment of a unit 2 aggregate the student's unit scores to obtain the overall grade for the qualification.	Please refer to the Edexcel Information Manual available on the Edexcel website.

How Science Works – mapping

How Science Works reference	Specification reference			
	Unit 1	Unit 2	Unit 4	Unit 5
1 Use theories, models and ideas to develop and modify scientific explanations	1.4d	2.3c	4.3h	5.3.1c
	1.4e	2.4a	4.3j	5.3.1d
	1.4g	2.4b	all of 4.4	5.3.1e
	1.5e	2.4c	4.5c	5.3.1f
	1.5f	2.4d	4.5f	5.3.2c
	1.5g	2.5b	4.5g	5.4.1a
	1.5k	2.5d	4.5h	
	1.6.1a	2.6a	all of 4.6	
	1.6.1h	all of 2.7	4.7a	
	1.6.1l	2.8b	4.7b	
	1.6.3b	2.8c	4.7c	
	1.7.2e	2.8d	4.7e	
	1.7.3b	2.8e		
	1.7.3e	2.11a		
		2.11b		
	2.11c			
	2.11d			
	2.11e			
	2.11f			
2 Use knowledge and understanding to pose scientific questions, define scientific problems, and present scientific arguments and ideas	1.7.2c	2.11g	4.6a	5.3.2g
	1.7.2d	2.12d	4.6b	5.4.2h
	1.7.2e	2.13b	4.6c	5.4.3a
	1.7.3b		4.6d	5.4.3d
	1.7.3h		4.7g	
3 Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems	1.4d	2.11g	4.3c	5.4.3a
	1.4f		4.3d	5.4.3d
	1.5b		4.3e	
	1.7.2c		4.8.1d	
	1.7.2d			
	1.7.3h			
4 Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts	General laboratory work and practical assessment			

Appendix 4 How Science Works – mapping and expansion on specification content

How Science Works reference	Specification reference			
	Unit 1	Unit 2	Unit 4	Unit 5
5 Analyse and interpret data to provide evidence, recognising correlations and causal relationships	1.3j 1.4f 1.7.1c	all of 2.7 2.11g	4.5c 4.8.1d	5.3.1I 5.4.3b 5.4.3c
6 Evaluate methodology, evidence and data and resolve conflicting evidence	1.3i 1.7.3h			5.3.1j 5.3.1.k 5.4.3.b 5.4.3.c
7 Appreciate the tentative nature of scientific knowledge	1.5e 1.5f	2.4a 2.4b 2.4c 2.4d		5.3.1d 5.3.1e 5.3.1f 5.3.2c 5.4.1a
8 Communicate information and ideas in appropriate ways using appropriate terminology	1.7.2c 1.7.2d 1.7.3h	2.11g all of 2.13	4.6a 4.6b 4.6c 4.6d	5.3.1i 5.3.2h
9 Consider the applications and implications of science and appreciate their associated benefits and risks	1.7.1c 1.7.1d 1.7.3d 1.7.3h	2.3e 2.9c 2.10.2f all of 2.13	4.6a 4.6b 4.6c 4.6d 4.7m all of 4.9	5.3.1j 5.3.1k 5.3.2h 5.3.2k 5.4.3a 5.4.3d
10 Consider ethical issues in the treatment of humans, other organisms and the environment		2.3e 2.11g all of 2.13	4.6a 4.6b 4.6c 4.6d all of 4.9	5.3.2I
11 Appreciate the role of the scientific community in validating new knowledge and ensuring integrity	1.7.3h	all of 2.13	all of 4.9	5.3.2h 5.4.3b 5.4.3c
12 Appreciate the ways in which society uses science to inform decision making	1.3c 1.7.2c 1.7.2d 1.7.3h	2.7.1h 2.11g all of 2.13	4.6a 4.6b 4.6c 4.6d all of 4.9	5.3.1i

How Science Works — expansion of specification content

The following notes show how the ideas involved with *How Science Works* can be developed from the specification content. In many cases this will involve a change in approach to a topic rather than the introduction of unfamiliar content

Unit 1: The Core Principles of Chemistry

Topic 1.3 – Formulae, equations and amounts of substance

Throughout the unit students see the importance of chemical data and learn to select data from databases and use it to look for patterns and calculate other quantities.

1.3c	Students should appreciate that mol dm ⁻³ is not a very useful unit when dealing with very small concentrations and alternatives provide a better understanding for comparative purposes. Students could also consider examples of the labelling of contents of food by supermarkets and discuss whether they have scientific and mathematical validity, eg the use of pie charts. HSW 12
1.3i	Quantitative exercises of this type provide an opportunity to introduce evaluation of methodology such as limitations of techniques, accuracy of measurement, types of errors and uncertainty of the final result and the idea that it is impossible to get a 100 per cent accurate result in experiments of this type and the implications this may have for testing for drugs etc. HSW 6
1.3j	These exercises are designed to get students to interpret information generated at a macroscopic level, to suggest what is happening at a molecular level and to use this to write different types of equation. Much of this could be used to introduce the ideas of microscale chemistry. HSW 5

Topic 1.4 – Energetics

Practical work to measure energy changes helps students to understand the ideas of uncertainty in measurements and evaluate their results in terms of systematic and random errors.

1.4d	Students need to consider why it is necessary to have a standard set of conditions when quoting thermochemical data and the idea that only energy changes can be measured and, consequently, some fixed points are needed (such as the standard heat of formation of elements being defined as 0 Jmol ⁻¹). Examples might include the energy generated by burning different fuels. HSW 1, HSW 3
1.4e	Hess's law is an example of a mathematical model that can be used to bring together data and allow it to be used to calculate energy changes that cannot be measured directly such as standard heat of formation of hydrocarbon fuels. HSW 1

1.4f	<p>Students should consider the assumptions made in calculations based on data from thermochemical experiments and their validity. Students could be asked to plan and carry out an investigation to find an energy change that cannot be measured directly such as the hydration of magnesium sulfate.</p> <p>HSW 4</p> <p>These exercises are designed to allow students to carry out a range of different data collecting techniques. Experiments of this type can be used to discuss alternative techniques to produce more accurate results but also show that repeating an experiment leads to reliability rather than improved accuracy.</p> <p>HSW 3, HSW 5</p>
1.4g	<p>Students could use bond data as a tool to provide ideas about possible mechanisms for reactions such as free radical substitution, structures of compounds and energy changes for reactions. They should realise the limitations of using mean bond energy data by comparing actual data from experiments to theoretical data based on bond energy.</p> <p>HSW 1</p>
<p>Topic 1.5 – Atomic structure and the periodic table</p>	
<p><i>The role of instrumentation in analytical chemistry is illustrated by mass spectrometry.</i></p> <p><i>The study of atomic structure gives some insight into the types of evidence which scientists use to study electrons in atoms. This leads to an appreciation of one of the central features of chemistry which is the explanation of the properties of elements and of the patterns in the periodic table in terms of atomic structure.</i></p>	
1.5b	<p>Students could consider the use of the mass spectrometer by the pharmaceutical industry to produce data concerning molecular mass.</p> <p>HSW 3</p>
1.5e	<p>Looking at electronic structure can provide an opportunity to discuss the historical development of a model and the way that evidence is used to generate a chemical model that is then modified as more data becomes available.</p> <p>HSW 1, HSW 7</p>
1.5f	<p>Students should consider why a more sophisticated model is needed to explain the properties of electrons in atoms and the way atoms join together.</p> <p>HSW 1, HSW 7</p>
1.5g	<p>Students could discuss the idea that trying to remember the electronic structure of every element is difficult so chemists devised a way to rationalise the information about the electronic structure of each atom into a pattern that could help to predict the electronic structure of other atoms. Students need to realise that the idea helps chemists decide on the minimum energy arrangement of a particular number of electrons around a nucleus and that this has limitations.</p> <p>HSW 1</p>
1.5k	<p>Use the model of bonding theory to explain the properties of the elements.</p> <p>HSW 1</p>

Topic 1.6 – Bonding

Students are introduced to some of the evidence which will help them to understand the different kinds of chemical bonding.

Chemists set up theoretical models and gain insights by comparing real and ideal properties of chemicals. This is illustrated in the unit by the ionic model and the comparison of lattice energies calculated from theory with those determined with the help of Born-Haber cycles.

1.6.1a and 1.6.1l	Students could discuss the evidence for complete electron transfer or electron sharing based on electron density maps. HSW 1
1.6.1h	Compare theoretical data based on the assumption of complete electron transfer data with that from practical measurement of lattice energy based on Born-Haber cycles. HSW 1
1.6.3b	Use of the model of metallic bonding to explain properties of metals. HSW 1

Topic 1.7 – Introductory organic chemistry

The introduction to organic chemistry shows how chemists work safely with potentially hazardous chemicals by managing risks.

1.7.1c and 1.7.1d	Students should be encouraged in their laboratory work to appreciate the difference between hazard and risk. They should appreciate that the total elimination of risk is almost impossible if society is to function normally and that laboratories are generally very safe environments compared with the risks of everyday life such as taking a car ride. Students could be encouraged to look at comparative risks associated with the use of applied pesticides compared with those from natural pesticides generated by nature. Students should understand the reasoning behind the steps that can be taken to minimise risk so that laboratory reactions can be carried out in safety. HSW 5, HSW 9
1.7.2c and 1.7.2d	Students could use the internet to research data concerning alternative fuels and compare the relative environmental impact in terms of reducing emissions and sustainability. The data could then be presented using ICT. An example might include the use of hydrogen as a fuel in motor cycles. Questions such as the carbon neutrality of hydrogen could be considered taking into account the energy used to produce the hydrogen, the problems associated with refuelling, the fact that the emissions are greenhouse gases and the myth that hydrogen is dangerous because it is 'explosive' could be exposed. HSW 8, HSW 2, HSW 3, HSW 12
1.7.2e	If linked with 1.4g several potential mechanisms could be offered and tested using bond energy and could provide evidence for the probable mechanism. This is an example of the use of a model to help chemists explain and classify reactions. HSW 1, HSW 2
1.7.3b	The introduction of the need for the E-Z nomenclature could be developed by looking at examples of structures that cannot be classified using the cis-trans convention. This needs to be in the context of why it is necessary to be able to distinguish between E-Z isomers (geometric). An example might include the colours in tomatoes. HSW 1, HSW 2
1.7.3d i	Students describe the addition reactions of alkenes, limited to the addition of hydrogen with a nickel catalyst to form an alkane. HSW 9

1.7.3e	This is an example of the collection of data to be used to support an hypothesis that develops into a model that helps our understanding of reactions at a molecular level. HSW 1
1.7.3h	Data on polymers could be collected to investigate their overall environmental impact and introduce the idea of carbon footprint and what can be done to reduce the impact on the environment. HSW 2, HSW 3, HSW 6, HSW 8, HSW 9, HSW 11, HSW 12

Unit 2: Application of Core Principles of Chemistry

Topics 2.3, 2.4 and 2.5 – Shapes of molecules and ions, intermediate bonding and bond polarity, intermolecular forces

Electron-pair repulsion theory shows how chemists can make generalisations and use them to make predictions.

2.3c	Students use the electron-pair repulsion theory to predict the shapes of unfamiliar molecules. HSW 1
2.3e	The work on nanochemistry could include colloid chemistry and the increased reactivity of nanoparticles compared to larger ones. Also in the cosmetics industry the use of nano sized particles in creams etc so that they can be more easily absorbed through the skin, as in moisturisers, and particles that are smaller than the wavelength of light and are therefore too small to see, and can be used in sunscreen creams but are transparent to light rather than opaque. This could raise issues about risks to and implications for humans. HSW 9, HSW 10
2.4a to 2.4d	This topic raises the issue of the bonding model as applied to actual compounds and can lead students to consider the limitations of the model and the need to consider other ideas to explain observed phenomena. HSW 1, HSW 7
2.5b and 2.5d	Use of the bonding models to explain observed phenomena. HSW 1

Topics 2.6 and 2.7 – Redox, the periodic table – groups 2 and 7

Chemists rationalise a great deal of information about chemical changes by using theory to categorise reagents and types of chemical change. This is illustrated by the use of inorganic and organic examples in this unit.

2.6a	Students use the concept of oxidation number to classify reactions and to help their understanding of changes at the atomic level. HSW 1
2.7	This topic on the periodic table can be used to illustrate the ways in which chemists collate data, search for patterns, reduce the need to remember every single reaction of every compound and predict the chemistry of unfamiliar compounds such as those of astatine. HSW 1, HSW 5

2.7.1h and 2.7.2c	Using the technique of volumetric analysis provides an opportunity for students to evaluate their own methodology to include the limitations of the apparatus, accuracy of measurement, types of errors and uncertainty of the final result. The difference between reliability and uncertainty could be explored, including the idea that repeating an experiment with the same apparatus will not improve the accuracy, only the reliability and the need to appreciate that an uncertainty in a final result can have implications for how the information may be used. HSW 5 with potential for HSW 12
Topics 2.8 and 2.9 – Kinetics, chemical equilibria	
<i>The use of models in chemistry is illustrated by the way in which the Maxwell-Boltzmann distribution and collision theory can account for the effects of temperature on the rates of chemical reactions.</i>	
2.8b	The collision theory provides a model that students can apply to help their understanding of how reactions happen at the molecular level and explain the effect of changing conditions on the rate of a reaction. HSW 1
2.8c	The Maxwell – Boltzmann curves provides students with a mathematical model that allows them to understand and predict the effect of changing conditions on the rate of a reaction. HSW 1
2.8d and 2.8e	Use of the concept of activation energy to explain changes in rate of reactions. HSW 1
2.9c	The equilibrium model and the effect of changes on the position of equilibrium can be applied to industrial situations. This can lead into discussions of atom economy and the ways in which industrial chemists and chemical engineers manipulate the conditions in a reaction to maximise yield and minimise waste of raw materials. Examples might include recycling of unreacted gases and finding new catalysts that work at lower temperatures. HSW 9
Topics 2.10, 2.11 and 2.12 – Organic chemistry, mechanisms, mass spectra and IR	
<i>The unit shows how chemists study chemical changes on an atomic scale and propose mechanisms to account for their observations.</i>	
2.10.2f	Discussion of the use of fire retardants and a consideration of the benefits against the risks involved with the use of halogenoalkanes. HSW 9
2.11a to 2.11e	The work on mechanisms provides an example of the advantages of classifying reactions and models and will help students' understanding of what is happening at the molecular level. HSW 1
2.11f	Students can apply the model to deepen their understanding of how reactions proceed at the molecular level including substitution in halogenoalkanes. HSW 1
2.11g	Consideration of the depletion of the ozone layer, NO emissions from cars and the problem of exhaust NO from high flying aircraft could be used a starting point for discussions on how understanding the mechanism of a reaction can help scientists to propose solutions to environmental problems such as the role catalytic converters in cars can play in reducing of NO emissions. Students should understand the difference between greenhouse gases and those associated with the ozone layer depletion but also that some are the same. HSW 2, HSW 3, HSW 5, HSW 8, HSW 10, HSW 12

2.12d and 2.13b	The model of polarity allows chemists to understand why some gases present problems in terms of global warming while others do not. HSW 2
Topic 2.13 – Green chemistry	
2.13	This topic provides an opportunity to bring together areas where chemists are involved in attempting to solve environmental problems by the application of theories and new technologies and are helping the public to understand the implications of the decisions that they make. This includes efforts by industry such as: <ul style="list-style-type: none"> ■ consideration of renewable resources ■ making industrial processes more environmentally friendly ■ using more efficient energy sources for reactions ■ reducing waste. <p>Students should consider the concept of carbon neutrality and explore the need to consider all stages of a process.</p> <p>Students should identify examples of the way scientific information has helped society to change.</p> HSW 9, HSW 10, HSW 11, HSW 12

Unit 4: General Principles of Chemistry I — Rates, Equilibria and Further Organic Chemistry

Topic 4.3 – How fast? – rates	
<i>Through practical work, students will learn about the methods used to measure reaction rates. They will collect data, analyse it and interpret the results. They can then see how a knowledge of rate equations, and other evidence, can enable chemists to propose models to describe the mechanisms of reactions.</i>	
4.3c and 4.3d	Practical investigations in kinetics can help improve students' skills in presenting and interpretation of data. HSW 3
4.3d and 4.3e	This investigation can be used to bring together all the basic ideas associated with kinetics and introduce ideas of how the data can be used to help understand reactions at the molecular level. HSW 3
4.3h, 4.3i and 4.3j	This looks at how knowledge of rate equations, and other evidence, can enable chemists to propose models to describe the mechanisms of reactions. HSW 1, HSW 2
Topic 4.4 – How far? – entropy	
Topic 4.4	The study of entropy introduces students to the methods of thermodynamics and shows how chemists use formal, quantitative and abstract thinking to answer fundamental questions about the stability of chemicals and the direction of chemical change. HSW 1

Topics 4.5, 4.6 and 4.7 – Equilibria, application of rates and equilibrium, acid/base equilibria

This unit tests the equilibrium law by showing the degree to which it can accurately predict changes during acid-base reactions, notably the changes to pH during titrations.

The historical development of theories explaining acids and bases shows how scientific ideas change as a result of new evidence and fresh thinking.

4.5c	Students could be encouraged to analyse data from theory or experiments to establish equilibrium relationships. They should appreciate that the relationships are empirical and apply only to the system under consideration. HSW 1, HSW 5
4.5f to 4.5h	These sections link thermodynamic theories with equilibrium situations and allows students to obtain a deeper understanding of the reasons for observed effects of changes of conditions on equilibrium. HSW 1
4.6a to 4.6d	This topic applies the material in topics 4.3, 4.4 and 4.5 of this unit to industrial situations and begins to look at the way industry can use models/theories, including kinetics, equilibrium and thermodynamic data, in the search for better yields at a lower cost to the environment. HSW 1, HSW 2, HSW 8, HSW 9, HSW 10, HSW 12
4.7a to 4.7c	Students could look at how our understanding of acid and bases has developed over the last 150 years as knowledge has increased and new theories of atomic behaviour have been formulated. HSW 1
4.7e	Students can use the model of ionic dissociation to explain acid/base behaviour. HSW 1
4.7g	Determination of K_a from pH and concentration data provides a good example of when it is appropriate to make approximations in chemistry and when it is not. HSW 2
4.7m	This can be used as an example of how chemists can help society to understand and minimise risk. HSW 9

Topic 4.8 – Further organic chemistry

4.8.1d	Analysis of data for optical activity – ie production of a racemic mixture or a single enantiomorph could be used to provide evidence for proposed mechanisms. HSW 3, HSW 5
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Topic 4.9 – Spectroscopy and chromatography

Topic 4.9	This considers how chemists use the interaction of various types of radiation with molecules, including the use of: <ul style="list-style-type: none"> ■ IR by the chemical industry as a non-invasive technique to follow the extent of a reaction ■ microwaves to provide a heat source in a closed system that can allow reactions to proceed at a temperature double that of the highest boiling point component thus reducing the time for a reaction by orders of magnitude, saving time and energy ■ nmr spectroscopy in medicine and industry. It also includes the use of HPLC as a method of rapid separation of liquid mixtures prior to further analysis. HSW 9, HSW 10, HSW 11, HSW 12
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Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry

Topic 5.3 – Redox and the chemistry of the transition metals

The study of chemical cells provides an opportunity to illustrate the impact on scientific thinking when it emerges that ideas developed in different contexts can be shown to be related to a major explanatory principle. In this unit, cell emfs and equilibrium constants are shown to be related to the fundamental criterion for the feasibility of a chemical reaction: the total entropy change.

5.3.1c	Students need to understand that electrode potentials are relative and therefore some reference point is needed to classify the data. Hence the need for a standard reference electrode. HSW 1
5.3.1d to 5.3.1f	Students apply the model to predict the direction of possible change and then link this to other theories to get a more complete picture of why reactions do or do not actually occur. HSW 1, HSW 7
5.3.1i	Using the technique of volumetric analysis provides an opportunity for students to evaluate their own methodology to include limitations of the apparatus, accuracy of measurement, types of errors and uncertainty of the final result. The difference between reliability and uncertainty could be explored, including the idea that repeating an experiment with the same apparatus will not improve the accuracy, only the reliability and the need to appreciate that an uncertainty in a final result can have implications for how the information may be used. HSW 5 with potential for HSW 8, HSW 12
5.3.1j and 5.3.1k	These are some applications of electrode potential to the solution of problems. HSW 9 with potential for HSW 6
<i>The explanatory power of the energy-level model for electronic structures is further illustrated by showing how it can help to account for the existence and properties of transition metals. In this context there are opportunities to show the limitations of the models used at this level and to indicate the need for more sophisticated explanations.</i>	
5.3.2c	The energy-level model can be used to provide evidence for the proposed electronic structures of d-block elements by consideration of plots of the first, second and third ionisation energies, particularly those of chromium and copper where evidence for the presence of half-full and full shells in the elements shows up clearly. HSW 1, HSW 7
5.3.2h	Students can use the energy-level model and ideas of bonding to explain the catalytic behaviour of the elements and their compounds. HSW 2
5.3.2i	This encourages students to explore the development of new catalysts as a priority area for chemical research today. This could be used to explain how the scientific community reports and validates new discoveries and explanations, eg the development of new catalysts for making ethanoic acid from methanol and carbon monoxide with a high atom economy. HSW 8, HSW 9, HSW 11
5.3.2l	This is an example of the application of the properties of transition metals and their compounds and their impact on society, with the associated risk and benefits in the case of chemotherapy drugs. HSW 9

Topic 5.4 – Further organic chemistry

The topic of organic synthesis illustrates a selection of the techniques that chemists have developed to carry out reactions and purify products efficiently and safely.

5.4.1a	The development of theories concerning the structure of benzene provides evidence for the way theories develop as new knowledge becomes available. HSW 1, HSW 7
5.4.2h	This is an example of the development of polymers with specific properties and the ways in which effects on the environment can be minimised by application of the theories of bonding and structure. HSW 2
5.4.3a and 5.4.3d	Students need to appreciate the importance of organic synthesis in the production of new materials and the way that the pharmaceutical industry makes tens of thousands of new compounds a year which are then tested for biological activity. HSW 2, HSW 3, HSW 9
5.4.3b and 5.4.3c	This could be used to develop ideas associated with the need to know exactly the shape of a molecule and the way the production process proceeds in the context of stereo-specific drugs. HSW 5, HSW 6, HSW 11
5.4.3d i ii	This is an example of how knowledge of organic chemistry can be applied to the properties of new compounds, development of synthesis routes, selection of procedures and the identification of associated risks. HSW 2
5.4.3f	Students need to be familiar with basic laboratory techniques. HSW 4

The mathematical requirements are embedded throughout the units of this specification. This table shows the types of activities that students will undertake and how they relate to the mathematical requirements.

QCA reference	Coverage of mathematical requirements
Arithmetical and numerical computation	
a recognise and use expressions in decimal and standard form	All calculations involving concentrations in solution, all calculations involving enthalpy changes, acid base calculations and most involving rate
b use ratios, fractions and percentages	All mole calculations and accuracy discussions
c make estimates of the results of calculations (without using a calculator)	Not explicit but encourage students to look at their answers and estimate if the order of magnitude is correct
d use calculators to find and use power, exponential and logarithmic functions	Activation energy calculations, kinetics calculations and all acid/base calculations
Handling data	
a use an appropriate number of significant figures	A vital element of all quantitative work particularly the practical aspects
b find arithmetic means	Volumetric analysis
Algebra	
a understand and use the symbols: =, <, <<, >>, >, μ , \sim	Use as appropriate mainly = <, >
b change the subject of an equation	All mole calculations and most equilibrium and acid/base calculations
c substitute numerical values into algebraic equations using appropriate units for physical quantities	Enthalpy calculations, kinetics calculations, equilibrium calculations
d solve simple algebraic equations	Equilibrium calculations
e use logarithms in relation to quantities which range over several orders of magnitude	pH, pK_a , pK_w , K_p , successive ionisation energy
Graphs	
a translate information between graphical, numerical and algebraic forms	Kinetics and enthalpy practical data
b plot two variables from experimental or other data	Almost all experiments where data is collected
c understand that $y = mx + c$ represents a linear relationship	Kinetics
d determine the slope and intercept of a linear graph	Kinetics
e calculate rate of change from a graph showing a linear relationship	Kinetics
f draw and use the slope of a tangent to a curve as a measure of rate of change	Kinetics

QCA reference	Coverage of mathematical requirements
Geometry	
a appreciate angles and shapes in regular 2D and 3D structures	Molecular shape descriptions
b visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Solid shape descriptions
c understand the symmetry of 2D and 3D shapes	E-Z isomerism

The Periodic Table of Elements

	1	2	3	4	5	6	7	0 (8)	
	6.9 Li lithium 3	9.0 Be beryllium 4	<div style="border: 1px solid black; padding: 2px; display: inline-block;"> 1.0 H hydrogen 1 </div>					19.0 F fluorine 9	4.0 He helium 2
	23.0 Na sodium 11	24.3 Mg magnesium 12	(13)	(14)	(15)	(16)	(17)	(18)	
	39.1 K potassium 19	40.1 Ca calcium 20	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	
	85.5 Rb rubidium 37	87.6 Sr strontium 38	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18	
	132.9 Cs caesium 55	137.3 Ba barium 56	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	
	[223] Fr francium 87	[226] Ra radium 88	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54	
			204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86	
			107.9 Cu copper 29	112.4 Cd cadmium 48	114.8 In indium 49	117.0 Hg mercury 80	Elements with atomic numbers 112-116 have been reported but not fully authenticated		
			58.7 Ni nickel 28	106.4 Pd palladium 46	197.0 Au gold 79	[272] Rg roentgenium 111			
			55.8 Fe iron 26	101.1 Ru ruthenium 44	190.2 Os osmium 76	[277] Hs hassium 108			
			54.9 Mn manganese 25	[98] Tc technetium 43	186.2 Re rhenium 75	[264] Bh bohrium 107			
			50.9 V vanadium 23	92.9 Nb niobium 41	180.9 Ta tantalum 73	[262] Db dubnium 105			
			47.9 Ti titanium 22	91.2 Zr zirconium 40	178.5 Hf hafnium 72	[261] Rf rutherfordium 104			
			45.0 Sc scandium 21	88.9 Y yttrium 39	138.9 La* lanthanum 57	[227] Ac* actinium 89			
			150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	163 Dy dysprosium 66	165 Ho holmium 67	169 Tm thulium 69	
			147 Pm promethium 61	144 Nd neodymium 60	152 Eu europium 63	163 Dy dysprosium 66	167 Er erbium 68	173 Yb ytterbium 70	
			237 Np neptunium 93	238 U uranium 92	243 Am americium 95	251 Cf californium 98	253 Fm fermium 100	254 No nobelium 102	
			141 Pr praseodymium 59	144 Nd neodymium 60	150 Sm samarium 62	159 Tb terbium 65	165 Ho holmium 67	175 Lu lutetium 71	
			232 Th thorium 90	238 U uranium 92	242 Pu plutonium 94	245 Bk berkelium 97	254 Fm fermium 100	257 Lr lawrencium 103	
			91 Pa protactinium 91	92 U uranium 92	95 Am americium 95	97 Bk berkelium 97	101 Md mendelevium 101	103 Lr lawrencium 103	

* Lanthanide series

* Actinide series

Unit	Activity code	Title
Unit 1: The Core Principles of Chemistry		
Unit 1, Topic 1.3: Formulae, equations and amounts of substance	ASC1	Acid-base titration — finding the molar mass of a solid acid
Unit 1, Topic 1.3: Formulae, equations and amounts of substance	ASD1	Preparation of a double salt
Unit 1, Topic 1.3: Formulae, equations and amounts of substance	ASD2	Preparation of a salt
Unit 1, Topic 1.4: Energetics	ASC2	Finding the enthalpy change for the reaction between an acid and a base
Unit 1, Topic 1.4: Energetics	ASC4	Hess's Law
Unit 1, Topic 1.7: Introductory organic chemistry	ASB3	Observation exercise on three organic compounds
Unit 2: Application of Core Principles of Chemistry		
Unit 2, Topic 2.7: The periodic table — groups 2 and 7	ASB1	Observation exercise on three inorganic compounds — 1
Unit 2, Topic 2.7: The periodic table — groups 2 and 7	ASB2	Observation exercise on three inorganic compounds — 2
Unit 2, Topic 2.7: The periodic table — groups 2 and 7	ASC3	Sodium thiosulfate(V)-iodine titration
Unit 2, Topic 2.10: Organic chemistry	ASB3	Observation exercise on three organic compounds
Unit 2, Topic 2.10: Organic chemistry	ASB4	Observation exercise on two organic compounds
Unit 2, Topic 2.10: Organic chemistry	ASD3	Preparation of an organic compound
Unit 4: General Principles of Chemistry I — Rates, Equilibria and Further Organic Chemistry		
Unit 4, Topic 4.3: How fast? — rates	A2C2	Following the rate of a reaction
Unit 4, Topic 4.3: How fast? — rates	A2C4	Finding the activation energy of a reaction
Unit 4, Topic 4.7: Acid/base equilibria	A2C1	pH titration — finding the K_a value of a weak acid
Unit 4, Topic 4.8: Further organic chemistry	A2B4	Observation exercise on three organic compounds

Appendix 7 Mapping of internal assessment activities to the units

Unit	Activity code	Title
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry		
Unit 5, Topic 5.3: Redox and the chemistry of the transition metals	A2B1	Observation exercise on two inorganic compounds
Unit 5, Topic 5.3: Redox and the chemistry of the transition metals	A2B2	Observation exercise on three transition metal ions
Unit 5, Topic 5.3: Redox and the chemistry of the transition metals	A2B3	Observation exercise on two inorganic salt solutions
Unit 5, Topic 5.3: Redox and the chemistry of the transition metals	A2C3	Potassium manganate(VII) titration
Unit 5, Topic 5.3: Redox and the chemistry of the transition metals	A2D2	Preparation of a transition metal complex salt
Unit 5, Topic 5.3: Redox and the chemistry of the transition metals	A2D1	Preparation of aspirin
Unit 5, Topic 5.4: Organic chemistry – arenes, nitrogen compounds and synthesis	A2D3	Preparation of an ester
Unit 5, Topic 5.4: Organic chemistry – arenes, nitrogen compounds and synthesis	A2M1	The synthesis of aspirin in two stages

Appendix 8 Further resources and support

Please note that while resources are checked at the time of publication, materials may be withdrawn from circulation and website locations may change at any time.

Books

Chapman B — *Transition Metals, Quantitative Kinetics and Applied Organic Chemistry* (Nelson Thornes, 2001) ISBN 0174482922

Chapman B, Beavon R and Jarvis A — *Structure, Bonding and Main Group Chemistry* (Nelson Thornes, 2003) ISBN 0748776559

Chapman B and Jarvis A — *Organic Chemistry, Energetics, Kinetics and Equilibrium* (Nelson Thornes, 2000) ISBN 0174482906

Clark J — *Calculations in AS/A Level Chemistry* (Longman, 2000) ISBN 0582411270

Clugston M and Flemming R — *Advanced Chemistry* (Oxford University Press, 2000) ISBN 0199146330

Facer G — *Edexcel AS Chemistry* (Philip Allan Updates, 2005) ISBN 1844892123

Facer G — *Edexcel A2 Chemistry* (Philip Allan Updates, 2006) ISBN 1844892131

Hill G and Holman J — *Chemistry in Context* (Nelson Thornes, 2000) ISBN 0174482760

Hill G and Holman J — *Chemistry in Context, Laboratory Manual and Study Guide* (Nelson Thornes, 2001) ISBN 0174483074

Hunt A — *Advanced Practical Work for Chemistry* (Hodder Murray, 2004) ISBN 0340886722

Jarvis A and Beavon R — *Periodicity, Quantitative Equilibria and Functional Group Chemistry* (Nelson Thornes, 2001) ISBN 0174482914

LGC — *Basic Laboratory Skills — A training pack for laboratory techniques* (LGC, 1999) ISBN 0948926147

Nuffield Advanced Science Book of Data (Longman, 1984) ISBN 058235448X

Ramsden E — *Calculations for A-Level Chemistry* (Nelson Thornes, 2001) ISBN 0748758399

Vokins M — *Nuffield Advanced Level Chemistry: Students Book* (Longman, 2000) ISBN 0582328357

Vokins M — *Nuffield Advanced Level Chemistry: Teachers Guide* (Longman, 2000) ISBN 0582328365

Many books produced by the Royal Society of Chemistry (see RSC websites on the next page)

Websites

www.edexcel.com/gce2008

About Chemistry chemistry.about.com

ASE School Science www.schoolscience.co.uk

At Work With Science www.abpischools.org.uk

BBC News Science and Environment news.bbc.co.uk/news/science_and_environment

Carbonfootprint www.carbonfootprint.com

Chemistryteachers.org www.rsc.org/learn-chemistry

CLEAPSS www.cleapss.org.uk

Greener Industry www.greener-industry.org

Inspirational Chemistry www.rsc.org/inspirational

IUPAC Gold Book goldbook.iupac.org/index.html

Nobel Prize www.nobelprize.org

Practical Chemistry-Nuffield Foundation (for teachers and technicians) www.nuffieldfoundation.org/practical-chemistry

React Chemistry	www.nuffieldfoundation.org/react-nuffield-advanced-chemistry
RSC Advancing the Chemical Sciences	www.chemsoc.org/networks/learnnet/data
RSC Education	www.rsc.org/education
RSC LearnNet	www.chemsoc.org/learnnet
University of Surrey Chemical and Analytical Sciences	www.surrey.ac.uk/Chemistry

Multi-media

At Work With Science — Lab and Pilot Plant Tours www.abpishools.org.uk
IMPACT — University of Surrey www.surrey.ac.uk/IMPACT
Roger Frost's Chemistry Teaching Tools — CD ROM www.organic.rogerfrost.com

Other support

Journals	<i>Chemistry World</i>	www.rsc.org/chemistryworld
	<i>Education in Chemistry</i>	www.rsc.org/Education/EiC
	<i>Guardian Science</i>	www.guardian.co.uk/science
	<i>Nature</i>	www.nature.com
	<i>New Scientist</i>	www.newscientist.com

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