



CHEMISTRY (Revised)

Advanced Higher

Valid from August 2012

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National Course specification

Chemistry (Revised) Advanced Higher

COURSE CODE C273 13

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Course structure

This Course has four mandatory Units as follows:

H1FJ 13	<i>Inorganic Chemistry (AH)</i>	0.5 credit (20 hours)
H1FR 13	<i>Organic Chemistry (AH)</i>	1.0 credit (40 hours)
H1FK 13	<i>Physical Chemistry (AH)</i>	0.5 credit (20 hours)
FE4J 13	<i>Researching Chemistry (AH)</i>	1.0 credit (40 hours)

All Courses include 40 hours over and above the 120 hours for the Units. This may be used for induction, extending the range of learning and teaching approaches, support, consolidation, integration of learning and preparation for Course assessment.

Recommended entry

While entry is at the discretion of the centre, candidates would normally be expected to have attained one of the following, or equivalent:

- ◆ Higher Chemistry (Revised) Course or its equivalent Units
- ◆ Higher Chemistry Course or its equivalent Units

Progression

This Course or its Units may provide progression to:

- ◆ A study of a science related Course in higher education
- ◆ employment

National Course specification: (cont)

COURSE Chemistry (Revised) Advanced Higher

Credit value

The Advanced Higher Course in Chemistry (Revised) is allocated 32 SCQF credit points at SCQF level 7*

**SCQF points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Course gives automatic certification of the following:

Complete Core Skills	None
Core Skill components	Using Graphical Information @ SCQL Level 6 Critical Thinking @ SCQF level 6 Planning and Organising @ SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of the Unit Specifications for this Course..

COURSE Chemistry (Revised) Advanced Higher

Rationale

The study of chemistry at Advanced Higher level develops the candidate's knowledge and understanding of the physical and natural environments beyond Higher level. The Course builds on Revised Higher Chemistry, continuing to develop the underlying theories of chemistry and the practical skills used in the chemical laboratory. The Course also develops the skills of independent study and thought that are essential in a wide range of occupations. The Course provides a sound basis for direct entry into chemistry-related employment.

The Course is also particularly suitable for candidates who wish to progress to degree courses either in chemistry or in subjects of which chemistry is a major component such as medicine, dentistry, chemical engineering, and the environmental and health sciences.

In addition to providing an excellent grounding for the future study of chemistry and chemistry-related subjects, the Course also equips all candidates with an understanding of the positive impact of Chemistry on everyday life.

It also serves to equip all candidates with the knowledge and skills to be able to reflect critically on scientific reports and media reports concerning chemistry and to make their own reasoned judgements on many issues within a modern society increasingly dependent on chemistry, science and technology.

Like Revised Higher Chemistry, the development of skills is central to this Course. Practical investigative skills are particularly important at this level. This is reflected in the opportunities to carry out high quality experimental work within all of the Course Units and particularly in the *Researching Chemistry (AH)* Unit which incorporates both practical techniques and skills of scientific investigation. Communication skills, literacy and numeracy are all further developed and assessed within the Course.

There are also many opportunities to develop the skills required in working with others. Collaborative and co-operative practical work is promoted throughout the 'Possible contexts and activities' contained within the Unit specification appendices and particularly within the skills and techniques part of the *Researching Chemistry (AH)* Unit. By working with others in the laboratory, candidates can achieve self-awareness and develop an enhanced sense of self-worth and respect for others.

The Course should also equip candidates with the knowledge and understanding to make well-informed personal decisions.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

As a result of following an Advanced Higher Chemistry Course, candidates should acquire and develop:

- ◆ knowledge and understanding of chemical facts, theories and symbols.
- ◆ the ability to solve chemical problems.
- ◆ the ability to think creatively and independently.
- ◆ the ability to carry out chemical techniques and a chemical investigation.
- ◆ an awareness of the relationship between experimental evidence and chemical theory.
- ◆ apply critical thinking within new or unfamiliar contexts.
- ◆ the ability to make reasoned evaluations based on the evidence available.
- ◆ the skills required to communicate facts, ideas and theories clearly with others.
- ◆ positive attitudes, by helping candidates to be open-minded and willing to recognise alternative points of view, and to be interested in science and aware that they can take decisions which affect the well-being of themselves and others, and the quality of their environment.
- ◆ the ability to critically assess scientific claims made in the media.
- ◆ the ability to assess the risk associated with practical activities.
- ◆ the skills of independent study and research.

During the Course candidates will be expected to:

- ◆ select and present information.
- ◆ carry out calculations.
- ◆ plan, design, analyse and evaluate investigative practical work.
- ◆ draw conclusions and give explanations.
- ◆ make generalisations and predictions.
- ◆ communicate their findings and critical evaluations in an appropriate format.

The study of Advanced Higher Chemistry should also foster an interest in current developments in, and applications of Chemistry, the willingness to make critical and evaluative comment, and the acceptance that Chemistry is a changing subject. It should also raise awareness of the links between chemistry and the world of work and the importance of the chemical industry to the wealth of a nation.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Course content

The Course is made up of four mandatory Units: *Inorganic Chemistry*; *Organic Chemistry*; *Physical Chemistry* and *Researching Chemistry (AH)*. *The Researching Chemistry* Unit develops skills and techniques, equipping candidates with the practical, investigative and reporting skills demanded by employers and further and higher education.

While each Unit is valuable in its own right, candidates will gain considerable additional benefit from completing the Course, since there will be opportunities for the integration of knowledge and skills developed through study of the Units, and for tackling problem solving of a more complex nature than that required for attainment of the Performance Criteria of the individual Units.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Assessment

To gain the Course award the candidate must achieve all the component Units of the Course as well as pass the external Course assessment. External assessment will provide the basis for grading attainment in the Course award.

When Units are taken as component parts of a Course, candidates will have the opportunity to demonstrate achievement beyond that required to attain each of the Unit Outcomes. This attainment may, where appropriate, be recorded and used to contribute towards Course estimates, and to provide evidence for appeals. Additional details are provided, where appropriate, with the exemplar assessment materials. Further information on the key principles of assessment is provided in the paper *Assessment* (HSDU, 1996) and in *Managing Assessment* (HSDU, 1998).

Details of the instruments for external assessment

The instrument of assessment will be an externally set question paper of 2 hours 30 minutes duration and a completed Investigation report.

The question paper will sample the content and skills developed in all component Units.

The paper will assess a candidate's ability to demonstrate and apply knowledge and understanding in familiar and unfamiliar contexts.

The candidate will be required to:

- 1 Make accurate statements about facts, concepts and relationships.
- 2 Apply knowledge to solve problems.
- 3 Use knowledge to explain observations and phenomena.

The paper will also assess a candidate's ability to demonstrate skills of scientific experimentation and investigation. The paper will sample a range of skills and candidates may be required to:

- 1 Select relevant information from texts, tables, charts, graphs and diagrams.
- 2 Present information in a variety of forms.
- 3 Process information accurately using calculations where appropriate.
- 4 Plan and design experimental procedures to test given hypotheses or to illustrate particular effects.
- 5 Evaluate experimental procedures.
- 6 Draw valid conclusions supported by evidence or justification.
- 7 Make predictions and generalisations based upon available evidence.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

The examination will consist of one paper of 2 hours 30 minutes with a total allocation of 100 marks.

The paper will consist of two sections.

Candidates will be expected to answer all of the questions.

Section A

Section A will be made up of 30 multiple-choice questions and is worth 30 marks.

Section B

Section B will be made up of questions requiring:

- ◆ A short answer (a few words)
- ◆ A response in the form of a numerical calculation
- ◆ A restricted or open-ended response (a few sentences or paragraphs)

Mark allocation to Knowledge and Understanding

Between 70 and 80 marks will be allocated to questions that require candidates to demonstrate and apply Knowledge and Understanding.

Of these marks:

8–14 marks will assess a candidate's ability to make accurate statements about facts, concepts and relationships.

45–60 marks will assess a candidate's ability to apply knowledge to solve problems of which 14–24 marks will involve the use of calculations to solve problems.

10–20 marks will assess a candidate's ability to use knowledge to explain observations and phenomena.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Mark allocation to Skills of Scientific Experimentation and Investigation

Between 20 and 30 marks will be allocated to questions that require candidates to demonstrate skills of scientific experimentation and investigation.

The questions assessing skills will sample from a number of different skills areas including:

- (a) Selecting information from texts, tables, charts, graphs and diagrams.
- (b) Presenting information in a variety of forms.
- (c) Processing information accurately using calculations where appropriate.
- (d) Planning or designing experimental procedures to test given hypotheses or to illustrate particular effects.
- (e) Evaluating experimental procedures.
- (f) Drawing valid conclusions supported by evidence or justification.
- (g) Making predictions and generalisations based upon available evidence.

Of the marks available for Skills of Scientific Experimentation and Investigation:

5–10 will be available for the processing of information using calculations.

8–15 will be available for the application of skills developed within the *Researching Chemistry (AH)* Unit

Mark allocation across Units

Within the examination, candidates will be required to answer both Knowledge and Understanding and Skills based questions relating to all four Units.

The minimum number of marks closely linked to the content of each of these Units is shown below:

<i>Researching Chemistry</i>	15–25 marks
<i>Inorganic Chemistry</i>	15–25 marks
<i>Physical Chemistry</i>	15–25 marks
<i>Organic Chemistry</i>	35–45 marks

Candidates will be required to demonstrate the application of Knowledge and Understanding and of Skills of Scientific Experimentation and Investigation in a number of unfamiliar contexts.

Candidates will be required to demonstrate that they can integrate the Knowledge and Understanding acquired through study of the component Units.

20–25 marks within the exam will be associated with questions which assess candidate performance as described by the 'Grade A' grade description.

20–30 marks within the exam will involve calculations.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Investigation report

The Investigation report will be based on the work carried out in the investigation part of the *Researching Chemistry* Unit. It is expected that approximately 10 hours of the 'additional 40 hours' will be required for the candidate to complete the report for the Course award.

A total of 25 marks will be allocated to the Investigation report. The Investigation report will be externally assessed using the following assessment categories and mark allocations:

- (a) Presentation (3 marks)
- (b) Underlying Chemistry (4 marks)
- (c) Procedures (6 marks)
- (d) Results (5 marks)
- (e) Conclusion and Evaluation (7 marks)

The grade awarded for the Course will depend on the marks obtained by the candidate (out of 125) for the question paper and the investigation report. The certificate will record an award for overall attainment.

Unit assessment

Further details about Unit assessment for this Course can be found in the Unit specifications and the National Assessment Bank (NAB) materials.

Course assessment

Further details of the Course assessment are given in the Course Assessment specification and in the Specimen Question Paper.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Grade Descriptions at A and C

Grade C

Candidates at Grade C will have demonstrated success in achieving the component Units of the Course. In the Course assessment candidates achieving a Grade C will have demonstrated an overall satisfactory level of performance by:

- ◆ retaining knowledge and understanding over a longer period of time.
- ◆ integrating knowledge and understanding across the component Units of the Course.
- ◆ displaying problem solving skills in less familiar contexts.
- ◆ applying skills of scientific experimentation and investigation in straightforward contexts with data of limited complexity.

Grade A

In addition candidates achieving a Grade A will have demonstrated a high overall level of performance by:

- ◆ retaining knowledge and understanding over a longer period of time.
- ◆ showing a deeper level of knowledge and understanding.
- ◆ integrating knowledge and understanding across the three component Units of the Course.
- ◆ displaying problem solving skills in less familiar and more complex contexts.
- ◆ applying skills of scientific experimentation and investigation in complex contexts that involve more complex data.

Estimates and appeals

Estimates

In preparing estimates, evidence must take account of performance across the Course and must be judged against the Grade Descriptions. Further advice on the preparation of estimates is given in the Course Assessment specification.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Quality Assurance

All National Courses are subject to external marking and/or verification. External Markers, visiting Examiners and Verifiers are trained by SQA to apply national standards.

The Units of all Courses are subject to internal verification and may also be chosen for external verification. This is to ensure that national standards are being applied across all subjects.

Courses may be assessed by a variety of methods. Where marking is undertaken by a trained Marker in their own time, Marker meetings are held to ensure that a consistent standard is applied. The work of all Markers is subject to scrutiny by the Principal Assessor.

To assist centres, External Assessment and Internal Assessment reports are published on SQA's website www.sqa.org.uk.

Details of the instruments for internal assessment

The three content based Units (*Inorganic Chemistry*, *Organic Chemistry* and *Physical Chemistry*) are each assessed by means of a closed-book test. The test should include items covering all of the Performance Criteria associated with both Outcomes 1 and 2. The tests for *Inorganic Chemistry* and *Physical Chemistry* should each take approximately 30 minutes and the test for *Organic Chemistry* should take approximately 45 minutes and they should all be sat under supervised examination conditions. Details of the breadth and depth of content to be covered by each Unit test are provided within in the appendix to the specification in addition to the specification of the formats within which data is to be processed in the assessment of Outcome 2.

For the *Researching Chemistry (AH)* Unit, evidence is required to demonstrate that candidates have met the requirements of the two Unit Outcomes. Assessors should use their professional judgement to determine the most appropriate instruments of assessments for generating evidence and the conditions and contexts in which they are used.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Outcome 1

Develop a plan to carry out investigative practical work on a chosen chemistry topic.

Performance Criteria

- (a) The aims of the investigation are clearly stated.
- (b) Appropriate experimental procedures are selected and planned using appropriate apparatus and chemicals.

Candidates should plan their investigative practical work after discussion with teachers or lecturers. The plan must be recorded in an appropriate format, which may be electronic, and should include the aim(s) of the investigation and details of all experimental procedures. The aims of planned experiments should also be recorded.

Outcome 2

Collect and record experimental results from the investigative practical work.

Performance Criteria

- (a) Appropriate techniques and procedures are used effectively to collect experimental results.
- (b) Experimental results are recorded in an appropriate format.

The collection of experimental data must be the work of the individual candidate. The assessor must attest that, other than help from technicians, teachers, lecturers or support staff in setting up equipment, the investigative practical work is the work of the individual candidate.

All experimental data must be recorded in an appropriate format which may be paper-based or in electronic format.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Guidance on learning and teaching approaches for this Course

Appropriate selection from a variety of learning and teaching approaches is required to deliver both knowledge-based and skill-based objectives to candidates with different needs and abilities. In doing so, opportunities should be provided for candidates to work independently, sometimes collaboratively or co-operatively and on other occasions as a whole class. Exposition, used in conjunction with questioning and discussion, is a very effective way of developing candidates' knowledge and understanding of the more theoretical chemical concepts as well as a good means of introducing new topics and consolidating completed topics. Both teachers and candidates should make full use of opportunities to use models to help the understanding of concepts in chemistry and to use information technology to support learning and to process data.

The Course is made up of four mandatory Units: *Inorganic Chemistry*; *Organic Chemistry*; *Physical Chemistry* and *Researching Chemistry (AH)*. The *Researching Chemistry* Unit develops skills and techniques, equipping candidates with the practical, investigative and reporting skills demanded by employers and further and higher education.

While each Unit is valuable in its own right, candidates will gain considerable additional benefit from completing the Course, since there will be opportunities for the integration of knowledge and skills developed through study of the Units, and for tackling problem solving of a more complex nature than that required for attainment of the Performance Criteria of the individual Units.

Centres are free to deliver the three content-rich Course Units in whichever order best meets the needs of their candidates. It is likely that most centres will prefer to cover the atomic orbitals part of the *Inorganic Chemistry* Unit before attempting molecular orbitals and hybridisation in the *Organic Chemistry* Unit.

In the school context it is common for candidates to start the Advanced Higher Course shortly before the summer vacation. Where this is the case some schools may wish to consider introducing the Advanced Higher Course through the study of the skills and techniques in the *Researching Chemistry (AH)* Unit.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

The *Researching Chemistry (AH)* Unit develops the skills required to undertake investigative work in Chemistry. As part of this Unit, candidates are required to become familiar with commonly used experimental techniques and data-analysis skills. Within the further education context this Unit may well be delivered as a free-standing Unit, but in schools, parts of this Unit can be very effectively run concurrently with the other Course Units. The advantage of such an approach is that each technique can be developed and practised within the real-life contexts provided by the other Course Units. For example, carrying out a practical laboratory exercise on the hydrolysis of ethyl benzoate involving refluxing, distillation, vacuum filtration, recrystallisation and melting point determination, which are some of the techniques specified in the *Researching Chemistry* Unit, could be undertaken when studying carboxylic acids in the *Organic Chemistry* Unit.

Candidates should be encouraged to understand that producing a risk assessment is a natural part of the planning process for any practical activity. In this context candidates would be expected to produce a full written risk assessment themselves, as part of the planning process before undertaking the practical work in their Investigation. As a result of the risk assessment, candidates should become aware of how to minimise risks by taking necessary precautions and appropriate control measures which may lead to using alternative and safer procedures.

It is advisable that candidates begin the Investigation part of the *Researching Chemistry* Unit only after they have covered many of the skills and techniques within the Unit and have also covered some of the theory in at least one of the other Units. This may help the candidates make better informed choices on the subject of their Investigation and help them understand the Underlying Chemistry more effectively.

Use of the additional 40 hours

This time may be used:

- ◆ to provide an introduction to the Course and assessment methods.
- ◆ to allow candidates to develop their ability to integrate knowledge, understanding problem solving and practical skills acquired through the study of the different component Units.
- ◆ to allow some more practical work, on an individual basis if appropriate, within the Units to enhance skills and understanding.
- ◆ for consolidation and integration of learning.
- ◆ for remediation.
- ◆ for practice in examination techniques and preparation for the external examination.
- ◆ for completion of the report of the chemical investigation for the external assessment.
- ◆ to investigate the chemistry relating to current news stories or articles in the media.
- ◆ to discuss and debate the ethical and moral implications of Chemistry related issues.

National Course specification: Course details (cont)

COURSE Chemistry (Revised) Advanced Higher

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

History of changes

Version	Description of change	Date

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National Unit specification: general information

Unit title: Inorganic Chemistry (SCQF level 7)

Unit code: H1FJ 13

Course: Chemistry (Revised)

Superclass: RD

Publication date: April 2012

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit develops a knowledge and understanding of Inorganic Chemistry within the contexts of electromagnetic radiation and atomic spectra, atomic orbitals and electronic configurations, valence shell electron pair repulsion theory (VSEPR) to predict molecular shape and transition metal chemistry. The Unit develops the candidate's knowledge and understanding of atomic theory, shapes of molecules and polyatomic ions as well as reasons why transition metal compounds are coloured and make such good catalysts in the manufacture of the many useful materials produced by the chemical industry. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

Outcomes

- 1 Demonstrate and apply knowledge and understanding related to *Inorganic Chemistry*.
- 2 Demonstrate skills of scientific experimentation and investigation within the context of *Inorganic Chemistry*.

Recommended entry

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by the following or equivalent:

- ◆ Higher Chemistry (Revised)
- ◆ Higher Chemistry

General information (cont)

Unit title: Inorganic Chemistry (SCQF level 7)

Credit points and level

0.5 National Unit credit at SCQF level 7: (4 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Unit gives automatic certification of the following:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Graphical Information at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

National Unit specification: statement of standards

Unit title: Inorganic Chemistry (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate and apply knowledge and understanding related to *Inorganic Chemistry*.

Performance Criteria

- (a) Make accurate statements about facts, concepts and relationships relating to *Inorganic Chemistry*.
- (b) Use knowledge of *Inorganic Chemistry* to solve problems.
- (c) Use knowledge of *Inorganic Chemistry* to explain observations and phenomena.

Outcome 2

Demonstrate skills of scientific experimentation and investigation in the context of *Inorganic Chemistry*.

Performance Criteria

- (a) Use a range of data-handling skills in a scientific context.
- (b) Use a range of skills related to the evaluation of scientific evidence.

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

For each of the Unit Outcomes, written and/or recorded oral evidence of the appropriate level of achievement is required. This evidence must be produced under closed-book, supervised conditions within a time limit of 30 minutes.

The Instrument of Assessment must sample the content in each of the following areas:

- ◆ Electromagnetic radiation and atomic spectra
- ◆ Atomic orbitals and electronic configurations
- ◆ Shapes of molecules and polyatomic ions
- ◆ Transition metals

An appropriate Instrument of Assessment would be a closed-book, supervised test with a time limit of 30 minutes. Items in the test should cover all the Performance Criteria associated with both Outcomes 1 and 2, and could be set in familiar or unfamiliar contexts.

Further detail on the breadth and depth of content is provided within in the appendix to the specification.

National Unit specification: statement of standards (cont)

Unit title: Inorganic Chemistry (SCQF level 7)

For Outcome 2, PC (a) candidates are required to demonstrate that they can use a range of data-handling skills. These skills include selecting, processing and presenting information. Information can be presented in a number of formats including: chemical formulae, balanced chemical equations, diagrams showing molecular shape, diagrams depicting laboratory apparatus, line graphs, scatter graphs, tables, diagrams and text.

For Outcome 2, PC (b), candidates are required to demonstrate that they can use a range of skills associated with the evaluation of scientific evidence. These skills include drawing valid conclusions and making predictions.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

National Unit specification: support notes

Unit title: Inorganic Chemistry (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 20 hours.

Guidance on the content and context for this Unit

The recommended content together with suggestions for possible contexts and activities to support and enrich learning and teaching are detailed in the Course specification.

This Unit allows candidates to develop knowledge and understanding of Inorganic Chemistry within the contexts of electromagnetic radiation, atomic spectroscopy, shapes of atomic orbitals, electronic configurations, patterns in the Periodic Table, shapes of molecules and polyatomic ions and some chemistry of the transition metals including colour and catalysis. This Unit also seeks to develop the candidate's problem solving abilities and practical skills.

This Unit offers a diverse and rich vein of contexts and opportunities for practical work as highlighted in the 'Possible contexts and activities' column of the content tables. Opportunities exist for candidates to learn as part of a group through practical work undertaken in partnership or in teams. By developing a greater understanding of some of the concepts in atomic structure candidates are better able to understand more about electronic configurations, shapes of molecules, colour in inorganic compounds and how transition metal compounds can act as catalysts in chemical reactions used to produce everyday household products.

Guidance on learning and teaching approaches for this Unit

General advice on approaches to learning and teaching is contained in the Course specification.

Guidance on approaches to assessment for this Unit

Outcomes 1 and 2

It is recommended that a holistic approach is taken for assessment of these Outcomes. Outcomes 1 and 2 can be assessed by an integrated end of Unit test with questions covering all the Performance Criteria. Within one question, assessment of knowledge and understanding and skills of experimentation and investigation can occur. Each question can address a number of assessment standards from either Outcome 1 or 2.

Appropriate assessment items are available from the National Assessment Bank.

National Unit specification: support notes (cont)

Unit title: Inorganic Chemistry (SCQF level 7)

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003)*, *SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

This Unit provides opportunities to develop *Communication, Numeracy, Information and Communication Technology (ICT)* and *Problem Solving* skills in addition to providing contexts and activities within which the skills associated with *Working with Others* can be developed.

Outcome 1, PC (b) and (c) develop a candidate's ability to communicate effectively key concepts and to explain clearly chemical phenomena in written media.

Within this Unit candidates will need to extract and process information presented in both tabular and graphical formats developing the Core Skill of *Numeracy*. Candidates will gain experience in a range of calculations building competence in number.

The appendix to this Unit specification contains an extensive list of 'Possible Contexts and Activities' which include a large number of web based activities, computer simulations and modelling opportunities which all serve to develop higher levels of competence in the key *ICT* skills including; Accessing Information and Providing/Creating Information.

The Unit appendix contains an extensive range of practical laboratory exercises which provide candidates with the opportunity to Work Co-operatively with Others.

Problem Solving skills are central to the sciences and are assessed through Outcome 1, PCs (b) and (c) and also through Outcome 2, PCs (a) and (b).

This Unit has the Using Graphical Information component of Numeracy, and the Critical Thinking component of Problem Solving, embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show that they have achieved Using Graphical Information and Planning and Organising at SCQF level 6.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

History of changes to Unit

Version	Description of change	Date

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The left hand column below details the content in which candidates should develop knowledge and understanding. The middle column contains notes, which give further details of the breadth and depth of content expected. The right-hand column gives possible contexts and activities which could be used to develop knowledge, understanding and skills. Further details on many of the activities mentioned in the final column can be obtained from **National Qualifications Online**, part of the Education Scotland online service. Where such online support exists the  symbol appears in the text.

Inorganic Chemistry 20 hour Unit		
Content	Notes	Possible contexts and activities
1 Electromagnetic radiation and atomic spectra		
1(a) Electromagnetic waves	Electromagnetic radiation may be described in terms of waves and can be characterised in terms of wavelength and/or frequency. The relationship between these quantities is given by $c=f\lambda$ where c represents the speed of light, f represents the frequency of the wave (s^{-1}) and λ represents the wavelength (m). When radiation in the visible part of the electromagnetic spectrum is being described, it is common to specify wavelength in terms of nanometres (nm).	An internet search on 'CD or DVD spectroscope' will produce a plethora of sites with simple instructions which allow candidates to make individual spectroscopes from any unwanted CDs or CD-ROMs.  An online and printable electromagnetic spectrum is available from the Royal Society of Chemistry  c can be taken as $3.00 \times 10^8 \text{ m s}^{-1}$ (See Data Booklet) Frequency is often quoted in Hz which is the same as s^{-1} .
1(b) Dual nature of radiation — waves and particles	When electromagnetic radiation is absorbed or emitted by matter, it appears to be behaving more like a stream of particles than as a wave. These particles are known as photons. When a photon is absorbed or emitted, energy is gained or lost by electrons within the substance. The photons in high frequency radiation can transfer greater amounts of energy than photons in low frequency radiation. The energy associated with a single photon is given by $E=hf$ where 'h' represents Planck's constant. For Chemists, it is more convenient to express the energy associated with a mole of photons which is given by $E=Lhf$ giving the energy in J mol^{-1} where L represents Avogadro's constant.	Video on the dual nature of light can be found on the internet  $h = 6.63 \times 10^{-34} \text{ J s}$ (See Data Booklet) $L = 6.02 \times 10^{23} \text{ mol}^{-1}$ (See Data Booklet) To get E , in kJ mol^{-1} , it is more convenient to use $E = Lhf/1000$ or $E = Lhc/1000\lambda$. L is the number of formula units in one mole of the substance. (Formula units can be atoms, molecules or groups of ions depending on how the formula is usually written and on the type of bonding structure present).

Content	Notes	Possible contexts and activities
<p>1(c) Atomic emission</p>	<p>When energy is transferred to atoms, electrons within the atoms may be promoted to higher energy levels. To allow the electrons to return to their original levels, energy must be lost from the atom. This energy is released in the form of a photon. The spectrum of light emitted (atomic emission spectrum) is not continuous, but consists of a series of lines at discrete frequencies. This phenomenon provides direct evidence for the existence of discrete (quantised) energy levels for electrons. An atom can be considered as emitting a photon of light energy when an electron moves from a higher energy level to a lower energy level. Each element produces a unique pattern of frequencies of radiation in its emission spectrum.</p>	<p>Candidates can observe atomic emission by carrying out flame tests. RSC website gives more information. </p> <p>Spectacular demonstration versions in which an alcohol spray is used to produce coloured flames over a metre long could also be used. Can be found on the RSC website and in the RSC publication 'Classic Chemistry Demonstrations' No. 34 page 80. </p> <p>To view an atomic emission spectrum, a simple spectroscope (such as the 'homemade' devices produced from unwanted CDs) can be used to view a vapour discharge lamp or, if good blackout conditions are available, from a flame test. Fluorescent tube lamps, commonly used for classroom lighting, contain mercury vapour. If a spectroscope is used to view an illuminated fluorescent lamp, a series of purple lines from the atomic emission spectrum of mercury can be observed. SSERC activity with filter paper soaked in brine to observe sodium spectrum.</p> <p>A useful resource on spectroscopy and the identification of elements from emission spectra can be found on the 800mainstreet.com website. </p> <p>A method of making a home-made spectroscope can also be found on the internet. </p> <p>SSERC are currently developing an instrument using a camera or phone with a diffraction grating attachment.</p>

Content	Notes	Possible contexts and activities
<p>1(d) Atomic spectroscopy</p>	<p>Atomic emission spectroscopy and atomic absorption spectroscopy are used to identify and quantify the elements present in a sample.</p> <p>In absorption spectroscopy, electromagnetic radiation is directed at an atomised sample. Radiation is absorbed as electrons are promoted to higher energy levels. An absorption spectrum can be produced by measuring how a sample's transmission of light varies with wavelength.</p> <p>In emission spectroscopy, high temperatures are used to excite the electrons within atoms. As the electrons drop to lower energy levels, photons are emitted. An emission spectrum can be produced by measuring how much light is emitted at different wavelengths.</p> <p>Each element produces a characteristic absorption/emission spectrum which can be used to identify that element. In atomic spectroscopy, the concentration of an element within a sample is related to the intensity of light emitted or transmitted.</p>	<p>Resources describing Atomic Absorption are available from the RSC. </p> <p>Interesting anecdotes can be provided of the forensic uses of Atomic Absorption Spectroscopy in such cases as the investigation of toxic levels of heavy metals in Isaac Newton's hair due to his alchemical pastimes and the high levels of lead in men's hair treated with "Grecian" hair products.</p> <p>A free science video by 'Brightstorm' on atomic emission spectra is available </p> <p>Videos on use of spectroscopy in astronomy, on the spectrum of stars and on the absorption and emission spectra of hydrogen are also available. </p> <p>A very useful website from uoregon.edu has an applet which shows the absorption and emission spectra of most elements just by clicking on the appropriate element on a Periodic Table. </p> <p>Light from a sodium lamp passing through a sodium flame from, say, a sodium pencil produces a shadow when projected on to a white screen.</p>

Content	Notes	Possible contexts and activities
2 Atomic orbitals and electronic configurations		
2(a) Atomic orbitals	<p>The discrete lines observed in atomic emission spectra can be explained if electrons, like photons, display the properties of particles and waves. Within the atom, electrons behave as waves and there are different sizes and shapes of wave possible around the nucleus. These are known as orbitals and each can hold a maximum of two electrons. Any electron within an atom can be uniquely identified by a set of four quantum numbers. The principal quantum number, n, specifies the energy of the electron and also indicates the average distance of the electron from the nucleus. n can take the values 1, 2, 3, ... and all electrons with the same value of n constitute an electron shell or energy level. The angular momentum quantum number, l, specifies the shape of the orbital in which the electron is contained. l can take the values 0, 1, ..., $n-1$ and all electrons with the same value of l in a given shell constitute a subshell. It is often more convenient to use the letters s, p, d, \dots corresponding to $l = 0, 1, 2, \dots$ respectively to label the subshells. The magnetic quantum number, m, labels the orbitals within a subshell and indicates the orientation or direction of the orbital in which the electron is contained. The allowed values of m are $-l, \dots, 0, \dots, +l$. The spin magnetic quantum number, s indicates the spin direction of an electron within an orbital and can have only two values: $+\frac{1}{2}$ or $-\frac{1}{2}$. Candidates should be able to recognise s, p and d orbitals from their shapes and draw diagrams of s and p orbitals.</p>	<p>Electrons, in fact, behave as standing waves within the atom. Wave mechanics tells us that there are different shapes and sizes of standing waves possible around the nucleus, which are known as orbitals. The circumference of the standing wave is always equal to an integral number of wavelengths. The principal quantum number, n, is the circumference of the orbital in terms of the number of wavelengths. The RSC website has pages which offer very clear and attractive representations of orbitals with accompanying text which refers to the wave nature of the electron. A free science video by 'Brightstorm' covers quantum numbers but this is beyond the level required and would need some previous teaching or learning.  A Sci-Comm video showing 3D models helping to visualise s, p and d orbitals is available  The RSC website has an animation which can be used to illustrate the absorption and emission of light by an atom. It can also be run set at 'Orbital Model' and shows a pictorial representation of the orbitals and labels them using the "1s" "2p" type of nomenclature. </p>

Content	Notes	Possible contexts and activities
2(b) Electronic configurations of atoms in the ground state	<p>Any atom can only have a maximum of two electrons within any single orbital. The aufbau principle states that electrons fill orbitals in order of increasing energy. The relative energies corresponding to each orbital can be represented diagrammatically for the first four shells of a multi-electron atom. In an isolated atom the orbitals within each subshell are degenerate. Hund's Rule states that when degenerate orbitals are available, electrons fill each singly, keeping their spins parallel before spin pairing starts. The Pauli exclusion principle states that no two electrons in the one atom can have the same set of four quantum numbers. Put more simply it states that no orbital can hold more than 2 electrons and the 2 electrons must have opposite spins.</p> <p>Electronic configurations using spectroscopic notation and orbital box notation can be written for elements of atomic numbers 1 to 36.</p>	<p>A free science video by 'Brightstorm' covers orbital box diagrams and covers the aufbau principle, Pauli exclusion principle and Hund's rule.  Another free science video by 'Brightstorm' (brightstorm.com) covers electronic configurations </p> <p>Teachers/lecturers may wish to introduce only elements 1–20 at first and return to the remaining elements during the coverage of transition metals.</p>
2(c) The blocks of the Periodic Table	<p>The Periodic Table can be subdivided into four blocks (s, p, d and f) corresponding to the outer electronic configurations of the elements within these blocks.</p>	<p>f-orbitals are not assessable</p>
2(d) Patterns in the Periodic Table explained by the filling of orbitals	<p>The variation in first ionisation energy with increasing atomic number for the first 36 elements can be explained in terms of the relative stability of different electronic configurations, and so provides evidence for these electronic configurations. The relative values of first, second and subsequent ionisation energies can be explained in terms of the stabilities of different subshell electron configurations from which the electrons are being removed.</p>	<p>Graph of first IE v atomic number shows blips which gives good evidence of s and p orbitals being filled.</p>

Content	Notes	Possible contexts and activities
3 Shape		
3 Valence shell electron pair repulsion theory	VSEPR theory provides a quick-to-apply method which allows the shape of a molecule or polyatomic ion to be predicted from the numbers of bonding electron pairs and non-bonding electron pairs. The arrangement of electron pairs is linear, trigonal planar, tetrahedral, trigonal bipyramidal and octahedral when the total number of bonding and non-bonding electron pairs is 2, 3, 4, 5 and 6, respectively. Electron pair repulsions decrease in strength in the order: non-bonding pair/non-bonding pair > non-bonding pair/bonding pair > bonding pair/bonding pair. These different strengths of electron pair repulsion account for slight deviations from expected bond angles in molecules such as NH ₃ and H ₂ O.	Although VSEPR theory does not provide an accurate description of the actual molecular orbitals in a molecule, the shapes predicted are usually quite accurate. The RSC has links to sites allowing the 3D display of molecules with different numbers of bonding and non-bonding pairs. 
4 Transition metals		
4(a) Electronic configuration of transition metal atoms and ions	The d-block transition metals are metals with an incomplete d subshell in at least one of their ions. The filling of the d orbitals follows the aufbau principle, with the exception of chromium and copper atoms. These exceptions are due to a special stability associated with the d subshell being half filled or completely filled. When atoms from the first row of the transition elements form ions it is the 4s electrons which are lost first rather than the 3d electrons.	A striking display can be made by creating a set of sample bottles containing salts or compounds of the first 30 elements. If these are then positioned on an A1 or A2 sized Periodic Table poster it is striking that only the d-block compounds are coloured. Candidates may also notice that zinc compounds are white- indicating that, although lying in the central region of the Periodic Table- zinc is different from the transition metals. Scandium is also different since it forms only the 3+ ion which has no d electrons. A short 'Brightstorm' video on 'Exceptions to Electron Configurations' covers the electronic configurations of Cr and Cu. 

Content	Notes	Possible contexts and activities
4(b) Oxidation states of transition metals	An element is said to be in a particular oxidation state when it has a specific oxidation number. The oxidation number can be determined by following certain rules. Transition metals exhibit variable oxidation states of differing stability. Compounds of the same transition metal but in different oxidation states may have different colours. Oxidation can be considered as an increase in oxidation number and reduction can be considered as a decrease in oxidation number. Compounds containing metals in high oxidation states tend to be oxidising agents whereas compounds with metals in low oxidation states are often reducing agents.	Zinc is used to reduce a solution of yellow ammonium vanadate(V) to a mauve solution containing vanadium(II) ions. The intermediate oxidation states of vanadium(IV) (blue) and vanadium(III) (green) are also seen. Details from the RSC website and also from RSC publication 'Classic Chemistry Demonstrations' No. 92 page 258. A similar experiment using zinc amalgam is also shown in a one minute video produced by the Open University.  Can also do similar experiment with oxidation states of Mn. Bromfield Honors Chemistry video 'Assigning Oxidation Numbers' covers all the main points for assigning oxidation numbers.  A website which is a series of questions and answers on oxidation numbers is available. It is good but fast. Best to be done as revision after oxidation numbers have been taught 
4(c) Transition metal complexes	A complex consists of a central metal atom/ion surrounded by ligands. Ligands may be negative ions or molecules with non-bonding pairs of electrons which they donate to the central metal atom/ion forming dative bonds. Ligands can be classified as monodentate, bidentate up to hexadentate. The total number of bonds from the ligands to the central transition metal atom/ion is known as the co-ordination number. Complexes are written and named according to IUPAC rules.	Instructions for carrying out a microscale investigation into the chemistry of the transition elements, looking at their redox and precipitation reactions is available from the RSC website. 

Content	Notes	Possible contexts and activities
4(d) Coloured transition metal complexes	<p>In a complex of a transition metal the d orbitals are no longer degenerate. The energy difference between subsets of d orbitals depends on the ligand. Colours of many transition metal complexes can be explained in terms of d-d transitions. Light is absorbed when electrons in a lower energy d orbital are promoted to a d orbital of higher energy. If light of one colour is absorbed, then the complementary colour will be observed.</p>	<p>An interesting introduction into colour in transition metal compounds is through the production of coloured glass. More can be found in the RSC publication 'Classic Chemistry Experiments' No.44 page 112 and on the RSC website. This allows candidates to make glass and then colour some glass using transition metal oxides  RSC publication 'Classic Chemistry Demonstrations No. 93 page 261 shows different colours of nickel complexes with water and ethylenediamine as ligands in different ratios.</p> <p>The chemguide.co.uk website has pages which cover colours of transition metal complexes. Opportunity for candidates to find out about the spectrochemical series and investigate how the position of ligand in the series may affect the colour and paramagnetism of the complex.</p> <p>Prepare solutions containing $\text{Cu}^{2+}(\text{aq})$, $\text{Ni}^{2+}(\text{aq})$, $\text{Co}^{2+}(\text{aq})$. (Concentrations not important but concentrated enough to have characteristic colours). Add conc HCl to provide Cl^- ions as ligands and concentrated $\text{NH}_3(\text{aq})$ to provide NH_3 molecules as ligands. See colour changes due to differences in energy levels between d orbitals. Original solutions have H_2O molecules as ligands.</p>
4(e) UV and visible spectroscopy of transition metal complexes	<p>Ultra-violet and visible absorption spectroscopy involve transitions between electron energy levels in atoms and molecules where the energy difference corresponds to the ultra-violet and visible regions of the electromagnetic spectrum.</p>	<p>A UV-visible spectrometer measures the intensity of radiation transmitted through a sample, and compares this with the intensity of incident radiation. Determination of Mn in steel (PPA from unrevised AH) The wavelength ranges are approximately 200-400 nm for ultra-violet and 400-700 nm for visible.</p>

Content	Notes	Possible contexts and activities
4(f) Catalysis by transition metals	Transition metals or their compounds act as catalysts in many chemical reactions. It is believed that the presence of unpaired d electrons or unfilled d orbitals allows intermediate complexes to form, providing reaction pathways with lower activation energies compared to the uncatalysed reaction. The variability of oxidation states of transition metals is also an important factor.	Hydrogen peroxide oxidises potassium sodium tartrate (Rochelle salt) to carbon dioxide. The reaction is catalysed by cobalt(II) chloride. The colour of the cobalt(II) chloride turns from pink to green (an activated complex), returning to pink again as the reaction dies down. Details of the experiment are available from the RSC publication 'Classic Chemistry Demonstrations' page 1 and also from their website.  (The experiment may have been done at Higher but at AH discussion would involve oxidation states)



National Unit specification: general information

Unit title: Organic Chemistry (SCQF level 7)

Unit code: H1FR 13

Course: Chemistry (Advanced Higher)

Superclass: RD

Publication date: April 2012

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit develops a knowledge and understanding of Organic Chemistry within the contexts of molecular orbitals, molecular structure and stereochemistry, synthesis, molecules and colour, experimental determination of structure and drug interactions.

The Unit develops the candidate's knowledge and understanding of molecular orbitals, hybridisation of atomic orbitals, geometric and optical isomerism, a variety of different reactions in organic chemistry including reaction mechanisms for some and curly arrow notation used to represent electron shifts during a reaction. The Unit also introduces aromatic hydrocarbons and their more common chemical reactions as well as the concept of chromophores leading to coloured organic compounds. Methods used to determine the structure of organic compounds including elemental microanalysis and various spectrophotometric methods are covered in some detail as well as the development of the understanding of how drugs can be classified and how they work within the body. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

Outcomes

- 1 Demonstrate and apply knowledge and understanding related to *Organic Chemistry*.
- 2 Demonstrate skills of scientific experimentation and investigation within the context of *Organic Chemistry*.

General information (cont)

Unit title: Organic Chemistry (SCQF level 7)

Recommended entry

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by the following or equivalent:

- ◆ Higher Chemistry (Revised)
- ◆ Higher Chemistry

Credit points and level

1 National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Unit gives automatic certification of the following:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Graphical Information at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

National Unit specification: statement of standards

Unit title: Organic Chemistry (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate and apply knowledge and understanding related to *Organic Chemistry*.

Performance Criteria

- (a) Make accurate statements about facts, concepts and relationships relating to *Organic Chemistry*.
- (b) Use knowledge of *Organic Chemistry* to solve problems.
- (c) Use knowledge of *Organic Chemistry* to explain observations and phenomena.

Outcome 2

Demonstrate skills of scientific experimentation and investigation in the context of *Organic Chemistry*.

Performance Criteria

- (a) Use a range of data-handling skills in a scientific context.
- (b) Use a range of skills related to the evaluation of scientific evidence.

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

For each of the Unit Outcomes, written and/or recorded oral evidence of the appropriate level of achievement is required. This evidence must be produced under closed-book, supervised conditions within a time limit of 45 minutes.

The Instrument of Assessment must sample the content in each of the following areas:

- ◆ Molecular orbitals
- ◆ Molecular structure and stereochemistry
- ◆ Synthesis
- ◆ Molecules and colour
- ◆ Experimental determination of structure
- ◆ Drug interactions

An appropriate Instrument of Assessment would be a closed-book, supervised test with a time limit of 45 minutes. Items in the test should cover all the Performance Criteria associated with both Outcomes 1 and 2, and could be set in familiar or unfamiliar contexts.

National Unit specification: statement of standards (cont)

Unit title: Organic Chemistry (SCQF level 7)

Further detail on the breadth and depth of content is provided within the appendix to the specification.

For Outcome 2, PC (a) candidates are required to demonstrate that they can use a range of data-handling skills. These skills include selecting, processing and presenting information. Information can be presented in a number of formats including: chemical formulae, structural formulae including skeletal representations, balanced chemical equations, reaction mechanisms showing curly arrow notation, diagrams depicting laboratory apparatus, tables, diagrams and text.

For Outcome 2, PC (b), candidates are required to demonstrate that they can use a range of skills associated with the evaluation of scientific evidence. These skills include drawing valid conclusions and making predictions.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

National Unit specification: support notes

Unit title: Organic Chemistry (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

The recommended content together with suggestions for possible contexts and activities to support and enrich learning and teaching are detailed in the Course specification.

This Unit allows candidates to develop knowledge and understanding of Organic Chemistry within the contexts of molecular orbitals, hybridisation of atomic orbitals, geometric and optical isomerism, various reactions in organic chemistry including the reaction mechanisms for some and curly arrow notation used to represent electron shifts during a reaction. The Unit also introduces aromatic hydrocarbons and their more common chemical reactions as well as the concept of chromophores leading to coloured organic compounds. Methods used to determine the structure of organic compounds including elemental microanalysis and various spectrophotometric methods are covered in some detail as well as the development of the understanding of how drugs can be classified and how they work within the body. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

This Unit offers a diverse and rich vein of contexts and opportunities for practical work as highlighted in the 'Possible contexts and activities' column of the content tables. Opportunities exist for candidates to learn as part of a group through practical work undertaken in partnership or in teams.

By developing a greater understanding of the different types of bonds in organic compounds candidates are better able to understand more about shapes of organic molecules, stereoisomerism, reactions and reaction mechanisms in organic chemistry, different methods of elucidating structures of organic compounds and how drugs work within our bodies.

Guidance on learning and teaching approaches for this Unit

General advice on approaches to learning and teaching is contained in the Course specification.

National Unit specification: support notes (cont)

Unit title: Organic Chemistry (SCQF level 7)

Guidance on approaches to assessment for this Unit

Outcomes 1 and 2

It is recommended that a holistic approach is taken for assessment of these Outcomes. Outcomes 1 and 2 can be assessed by an integrated end of Unit test with questions covering all the Performance Criteria. Within one question, assessment of knowledge and understanding and skills of experimentation and investigation can occur. Each question can address a number of assessment standards from either Outcome 1 or 2.

Appropriate assessment items are available from the National Assessment Bank.

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003)*, *SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

This Unit provides opportunities to develop *Communication, Numeracy, Information and Communication Technology (ICT)* and *Problem Solving* skills in addition to providing contexts and activities within which the skills associated with *Working with Others* can be developed.

Outcome 1, PC (b) and (c) develop a candidate's ability to communicate effectively key concepts and to explain clearly chemical phenomena in written media.

Within this Unit candidates will need to extract and process information presented in both tabular and graphical formats developing the Core Skill of *Numeracy*. Candidates will gain experience in a range of calculations building competence in number.

The appendix to this Unit specification contains an extensive list of 'Possible Contexts and Activities' which include a large number of web based activities, computer simulations and modelling opportunities which all serve to develop higher levels of competence in the key *ICT* skills including; accessing information and providing/creating information.

The Unit appendix contains an extensive range of practical laboratory exercises which provide candidates with the opportunity to *Work Co-operatively with Others*.

Problem Solving skills are central to the sciences and are assessed through Outcome 1, PCs (b) and (c) and also through Outcome 2, PCs (a) and (b).

National Unit specification: support notes (cont)

Unit title: Organic Chemistry (SCQF level 7)

This Unit has the Using Graphical Information component of Numeracy, and the Critical Thinking component of Problem Solving, embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show that they have achieved Using Graphical Information and Planning and Organising at SCQF level 6.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

History of changes to Unit

Version	Description of change	Date

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The left hand column below details the content in which candidates should develop knowledge and understanding. The middle column contains notes, which give further details of the breadth and depth of content expected. The right-hand column gives possible contexts and activities which could be used to develop knowledge, understanding and skills. Further details on many of the activities mentioned in the final column can be obtained from **National Qualifications Online**, part of the Learning and Teaching Scotland online service. Where such online support exists the  symbol appears in the text.

Organic Chemistry 40 hour Unit		
Content	Notes	Possible contexts and activities
1 Molecular orbitals		
1(a) Molecular orbitals	When atoms approach each other, their separate sets of atomic orbitals merge to form a single set of molecular orbitals. Some of the molecular orbitals, known as 'bonding molecular orbitals', occupy the region between two nuclei. The attraction of positive nuclei to negative electrons occupying bonding molecular orbitals is the basis of bonding between atoms. Each molecular orbital can accommodate a maximum of two electrons.	Chem.purdue.edu has information about atomic orbitals becoming molecular orbitals 
1(b) The bonding continuum	In a non-polar covalent bond, the bonding molecular orbital is symmetrical about the midpoint between two atoms. Polar covalent bonds result from bonding molecular orbitals which are asymmetric about the midpoint between two atoms. Ionic compounds represent an extreme case of asymmetry with the bonding molecular orbitals being almost entirely located around just one atom.	Markrosengarten.com has a fun song and video covering covalent, polar covalent and ionic bonding. Useful as revision of Higher bonding. 
1(c) Hybridisation	Hybridisation is the process of mixing atomic orbitals within an atom to generate a set of new atomic orbitals called hybrid orbitals. Bonding in alkanes can be described in terms of sp^3 hybridisation and sigma bonds. Bonding in alkenes can be described in terms of sp^2 hybridisation and both sigma and pi bonds. A sigma bond is a covalent bond formed by end-on overlap of two atomic orbitals lying along the axis of the plane. A pi bond is a covalent bond formed by the sideways overlap of two parallel atomic orbitals lying perpendicular to the axis of the bond.	mhhe.com has pages which cover hybridisation including an animation  Consider effect that the different types of bonds have on the shapes of molecules, eg shape of CH_4 v C_2H_4 v C_2H_2 . As an extension, bonding in alkynes can be described in terms of sp hybridisation with both sigma and pi bonds. ibchem.com has information on sigma bonds, pi bonds and hybridisation  There are also other videos on the internet covering hybridisation.

Content	Notes	Possible contexts and activities
2 Molecular Structure and Stereochemistry		
2(a) Structural formulae	<p>Candidates should be able to draw structural formulae and skeletal formulae and to interconvert between molecular, structural and skeletal formulae for organic molecules with no more than 10 carbon atoms in their longest chain.</p> <p>In a skeletal formula neither the carbon atoms, nor any hydrogens attached to the carbon atoms, are shown. The presence of a carbon atom is implied by a 'kink' in the carbon backbone, and at the end of a line.</p>	<p>Molecular drawing packages such as ChemSketch can be set to display structures in skeletal representation if required. 3D representations of relatively small molecules (less than 10 carbon atoms) containing common functional groups can be created and manipulated by candidates using molymods or similar. Wireframe, stick, ball and stick and space-filling representations should all be familiar. Candidates can rotate molecules around the x, y and z axes to align any chosen bond horizontally or vertically, to align any three atoms in a given plane, to zoom in and out and to switch on and off atom labels. Molecules sketched in 2D mode can be converted into 3D representations in ChemsSketch. CHIME (a free plugin for web browsers) can also display a huge range of molecules in 3D. Extensive free libraries of 3D molecules are available to be downloaded from the internet. The structures of aliphatic compounds can be drawn on a ChemsSketch type system. The functional groups -OH, -COOH, -C=O, -NH₂, -CONH-, -COO- can also be drawn and added to these compound using a ChemsSketch type system. A free alternative to Chemdraw is ChemsSketch, which is available from ACD labs or ISIS Draw. The structural formulae of aliphatic compounds can be represented in skeletal form using a Chemdraw type system. Molecular drawing packages such as ChemSketch can be set to display structures in skeletal representation if required. Candidates may learn how to interconvert between full and shortened structural formulae and skeletal formulae using the ChemsSketch type system.</p>

Content	Notes	Possible contexts and activities
2(a) Structural formulae (cont)		Tutorials on using Chems sketch and drawing skeletal formulae are available on the internet.  Alternatives to Chems sketch include Chemdraw and ISIS Draw.
2(b) Stereoisomerism	Stereoisomers are molecules with the same molecular formula and in which the atoms are bonded together in the same order. However, they are non-superimposable due to a different 3D arrangement of their atoms.	Videos on different forms of isomerism by Dr. Chris Arthur and 'Brightstorm' are available on the internet. 
2(c) Geometric isomerism	Geometric isomerism is one type of stereoisomerism. It arises due to the lack of free rotation around a bond, frequently a carbon-carbon double bond, but not always. Geometric isomers are labelled <i>cis</i> and <i>trans</i> according to whether the substituent groups are on the same side or on different sides of the carbon-carbon double bond. Geometric isomers display differences in some physical properties. Geometric isomerism can also influence chemical properties.	Make molecular models of <i>cis</i> and <i>trans</i> isomers. The influence of geometric isomerism on chemical properties can be illustrated by the fact that <i>cis</i> -butenedioic acid is more readily dehydrated than <i>trans</i> -butenedioic acid. Melting points and densities of <i>cis</i> -butenedioic and <i>trans</i> -butenedioic acid can also be compared. Health issues associated with <i>trans</i> fatty acids Also the <i>cis</i> geometry of combretastatin is crucial to anticancer activity. Alkenes often used to rigidify structures into active conformations.
2(d) Optical isomerism	Optical isomers are non-superimposable mirror images of asymmetric molecules and such molecules can be described as chiral molecules or enantiomers. Optical isomerism occurs in substances in which four different substituent groups are arranged around a central 'chiral' carbon atom. Optical isomers, in general, have identical physical and chemical properties, except when they are in a chiral environment. However they have an opposite and equal effect on the direction of rotation of plane-polarised light, and are therefore said to be optically active. Racemic mixtures contain equal amounts of both optical isomers, and are optically inactive. In biological systems only one optical isomer of each asymmetric organic compound is usually present.	Thalidomide story could be discussed here.  Limonene exists in two isomeric forms. One has the scent of oranges, and the other of pine. A microscale investigation of the isomers of limonene is available from the RSC.  Chm.bris.ac.uk has more information about limonene.  Ibuprofen is normally sold as a mixture of two optical isomers, one of which is an effective pain-killing drug and the other of which is inactive. This gives a low atom economy for the desired product. Recent research has produced a more efficient synthetic route to produce only the desired isomer. More information from the RSC.  Chiral drugs are often sold as racemates despite the fact that activity is due mainly to one of the enantiomers.

Content	Notes	Possible contexts and activities
2(d) Optical isomerism (cont)		<p>However, there are cases where the pure enantiomer is sold if there is a clear clinical advantage (for example if the other enantiomer has toxic side effects). An example is esomeprazole which is the active enantiomer of omeprazole — an antiulcer agent.</p> <p>R- and S- enantiomers can be discussed but will not be assessed.</p> <p>Can discuss chirality in drugs such as ibuprofen. S-Naproxen is a pain reliever and its enantiomer R-Naproxen is a liver toxin. </p> <p>Use a polarimeter, if one is available, to demonstrate the rotation of plane polarised light by optical isomers.</p> <p>Many links show the number of synthetic steps involved in making an asymmetric compound. Enzymes are now being used to produce asymmetric compounds in fewer synthetic steps.</p> <p>A simple polarimeter can be made from polaroid sun glasses using the instructions from the RSC Classic Chemistry Demonstrations No.13, page 26 and is also available on the internet. </p> <p>Colby.edu has a video which covers chirality, stereoisomerism and optical activity. Also covers R- and S-enantiomers </p>
3 Synthesis	<p><i>An understanding of organic reaction types and mechanisms is key to understanding the types of reactions used in the synthesis of organic chemicals. By the end of this section, candidates should be able to look at a molecular structure and deduce the reactions it should undergo. Candidates should also be able to work out reaction sequences for the synthesis of given molecules.</i></p>	

Content	Notes	Possible contexts and activities
3(a) Bond fission	When an organic reaction takes place, bonds are broken and formed. If, when the bond between atoms breaks, each atom retains one electron from the former covalent bond, then two free radicals are formed. This is known as homolytic fission. Reactions involving free radicals tend to result in formation of very complex mixtures of products, thus making them unsuitable for synthesis. If, when the bond between atoms breaks, one atom retains both of the electrons from the former covalent bond, then an ion pair is formed. This is known as heterolytic fission. Reactions proceeding via heterolytic fission tend to produce far fewer products and are therefore better suited for synthesis. Heterolytic fission will be favoured when the bond between the atoms is polar.	Free radical chain reaction mechanism covered in Higher. Chemguide.co.uk has information which covers free radical substitution reaction mechanism in more detail than in Higher. 📄 Tutorvista provides more information on homolytic and heterolytic fission. 📄 Pi bonds are easier to break than sigma due to weaker overlap of orbitals. This can be used to explain why carbonyls are important in synthesis (pi bond and polarity).
3(b) Electrophiles and nucleophiles	In reactions involving heterolytic bond fission, attacking groups are classified as 'nucleophiles' or 'electrophiles'. Nucleophiles are atoms or groups of atoms which are attracted towards atoms bearing a (partial) positive charge. Nucleophiles are capable of donating and sharing an electron pair to form a new bond. Electrophiles are atoms or groups of atoms which are attracted towards atoms bearing a (partial) negative charge. Electrophiles are capable of accepting an electron pair.	Avogadro.co.uk provides definitions and examples of nucleophiles and electrophiles. 📄

Content	Notes	Possible contexts and activities
3(c) Curly arrow notation	<p>Curly arrows are used to show the movement of electron pairs during a reaction. The base of the arrow shows the original location of the pair of electrons. The head of the arrow indicates the destination of the pair of electrons. An arrow starting at the middle of a covalent bond indicates that heterolytic bond fission is occurring. When an arrow is drawn with the head pointing to the space between two atoms, this indicates that a covalent bond will be formed between the two atoms.</p> <p>A double-headed arrow indicates the movement of an electron pair and a single-headed arrow indicates the movement of a single electron.</p>	<p>Chemguide.co.uk has information on use of curly arrows. </p> <p>abdn.ac.uk also has a brief introduction to using curly arrows with some animations and examples of specific mechanisms. </p>
3(d) Haloalkanes	<p>Haloalkanes (alkyl halides) are named according to IUPAC rules. Monohaloalkanes can be classified as primary, secondary or tertiary. Monohaloalkanes undergo nucleophilic substitution reactions.</p> <p>They react with:</p> <ol style="list-style-type: none"> 1 alkalis to form alcohols, 2 alcoholic alkoxides to form ethers, 3 ethanolic cyanide to form nitriles which can be hydrolysed to carboxylic acids (chain length increased by one carbon atom). <p>Monohaloalkanes can also undergo elimination reactions to form alkenes.</p>	<p>Alkaline hydrolysis of a bromoalkane.</p> <p>Experiment on nucleophilic substitution reactions of haloalkanes — See 'Chemistry in Context Laboratory Manual, fifth edition' by Graham Hill and John Holman, published by Nelson Thornes.</p> <p>React monohaloalkanes with aqueous alkali and test for halide ion using silver nitrate solution</p> <p>React monohaloalkanes with ethanolic potassium hydroxide and test for alkene produced</p> <p>Some haloalkanes are used as anticancer agents and are called alkylating agents. Associated with toxic side effects.</p>

Content	Notes	Possible contexts and activities
3(e) The reaction mechanism for S_N1 and S_N2 reactions	The reaction mechanisms for S _N 1 and S _N 2 reactions can be represented using curly arrows. The dominance of an S _N 1 or S _N 2 mechanism for a particular haloalkane can be explained in terms of steric hindrance and the inductive stabilisation of an intermediate carbocation. An S _N 2 reaction proceeds via a single five-centred transition state, whereas an S _N 1 reaction occurs in two steps via a carbocation.	Not necessary to go into inductive stabilisation in great detail. Mechanisms and animations for S _N 1 and S _N 2 are available on the internet. ☞ Chemguide.co.uk gives information on nucleophilic substitution reactions. ☞ Abdn.ac.uk covers a variety of reaction mechanisms including nucleophilic substitution reactions. ☞
3(f) The properties, preparation and reactions of alcohols	Alcohols exhibit hydrogen bonding and as a result have anomalously high boiling points compared to many other organic compounds of comparable relative formula mass and shape. The shorter chain alcohols are miscible with water, but their solubility in water decreases as chain length increases. Alcohols can be prepared from: 1 alkenes by acid-catalysed hydration; 2 haloalkanes by substitution. Alcohols react with some reactive metals to form alkoxides. Alcohols can be dehydrated to alkenes. Alcohols undergo condensation reactions with carboxylic acids and react more vigorously with acid chlorides to form esters. Primary alcohols undergo mild oxidation reactions to form aldehydes. Secondary alcohols undergo mild oxidation reactions to form ketones.	Preparation of esters, ethanol reacting with Na to form sodium ethoxide, oxidation of ethanol, ethanal and propan-2-ol by acidified dichromate, etc. Dehydration of ethanol to ethene using aluminium oxide. Alcohol groups present in a lot of drugs since they are involved in hydrogen bonding with protein binding sites (for example β-blockers and anti-asthmatics).

Content	Notes	Possible contexts and activities
3(g) Ethers	Ethers have the general formula R'-O-R'' where R' and R'' are alkyl groups. Ethers are named according to IUPAC rules. Due to the lack of hydrogen bonding between ether molecules, they have lower boiling points than the corresponding isomeric alcohols. Ethers can be prepared by the reaction of haloalkanes with alkoxides. Ethers are commonly used as solvents since they are relatively inert chemically and will dissolve many organic compounds. The solubility of ethers in water decreases as the molecular size increases.	Ethers were the first anaesthetics. Williamson ether synthesis, eg synthesis of 1-ethoxy butane from 1-bromo butane and ethanol — can also be done as a kinetic experiment. Ethoxyethane is not fully miscible in water, having the same solubility as n-butanol. Methoxymethane and methoxyethane are more soluble in water than ethoxyethane, but they are not fully miscible. This is due to the formation of hydrogen bonds between the ether molecules and water molecules. Ethers, of low relative molecular mass are highly flammable and on exposure to air may form explosive peroxides. Ether runway experiment can be demonstrated.
3(h) Preparation of alkenes	Alkenes can be prepared in the laboratory by: 1 dehydration of alcohols using aluminium oxide, concentrated sulfuric acid or orthophosphoric acid; 2 base-induced elimination of hydrogen halides from monohaloalkanes.	Preparation of cyclohexene from cyclohexanol.
3(i) Electrophilic addition to alkenes	Alkenes can undergo the following electrophilic addition reactions: 1 catalytic addition of hydrogen to form alkanes; 2 addition of halogens to form dihaloalkanes; 3 addition of hydrogen halides according to Markovnikov's rule, to form monohaloalkanes; 4 acid-catalysed addition of water according to Markovnikov's rule, to form alcohols. The mechanism for both the addition of hydrogen halides and the acid-catalysed addition of water involves a carbocation intermediate. The mechanism for addition of a halogen involves a cyclic ion intermediate. Both mechanisms can be written using curly arrows.	abdn.ac.uk covers a variety of reaction mechanisms including reactions of alkenes such as addition of H-X to an alkene and also Markovnikov's rule (with a different spelling). 

Content	Notes	Possible contexts and activities
3(j) Oxidation and reduction of carbonyl compounds	<p>Both aldehydes and ketones contain the carbonyl C=O functional group. It is possible to further oxidise aldehydes to form carboxylic acids.</p> <p>Aldehydes reduce the complexed silver(I) ion to silver to produce a silver mirror with Tollens' reagent. Aldehydes also reduce the complexed copper(II) ion in Fehling's solution to copper(I) oxide.</p> <p>Aldehydes and ketones can be reduced to primary and secondary alcohols respectively, by reaction with lithium aluminium hydride in ethoxyethane.</p>	<p>Previous Higher PPA using Tollens' reagent.</p> <p>Lots of information about the silver mirror test can be found by carrying out an internet search. </p> <p>Chemguide.co.uk has pages on oxidation of aldehydes and ketones. </p> <p>Faraday Lecture on making double glazing by oxidation of glucose using Tollens' Reagent.</p> <p>Manufacture of silver mirrors.</p> <p>Aldehydes are fairly rare in the natural world due to air oxidation to carboxylic acids. Many drugs contain ketones (eg methadone), but none contain aldehydes.</p>
3(k) Preparation and reactions of carboxylic acids	<p>Carboxylic acids can be prepared by:</p> <ol style="list-style-type: none"> 1 oxidising primary alcohols and aldehydes; 2 hydrolysing nitriles, esters or amides. <p>Reactions of carboxylic acids include:</p> <ol style="list-style-type: none"> 1 formation of salts by reactions with metals or bases; 2 condensation reactions with alcohols to form esters in the presence of an acid catalyst; 3 reaction with amino groups to form amide links; 4 reduction with lithium aluminium hydride to form primary alcohols. 	<p>Preparation of benzoic acid from ethyl benzoate (previously a PPA).</p> <p>Carboxylic acids are weak acids, neutralisation with alkalis to form salts, reaction with Mg — covered in Physical Chemistry Unit.</p> <p>Carboxylic acids are often ionised in drugs and form ionic interactions with binding sites. Penicillins contain a carboxylate ion that plays a crucial binding role.</p> <p>Consider role of carboxyl functional group in polymerisation the formation of polyesters, polyamides and proteins.</p>
3(l) Amine classification and reactions	<p>Amines are organic derivatives of ammonia and can be classified as primary, secondary or tertiary. Primary and secondary amines, but not tertiary amines, associate by hydrogen bonding. As a result, primary and secondary amines have higher boiling points than isomeric tertiary amines. Amine molecules can hydrogen-bond with water molecules thus explaining the appreciable solubility of the shorter chain length amines in water. The nitrogen atom in amines has a lone pair of electrons which can accept a proton from water, producing hydroxide ions.</p>	<p>Solubility of lower amines in water, test pH of solutions formed. Compare pH of ethylamine solution with pH of ammonia. Neutralise solutions of amines with mineral acids. chem.purdue.edu provides some information about amines in drugs </p> <p>Indiana.edu also provides information about amines and their salts in medicines. </p> <p>Elmhurst.edu has some homework ideas on amines but need to be selective. </p>

Content	Notes	Possible contexts and activities
3(l) Amine classification and reactions (cont)	Amines are weak bases which react with aqueous mineral or carboxylic acids to form salts.	
3(m) Aromatic hydrocarbons and reactions of benzene	Benzene C ₆ H ₆ is the simplest member of the class of aromatic hydrocarbons. The benzene ring has a distinctive structural formula. The stability of the benzene ring is due to the delocalisation of electrons. A benzene ring in which one hydrogen atom has been substituted by another group is known as the phenyl group. The phenyl group has the formula -C ₆ H ₅ . The benzene ring resists addition reactions. One or more hydrogen atoms of a benzene molecule can be substituted to form a range of consumer products. Bonding in benzene can be described in terms of sp ² hybridisation, sigma and pi bonds and electron delocalisation. Consider only alkylation, nitration, sulfonation and halogenation as examples of electrophilic substitution in benzene and other aromatic compounds.	Many everyday consumer products have very distinctive smells as a result of the presence of key aromatic compounds. A brief interest raising activity can be a display of household products containing these products. Examples would include well known antiseptics and disinfectants containing trichlorophenol or 4-chloro-3,5-dimethylphenol, permanent markers containing xylene or toluene etc. An internet search using these compounds as key words will return the names of several well known products. Benzene and its related compounds are important as feedstocks in the dyes and pigments industry, the pharmaceuticals industry and the detergents industry. Many drugs contain aromatic rings. They play a crucial role in binding as a result of their planar shape and hydrophobic character Mechanism not necessary but should be able to work out the product formed from benzene and the electrophile/reaction mixture. Information about mechanisms is available on the internet. 
3(n) Recognising and using types of reaction in organic synthesis	Given equations, the following reaction types can be identified: substitution, addition, elimination, condensation, hydrolysis, oxidation, reduction. Candidates should be able to devise synthetic routes, with no more than three steps, from a given reactant to a final product.	It is important that many, varied, real-life contexts for these reactions are provided. Similarities/parallels between the different reaction types should be constantly reinforced and opportunities to make connections frequently provided.

Content	Notes	Possible contexts and activities
4 Molecules and Colour		
4(a) Absorption of visible light by organic molecules	<p>Most organic molecules appear colourless because the energy difference between the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) is relatively large resulting in the absorption of light in the ultraviolet region of the spectrum. Coloured organic compounds contain delocalised electrons within molecular orbitals which extend across several atoms. This is known as a conjugated system. The more atoms the delocalised molecular orbital spans, the smaller the energy gap between the delocalised orbital and the next unoccupied orbital and hence the lower the frequency of light (or longer the wavelength or lower the energy of radiation) absorbed by the compound. When the wavelength of the light absorbed is in the visible region, the organic substance will appear coloured. Molecules in which the structural formula contains alternate double bonds will exhibit molecular orbitals containing delocalised electrons which will extend the conjugated section of the molecule.</p>	<p>Candidates can examine information on a number of molecules comparing the absorptions of conjugated and non-conjugated dienes. Vitamin A very clearly exhibits a conjugated structure (retinol). They can also look at the structure of natural compounds such as beta-carotene. When ninhydrin reacts with amino acids a highly conjugated product is formed which absorbs light in the visible region and an intense purple colour (λ_{max} 750 nm) is observed. This is used in the detection of α-amino acids. Candidates can prepare a variety of dyes themselves and examine the structures to locate the chromophore. Examples would include the preparation of azo dye from aminobenzene (aniline), sodium nitrite and 2-naphthol at low temperatures. The azo dye can be used to dye a piece of cotton.  Synthetic Indigo can also be prepared using a microscale method. </p>
4(b) Chromophores	<p>The chromophore is the group of atoms within a molecule which is responsible for the absorption of light in the visible region of the spectrum. Light can be absorbed when electrons in a chromophore are promoted from one molecular orbital to another. If the chromophore absorbs light of one colour, the compound will exhibit the complementary colour.</p>	<p>For example, a compound in which the chromophore absorbs blue light will appear yellow. Complementary colours can be demonstrated very effectively using online resources which will allow colour mixing to be demonstrated on a computer screen or interactive whiteboard. An internet search using 'RGB colour mixing' will produce suitable simulations and animations.  Simple spectrometers made from DVDs can be used to view light transmitted or reflected by coloured compounds.</p>

Content	Notes	Possible contexts and activities
5 Experimental Determination of Structure	<i>In organic chemistry, a number of experimental techniques are carried out to verify that the correct chemical structure has been synthesised.</i>	The RSC has produced 'Spectroscopy in a suitcase' which is an outreach activity giving school students the chance to learn about spectroscopy through hands-on experience. As well as covering the principles of spectroscopic techniques, the activities use real-life contexts to demonstrate the applications of the techniques. This can be used to teach mass spectrometry, infra-red spectroscopy and proton nmr spectroscopy.  The RSC 'spectraschool' is also very useful and as well as providing useful background information, it also gives candidates the opportunity to print their own spectra for a range of compounds. 
5(a) Elemental microanalysis	Elemental microanalysis can be used to determine the masses of C, H, O, S and N in a sample of an organic compound in order to determine its empirical formula.	SnI ₄ or CuO empirical formula experiment can be done again here but probably not necessary Opportunity to practise empirical formula calculations from results of elemental microanalysis experiments. Other elements in organic compounds can also be determined by elemental microanalysis.
5(b) Mass spectrometry	Mass spectrometry can be used to determine the accurate molecular mass and structural features of an organic compound. Fragmentation takes place producing parent ion and ion fragments. A mass spectrum is obtained showing a plot of the relative abundance of the ions detected against the mass-to-charge ratio. The molecular formula can be confirmed from a high accuracy determination of the mass of the parent ion. The fragmentation pattern can also be interpreted to gain structural information.	In mass spectrometry, the sample is first vaporised and ionised, and fragmentation occurs when excessive energy is used to ionise the molecules. The ion fragments are separated according to their mass-to-charge ratio using an electric or magnetic field. Many types of mass spectrometer will automatically compare the mass spectrum of the sample against a large database of known organic compounds to look for an exact match and to allow identification. The mass spectrum is like a fingerprint for a particular compound.

Content	Notes	Possible contexts and activities
5(c) Infra-red spectroscopy	<p>Infra-red spectroscopy can be used to identify certain functional groups in an organic compound. Infra-red radiation causes parts of a molecule to vibrate. The wavelengths which are absorbed to cause the vibrations will depend on the type of chemical bond and the groups or atoms at the ends of these bonds. In infra-red spectroscopy, infra-red radiation is passed through a sample of the organic compound and then into a detector which measures the intensity of the transmitted radiation at different wavelengths. Infra-red absorbances are measured in wavenumbers, the reciprocal of wavelength, in units of cm^{-1}.</p>	<p>IR is still widely used as it is cheaper than NMR and can be used to follow reaction progress (ie carbonyl group present or absent).</p> <p>It also has many specialist applications in forensics, polymer chemistry and quality control.</p> <p>Chemguide.co.uk provides much background information on infra-red spectroscopy. </p>
5(d) Interpretation of ^1H NMR spectra	<p>Proton nuclear magnetic resonance spectroscopy (proton NMR) can give information about the different environments of hydrogen atoms in an organic molecule, and about how many hydrogen atoms there are in each of these environments. In the proton NMR spectrum the peak position (chemical shift) is related to the environment of the H atom. The area under the peak is related to the number of H atoms in that environment.</p> <p>An interaction with H-atoms on a neighbouring carbon atoms can result in the splitting of NMR peaks into 'multiplets'. The number of H-atoms on the neighbouring carbon will determine the number of lines within a multiplet.</p> <p>Candidates would be expected to be able to draw and analyse low resolution proton NMR spectra and to analyse high resolution proton NMR spectra.</p>	<p>Hydrogen nuclei behave like tiny magnets and in a strong magnetic field some are aligned with the field (lower energy) whilst the rest are aligned against it (higher energy). Absorption of radiation in the radio-frequency region of the electromagnetic spectrum will cause the hydrogen nuclei to 'flip' from the lower to the higher energy alignment. As they fall back from the higher to the lower level, the emitted radiation is detected. The standard reference substance used in NMR spectroscopy is tetramethylsilane (TMS) which is assigned a chemical shift value equal to zero.</p> <p>The RSC website provides online NMR spectroscopy resources with video, tutorials and spectra databases. </p> <p>There is also a large RSC resource providing background theory for nmr and simple correlation information. </p> <p>Chemguide.co.uk provides background information on NMR spectroscopy as well as information on interpreting both low resolution and high resolution nmr spectra. </p>

Content	Notes	Possible contexts and activities
5(d) Interpretation of ^1H NMR spectra (cont)		Application of NMR in medical body scanners can be discussed here.
6 Drug Interactions		
6(a) Medicines	Drugs are substances which alter the biochemical processes in the body. Drugs which have beneficial effects are used in medicines. A medicine usually contains the drug plus other ingredients.	<p>Discuss paracetamol which taken according to the correct dosage is beneficial but is very dangerous when taken in larger quantities and may lead to liver failure and death. Most drugs bind to a protein target by intermolecular binding forces and do not undergo any reaction. An induced fit normally leads to the effects observed.</p> <p>'The Design Studio' is a useful, interactive RSC resource to introduce the topic of drugs and medicines. The resource gives candidates the opportunity to learn about the causes and effects of diseases such as cancer, HIV and asthma using their knowledge of chemistry. It then challenges the candidate to design an 'optimal' drug to treat one of the diseases using their knowledge of organic chemistry. </p> <p>Another interactive resource from the RSC is the 'Masterminding Molecules' package. This resource combines learning with game-play and involves cracking a code to reveal hidden chemical concepts involved in design of drugs and medicines. Clinical trials allow safety and efficacy data to be collected for new drugs or devices. Depending on the nature of the study, healthy volunteers or patients may be used in a small pilot study. If the safety and efficacy data is satisfactory, the scale of the study will be increased. In randomised drug trials a group of patients are divided with some being given the drug. </p>

Content	Notes	Possible contexts and activities
6(b) How drugs work	<p>Most drugs work by binding to receptors. Receptors are usually protein molecules on the surface of cells where they interact with small biologically active molecules, or are enzymes that catalyse chemical reactions (catalytic receptors). The structural fragment of a drug molecule which confers pharmacological activity upon it normally consists of different functional groups correctly orientated with respect to each other. The overall shape and size of the drug has to be such that it fits a binding site. The functional groups on both the drugs and the receptor are positioned such that the drugs can interact with and bind to the receptor. Candidates should be able to identify the types of interaction between drugs and binding sites. By comparing the structures of drugs that have similar effects on the body, the structural fragment that is involved in the drug action can be identified.</p>	<p>Emphasise importance of shape. Binding of the active molecule to the binding site initiates a series of chemical events which results in a change in the cell chemistry. This can lead to an observable effect such as a muscle cell contracting, Protein databanks offer a huge number of PDB files containing examples of proteins with various drug molecules bound to a receptor site. Candidates can use CHIME, PYMOL or Chem3D to explore the interactions between the functional group and the receptor site. Some computer packages allow H-bonding interactions to be displayed- or electrostatic potential surfaces to be examined. Design Studio and Masterminding Molecules (RSC) can be used to illustrate these concepts. Excellent opportunity to investigate structural fragments common to different medicines using websites given above.</p>
6(c) Classification of drugs	<p>Many drugs can be classified as agonists or as antagonists at receptors, according to whether they enhance or block the body's natural responses. An agonist will produce a response similar to the body's natural active compound. An antagonist produces no response but prevents the action of the body's natural active compound. Many drugs act as enzyme inhibitors by binding to the enzyme's active site and blocking the reaction normally catalysed there.</p>	<p>Andanamide (also known as the bliss molecule) is a recently discovered messenger molecule that plays a role in pain, depression, appetite, memory, and fertility. Frostburg.edu provides more information about andanamide.  The resource also describes the way in which nerve cells communicate, through molecular keys and receptors. There are other drug targets apart from receptors and enzymes, such as DNA and RNA.</p>



National Unit specification: general information

Unit title: Physical Chemistry (SCQF level 7)

Unit code: H1FK 13

Course: Chemistry Advanced Higher

Superclass: RD

Publication date: April 2012

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit develops a knowledge and understanding of Physical Chemistry within the contexts of chemical equilibria in aqueous solution, feasibility of chemical reactions and reaction kinetics. The Unit develops the candidate's knowledge and understanding of some of the major concepts used to explain chemical behaviour. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

Outcomes

- 1 Demonstrate and apply knowledge and understanding related to *Physical Chemistry*.
- 2 Demonstrate skills of scientific experimentation and investigation within the context of *Physical Chemistry*.

Recommended entry

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by the following or equivalent:

- ◆ Higher Chemistry (Revised)
- ◆ Higher Chemistry

General information (cont)

Unit title: Physical Chemistry (SCQF level 7)

Credit points and level

0.5 National Unit credit at SCQF level 7: (4 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Unit gives automatic certification of the following:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Graphical Information at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

National Unit specification: statement of standards

Unit title: Physical Chemistry (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate and apply knowledge and understanding related to *Physical Chemistry*.

Performance Criteria

- (a) Make accurate statements about facts, concepts and relationships relating to *Physical Chemistry*.
- (b) Use knowledge of *Physical Chemistry* to solve problems.
- (c) Use knowledge of *Physical Chemistry* to explain observations and phenomena.

Outcome 2

Demonstrate skills of scientific experimentation and investigation in the context of *Physical Chemistry*.

Performance Criteria

- (a) Use a range of data-handling skills in a scientific context.
- (b) Use a range of skills related to the evaluation of scientific evidence.

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

For each of the Unit Outcomes, written and/or recorded oral evidence of the appropriate level of achievement is required. This evidence must be produced under closed-book, supervised conditions within a time limit of 30 minutes.

The Instrument of Assessment must sample the content in each of the following areas:

- ◆ Chemical equilibrium
- ◆ Reaction feasibility
- ◆ Kinetics

An appropriate Instrument of assessment would be a closed-book, supervised test with a time limit of 30 minutes. Items in the test should cover all the Performance Criteria associated with both Outcomes 1 and 2, and could be set in familiar or unfamiliar contexts.

Further detail on the breadth and depth of content is provided within in the appendix to the specification.

National Unit specification: statement of standards (cont)

Unit title: Physical Chemistry (SCQF level 7)

For Outcome 2, PC (a) candidates are required to demonstrate that they can use a range of data-handling skills. These skills include selecting, processing and presenting information. Information can be presented in a number of formats including: chemical formulae, balanced chemical equations, diagrams depicting laboratory apparatus, line graphs, scatter graphs, tables, diagrams and text.

For Outcome 2, PC (b), candidates are required to demonstrate that they can use a range of skills associated with the evaluation of scientific evidence. These skills include drawing valid conclusions and making predictions.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

National Unit specification: support notes

Unit title: Physical Chemistry (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 20 hours.

Guidance on the content and context for this Unit

The recommended content together with suggestions for possible contexts and activities to support and enrich learning and teaching are detailed in the Course specification.

This Unit allows candidates to develop knowledge and understanding of Physical Chemistry within the contexts of chemical equilibrium, feasibility of chemical reactions and reaction kinetics. The Unit should develop the candidate's knowledge and understanding of some of the major concepts used to explain chemical behaviour. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

This Unit offers a diverse and rich vein of contexts and opportunities for practical work as highlighted in the 'Possible contexts and activities' column of the content tables. Opportunities exist for candidates to learn as part of a group through practical work undertaken in partnership or in teams. By developing a greater understanding of some of the mathematical relationships in chemistry, candidates are better able to understand more about rates of chemical reactions and why chemical reactions take place in a particular direction.

Guidance on learning and teaching approaches for this Unit

General advice on approaches to learning and teaching is contained in the Course specification.

Guidance on approaches to assessment for this Unit

Outcomes 1 and 2

It is recommended that a holistic approach is taken for assessment of these Outcomes. Outcomes 1 and 2 can be assessed by an integrated end of Unit test with questions covering all the Performance Criteria. Within one question, assessment of knowledge and understanding and skills of experimentation and investigation can occur. Each question can address a number of assessment standards from either Outcome 1 or 2.

Appropriate assessment items are available from the National Assessment Bank.

National Unit specification: support notes (cont)

Unit title: Physical Chemistry (SCQF level 7)

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003)*, *SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

This Unit provides opportunities to develop *Communication, Numeracy, Information and Communication Technology (ICT)* and *Problem Solving* skills in addition to providing contexts and activities within which the skills associated with *Working with Others* can be developed.

Outcome 1, PC (b) and (c) develop a candidate's ability to communicate effectively key concepts and to explain clearly chemical phenomena in written media.

Within this Unit candidates will need to extract and process information presented in both tabular and graphical formats developing the Core Skill of *Numeracy*. Candidates will gain experience in a range of calculations building competence in number.

The appendix to this Unit specification contains an extensive list of 'Possible Contexts and Activities' which include a large number of web based activities, computer simulations and modelling opportunities which all serve to develop higher levels of competence in the key ICT skills including; accessing information and providing/creating information.

The Unit appendix contains an extensive range of practical laboratory exercises which provide candidates with the opportunity to Work Co-operatively with Others.

Problem Solving skills are central to the sciences and are assessed through Outcome 1, PCs (b) and (c) and also through Outcome 2, PCs (a) and (b).

This Unit has the Using Graphical Information component of Numeracy, and the Critical Thinking component of Problem Solving, embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show that they have achieved Using Graphical Information and Planning and Organising at SCQF level 6.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

History of changes to Unit

Version	Description of change	Date

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The left hand column below details the content in which candidates should develop knowledge and understanding. The middle column contains notes, which give further details of the breadth and depth of content expected. The right-hand column gives possible contexts and activities which could be used to develop knowledge, understanding and skills. Further details on many of the activities mentioned in the final column can be obtained from **National Qualifications Online**, part of the Education Scotland online service. Where such online support exists the  symbol appears in the text.

Physical Chemistry 20 hour Unit		
Content	Notes	Possible contexts and activities
1 Chemical Equilibrium		Try to ensure links to organic chemistry through pK_a values and buffers are constantly reinforced as well as links within the unit itself. Nclark.net and beckerdemos contain lots of good ideas for this Unit and other levels of Chemistry. These contain links to a variety of simulations, experiments and tutorials. 
1(a) Equilibrium Constants	<p>A chemical reaction is in equilibrium when the composition of the reactants and products remains constant indefinitely. The equilibrium constant (K) characterises the equilibrium composition of the reaction mixture.</p> <p>For the general reaction,</p> $aA + bB \rightleftharpoons cC + dD$ $K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$ <p>where [A], [B], [C] and [D] are the equilibrium concentrations of A, B, C and D respectively and a, b, c and d are the stoichiometric coefficients in the balanced reaction equation. Equilibrium constants are independent of the concentrations or pressures of species in a given reaction. The numerical value of the equilibrium constant depends on the reaction temperature. For endothermic reactions a rise in temperature causes an increase in K, ie, the yield of the product is increased.</p>	<p>Strictly speaking, equilibrium constants are defined in terms of the activities of the reactants and products, but a good working approximation is achieved by using the concentration of solutions, in mol l^{-1}, in place of activities. Because the concentrations of pure solids or pure liquids are constant, by convention they can be given the value 1 in the equilibrium equation.</p> <p>chm.davidson.edu has an equilibrium simulation showing the effect of temperature changes </p> <p>Partition coefficients could be included as a specific example of an equilibrium constant.</p>

Content	Notes	Possible contexts and activities
1 Chemical Equilibrium (cont)		
	For exothermic reactions a rise in temperature causes a decrease in K , ie, the yield of the product is decreased. The presence of a catalyst does not affect the value of the equilibrium constant. Equilibrium constants have no units.	
1(b) Ionic product of water	In water and aqueous solutions there is an equilibrium between the water molecules and hydrogen and hydroxide ions. This ionisation of water can be represented by: $\text{H}_2\text{O}(\ell) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})$. Water is amphoteric. The dissociation constant for the ionisation of water is known as the ionic product and is represented by K_w . The value of the ionic product varies with temperature. At 25 °C the value of K_w is approximately 1×10^{-14} . A shorthand representation of $\text{H}_3\text{O}^+(\text{aq})$ is $\text{H}^+(\text{aq})$. Stoichiometric equations and equilibrium expressions can be written using $\text{H}^+(\text{aq})$ instead of $\text{H}_3\text{O}^+(\text{aq})$ where the meaning is clear. The relationship between pH and the hydrogen ion concentration is given by $\text{pH} = -\log_{10} [\text{H}^+]$	Point out that the equilibrium does not involve free protons but $\text{H}_3\text{O}^+(\text{aq})$. Use K_w to calculate pH of water and it can be used to show that the pH of water varies with temperature. chemguide.co.uk website gives good information on the ionic product of water including variation of K_w at different temperatures. Unfortunately K_w has been given units. 📄
1(c) The pH scale linked to H^+ ion concentration	$\text{pH} = -\log_{10}[\text{H}^+]$ and conversely $[\text{H}^+] = 10^{-\text{pH}}$. In water and aqueous solutions with a pH value of 7 the concentrations of $\text{H}^+(\text{aq})$ and $\text{OH}^-(\text{aq})$ are both $10^{-7} \text{ mol l}^{-1}$ at 25 °C. If the concentration of $\text{H}^+(\text{aq})$ or the concentration of $\text{OH}^-(\text{aq})$ is known, the concentration of the other ion can be calculated using K_w or by using $\text{pH} + \text{pOH} = 14$.	Calculations of $[\text{H}^+]$ for different pH values. quia.com has a fun quiz on calculating pH based on Who Wants to be a Millionaire. 📄
1(d) Bronsted-Lowry acids/bases	The Bronsted-Lowry definitions of acid and base state that an acid is a proton donor and a base is a proton acceptor. For every acid there is a conjugate base, formed by the loss of a proton. For every base there is a conjugate acid, formed by the gain of a proton.	Video by Mark Rosengarten video defines Bronsted/Lowry acids and bases 📄 Videos by Papapodcasts go further covering conjugate acids and bases 📄

Content	Notes	Possible contexts and activities
1(e) Strong and weak acids and bases	<p>In aqueous solution, strong acids/bases are completely dissociated into ions but weak acids/bases are only partially dissociated. Examples of strong acids include hydrochloric acid, sulfuric acid and nitric acid. Ethanoic, carbonic and sulfurous acids are examples of weak acids. Solutions of metal hydroxides are strong bases. Ammonia and amines are examples of weak bases.</p> <p>The weakly acidic nature of solutions of carboxylic acids, sulfur dioxide and carbon dioxide can be explained by reference to equations showing the equilibria. The weakly alkaline nature of a solution of ammonia or amines can be explained by reference to an equation showing the equilibrium.</p> <p>The acid dissociation constant is represented by K_a or by pK_a where $pK_a = -\log_{10}K_a$</p> <p>Although equimolar solutions of weak and strong acids/bases differ in pH, conductivity, and reaction rates they do not differ in stoichiometry of reactions.</p>	<p>mhhe.com has a video of a simple animation showing the difference between the strong acid, HCl, and the weak acid HF in terms of ionisation. </p> <p>Other Papapodcasts' videos cover strong/ weak acids and strong/weak bases. </p> <p>Investigation of pH of strong & weak acids and bases using pH meter or indicators.</p> <p>Investigate pH of differing metal/non-metal hydroxide solutions.</p> <p>Possible look at titration curves for strong/weak acids and bases. Short videos of these are available. </p> <p>Chem.iastate.edu website shows a simple simulation using a pH meter to test pH of various acids and alkalis of differing concentrations. </p> <p>Library.thinkquest.org has information on strong and weak acids and on the acid dissociation constant </p>
1(f) The pH of salt solutions	<p>A soluble salt of a strong acid and a strong base dissolves in water to produce a neutral solution. A soluble salt of a weak acid and a strong base dissolves in water to produce an alkaline solution. A soluble salt of a strong acid and a weak base dissolves in water to produce an acidic solution. Soaps are salts of weak acids and strong bases. The acidity, alkalinity or neutrality of the above kinds of salt solution can be explained by reference to the appropriate equilibria.</p>	<p>Calculate acidity/basicity of a given salt solution and confirm by measurement of pH.</p> <p>Test pH of various salt solutions including sodium carbonate, sodium sulfite, sodium stearate, ammonium chloride, ammonium nitrate etc.</p> <p>The Chem.iastate.edu website also shows a simple simulation using a pH meter to test pH of various salt solutions of differing concentrations. </p>
1(g) Calculation of pH for a weak acid	<p>The approximate pH of a weak acid can be calculated using $pH = \frac{1}{2} pK_a - \frac{1}{2} \log_{10}c$ where c is the nominal concentration of the acid in the solution.</p>	<p>Calculate pH of a 0.1 mol l^{-1} solution of a weak acid and confirm by measurement. Dilute it tenfold to show pH rises by 0.5 rather than by 1 as it would when diluting a strong acid such as 0.1 mol l^{-1} HCl. Good opportunity for candidates to practise diluting accurately.</p>

Content	Notes	Possible contexts and activities
1(h) Buffer solutions	<p>A buffer solution is one in which the pH remains approximately constant when small amounts of acid or base are added. An acid buffer consists of a solution of a weak acid and one of its salts. In an acid buffer solution the weak acid can supply hydrogen ions when these are removed by the addition of a small amount of base. The salt of the weak acid provides the conjugate base, which can absorb excess hydrogen ions produced by the addition of a small amount of acid.</p> <p>A basic buffer consists of a solution of a weak base and one of its salts. In a basic buffer solution the weak base removes excess hydrogen ions and the conjugate acid provided by the salt supplies hydrogen ions when these are removed.</p> <p>An approximate pH of an acid buffer solution can be calculated from its composition and from the acid dissociation constant, $\text{pH} = \text{p}K_{\text{a}} - \log_{10} \frac{[\text{acid}]}{[\text{salt}]}$</p>	<p>Prepare buffer solution, measure pH and compare with calculated value.</p> <p>Opportunity to use pH meter and use buffer solution to calibrate it.</p> <p>pH of blood important. Small change in pH causes major problems.</p> <p>Mhhe.com shows an animation of how a buffer solution resists change in pH when a strong acid or a strong base are added. Need to explain to candidates that acetic acid and acetate are the same as ethanoic and ethanoate. </p> <p>The chem.iastate.edu website has another animation of a buffer solution in which candidates can prepare a buffer solution, test its pH, add acid or alkali and test the pH again. Can also use this to compare measured pH value of buffer against the calculated value. </p> <p>Chemcollective.org has an interesting but difficult quiz. Unfortunately answers are not provided. </p> <p>Michele.usc.edu has an animation showing the difference in pH changes when adding an acid or alkali to a buffer solution compared with adding acid or alkali to water. </p>
1(i) Indicators	<p>Indicators are weak acids for which the dissociation can be represented as:</p> $\text{HIn}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{In}^-(\text{aq})$ <p>The acid indicator dissociation constant is represented as K_{in} and is given by the following expression:</p> $K_{\text{in}} = \frac{[\text{H}_3\text{O}^+][\text{In}^-]}{[\text{HIn}]}$ <p>In aqueous solution the colour of the acid indicator is distinctly different from that of its conjugate base.</p> <p>The colour of the indicator is determined by the ratio of $[\text{HIn}]$ to $[\text{In}^-]$.</p> <p>The theoretical point at which colour change occurs is when $[\text{H}^+] = K_{\text{in}}$.</p>	<p>Determine pH range over which indicator colour changes. (possibly using natural indicator extracted from a plant)</p> <p>Select and use appropriate indicators for titration of:</p> <ul style="list-style-type: none"> weak acid and strong base strong acid and weak base. <p>Use indicator for weak acid/weak base titration to show that a single indicator is not appropriate</p> <p>chemguide.co.uk shows titration curves for different combinations of acids and alkalis </p> <p>jchemed.chem.wisc.edu has animations (series of slides) showing colour change in phenolphthalein in various titrations. </p>

Content	Notes	Possible contexts and activities
1(i) Indicators (cont)	The colour change is assumed to be distinguishable when $[HIn]$ and $[In^-]$ differ by a factor of 10. The pH range over which a colour change occurs can be estimated by the expression: $pH = pK_{In} \pm 1$	
2 Reaction feasibility		
2(a) Enthalpy of formation	The standard enthalpy of formation, ΔH_f° , is the enthalpy change when one mole of a substance is formed from its elements in their standard states. The standard enthalpy of a reaction can be calculated from the standard enthalpies of formation of the reactants and products. $\Delta H^\circ = \Sigma \Delta H_f^\circ (\text{products}) - \Sigma \Delta H_f^\circ (\text{reactants})$. Knowledge of standard conditions is important.	
2(b) Entropy	The entropy (S) of a system is a measure of the degree of disorder of the system. The greater the degree of disorder, the greater the entropy. Entropy increases as temperature increases. Changes of state involve changes in entropy.	Investigate simple exothermic and endothermic reactions. Discuss in terms of entropy changes.
2(c) Second and Third Laws of Thermodynamics	One version of the Second Law of Thermodynamics states that the total entropy of a reaction system and its surroundings always increases for a spontaneous process. Heat energy released by the reaction system into the surroundings increases the entropy of the surroundings, whereas heat absorbed by the reaction system from the surroundings decreases the entropy of the surroundings. One version of the Third Law of Thermodynamics states that the entropy of a perfect crystal at 0 K is zero. The standard entropy of a substance is the entropy value for the standard state of the substance.	Some information on the laws of thermodynamics can be found on the bbc.co.uk website 

Content	Notes	Possible contexts and activities
2(d) Calculating changes in entropy	The change in standard entropy for a reaction system can be calculated from the standard entropies of the reactants and products. $\Delta S^\circ = \sum S^\circ (\text{products}) - \sum S^\circ (\text{reactants}).$	Experiment/demo of endothermic reaction of $\text{Ba}(\text{OH})_2$ with NH_4Cl . Leek.high.staffs.sch.uk gives examples of practical work which can be carried out on spontaneous endothermic reactions. 
2(e) Free energy	The change in free energy for a reaction is related to the enthalpy and entropy changes; $\Delta G = \Delta H - T\Delta S$. If the change in free energy (ΔG) between reactants and products is negative, a reaction may occur. This is because the equilibrium composition favours the products over the reactants. The standard free energy change for a reaction can be calculated from the standard free energies of formation of the reactants and products using the relationship, $\Delta G^\circ = \sum \Delta G_f^\circ (\text{products}) - \sum \Delta G_f^\circ (\text{reactants}).$	Chemconnections.org has a little applet showing graph of ΔG v temperature. Candidates can change values of ΔH° and ΔS° . 
2(f) Applications of the concept of free energy	The feasibility of a chemical reaction under standard conditions can be predicted from the calculated value of the change in standard free energy (ΔG°). The temperatures at which a reaction may be feasible can be estimated from $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ by considering the range of values of T for which $\Delta G^\circ < 0$.	Former AH PPA, verification of a thermodynamic prediction could be carried out here as an example of a theoretical prediction working out fairly closely to the observed experimental value. Suggest a larger quantity of $\text{NaHCO}_3(\text{s})$ be used to ensure bulb of thermometer is completely covered but this will produce a volume of CO_2 greater than 100 cm^3 so needs to be monitored carefully and heating stopped and syringe removed from the barrel before 100 cm^3 reached. Ellingham diagrams can be used to show how ΔG° varies with temperature and they were useful in predicting temperatures at which reductions of metal oxides became feasible.

Content	Notes	Possible contexts and activities
2(g) Equilibrium and free energy	Under non-standard conditions any reaction is feasible if ΔG is negative. At equilibrium $\Delta G = 0$. A reaction will proceed spontaneously in the forward direction until the composition is reached where $\Delta G = 0$.	
3 Kinetics		
3(a) Orders of reaction	<p>The rate of a chemical reaction normally depends on the concentrations of the reactants. For a first order reaction the rate of reaction is proportional to the concentration of one reactant and the rate can be expressed as: $\text{rate} = k[A]$ where k is the rate constant and $[A]$ is the concentration of reactant A in mol l^{-1}. The order of a reaction with respect to any one reactant is the power to which the concentration of that reactant is raised in the rate equation. The overall order of a reaction is the sum of the powers to which the concentrations of the reactants are raised in the rate equation. The order of a reaction can only be determined from experimental data.</p> <p>The rate constant can be determined from initial rate data for a series of reactions in which the initial concentrations of reactants are varied. Integral orders of reaction from zero order to third order should be covered.</p>	<p>Propanone/iodine reaction PPA from current AH. Decolourisation of blue food dye. See SSERC bulletin No. 225. Within the body, drug molecules are converted into a number of different molecules that are more easily excreted into the urine. These molecules are called metabolites and the whole process is called metabolism. The metabolism of the drug will begin as soon as it is administered and in many cases the process follows first order kinetics, ie the rate of metabolism is proportional to the concentration of the drug.</p> <p>The RSC have a case study from The Horseracing Forensic Laboratory (HFL). There is a candidate worksheet and additional notes and answers for teachers. </p> <p>Saskschools.ca has an example on reaction rates in which candidates can calculate the order of reaction and work out the rate law. </p>
3(b) Reaction mechanisms	Reaction mechanisms usually occur by a series of steps. The rate of reaction is dependent on the slowest step which is called the 'rate determining step'. Experimentally determined rate equations can provide evidence for a proposed reaction mechanism.	<p>S_N1 and S_N2 reaction mechanisms can be discussed here but will also be covered in the Organic Chemistry Unit. Saskschools.ca has lots of information on reaction mechanisms including examples. </p>



National Unit specification: general information

Unit title: Researching Chemistry (SCQF level 7)

Unit code: FE4J 13

Course: Chemistry Advanced Higher

Superclass: RD

Publication date: April 2012

Source: Scottish Qualifications Authority

Version: 01

Summary

In this Unit candidates will develop key practical skills and investigative skills by studying and carrying out different practical techniques and procedures and using some of them through the completion of a practical investigation. The Unit offers opportunities for independent learning set within the context of experimental chemistry. Candidates will develop skills of planning, organising and carrying out experimental work, requiring self-motivation and independent learning. They will also collect and record experimental results and observations in an appropriate format.

This Unit is suitable for candidates who are interested in pursuing a chemistry related career, as well as those whose interest is more general.

Outcomes

- 1 Plan and carry out investigative practical work on a chosen chemistry topic.
- 2 Collect and record raw results and observations from the investigative practical work.

Recommended entry

While entry is at the discretion of the centre, candidates would normally be expected to have attained one of the following, or equivalent:

- ◆ Higher Chemistry
- ◆ Researching Chemistry Unit in Higher Chemistry (Revised)

General information (cont)

Unit title: Researching Chemistry (SCQF level 7)

Credit points and level

1 National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Unit gives automatic certification of the following:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Planning and Organising at SCQF level 6 Using Graphical Information at SCQF level 6

National Unit specification: statement of standards

Unit title: Researching Chemistry (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Develop a plan to carry out investigative practical work on a chosen chemistry topic.

Performance Criteria

- (a) The aims of the investigation are clearly stated
- (b) Appropriate experimental procedures are selected and planned using appropriate apparatus and chemicals.

Outcome 2

Collect and record experimental results from the investigative practical work.

Performance Criteria

- (a) Appropriate techniques and procedures are used effectively to collect experimental results.
- (b) Experimental results are recorded in an appropriate format.

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

Assessors should use their professional judgement to determine the most appropriate Instruments of Assessments for generating evidence and the conditions and contexts in which they are used. Exemplification of possible approaches may be found in the Unit support notes.

Outcome 1

Candidates should plan their investigative practical work after discussion with teachers or lecturers. The plan must be recorded in an appropriate format, which may be electronic, and should include the aim(s) of the investigation and details of all experimental procedures. The aims of planned experiments should also be recorded.

National Unit specification: statement of standards (cont)

Unit title: Researching Chemistry (SCQF level 7)

Outcome 2

The collection of experimental data must be the work of the individual candidate. The assessor must attest that, other than help from technicians, teachers, lecturers or support staff in setting up equipment, the investigative practical work is the work of the individual candidate.

All experimental data must be recorded in an appropriate format which may be paper-based or in electronic format.

National Unit specification: support notes

Unit title: Researching Chemistry (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

In this Unit candidates will develop the key techniques and practical skills identified by Higher Education and Industry as being necessary to undertake experimental research in chemistry.

It is intended that approximately 20 hours be spent on developing the theory behind these procedures and on practising these techniques and skills and that a further 20 hours be spent on the Investigation part of the Unit.

Candidates should be encouraged to see risk assessment as an important and necessary part of the planning process for any practical activity. Whilst not required as evidence for the Unit, each candidate should produce a full written risk assessment for the chemicals and procedures to be used in the Investigation. This Unit provides an excellent opportunity to assess risks and to make informed decisions regarding the use of appropriate control measures during the planning stage of the Investigation.

As with all practical investigative work in Science, centres must ensure that appropriate risk assessments have been carried out for all practical activities and must comply with current health and safety legislation and regulation.

Candidates can select any suitable topic for the Investigation provided the chemistry is at an appropriate level of demand. The topic chosen may be outwith the chemistry covered in other Units of the Advanced Higher Chemistry Course.

The number of procedures undertaken within the investigation will depend on the complexity of the experiments. It may be possible to undertake a successful investigation which consists of only one procedure. In this case, carrying out that procedure would take a significant proportion of the time within the Unit allocated for the Investigation.

The largest proportion of time spent on the Unit should be allocated to undertaking practical experimental work, together with the associated planning.

National Unit specification: support notes (cont)

Unit title: Researching Chemistry (SCQF level 7)

Outcome 1

In order to be able to make informed choices and decisions during the planning stage of the Investigation, teachers/lecturers should ensure that candidates are familiar with the following apparatus.

- ◆ Digital balance
- ◆ Colorimeter or visible spectrophotometer
- ◆ Buchner or Hirsch or sintered glass funnel
- ◆ Glassware with ground glass joints ('Quickfit' or similar)
- ◆ Thin layer chromatography apparatus
- ◆ Melting point apparatus
- ◆ Separating funnel

Candidates should also be familiar with the following skills and techniques including any relevant background theory as well as having opportunities to practise them prior to undertaking the Investigation. Further details are given in the Appendix.

- (a) Weighing by difference and gravimetric analysis
- (b) Preparing a standard solution
- (c) Using a reference or control or blank determination
- (d) Carrying out a complexometric titration
- (e) Carrying out a back titration
- (f) Using a colorimeter or visible spectrophotometer and carrying out dilution to prepare a calibration graph
- (g) Distilling
- (h) Refluxing
- (i) Using vacuum filtration methods
- (j) Recrystallising
- (k) Determining % yield experimentally
- (l) Using thin-layer chromatography
- (m) Using melting point apparatus and mixed melting point determination
- (n) Using a separating funnel and solvent extraction
- (o) Carrying out stoichiometric calculations

Candidates should become familiar with the above skills/techniques as a preparation for any practical work in their Investigation. It is not intended that candidates carry these out one by one independently but that they work in small groups carrying out experiments which may cover more than one skill/technique. Possible experiments are shown on the matrix on page 88.

National Unit specification: support notes (cont)

Unit title: Researching Chemistry (SCQF level 7)

Outcome 2

Candidates should agree with their teacher/lecturer on the apparatus, technique(s) and/or procedures which are most appropriate to meet the aim of their Investigation. The procedures should be carried out effectively taking into account any safety considerations highlighted and agreed upon in the risk assessment.

Tables and other formats used to record results should have appropriate headings and Units. Raw data must be recorded. For example, initial and final burette volumes for each titration must be recorded, not just the calculated titres. Interfacing data in the form of graphs is also acceptable as raw data. Observations such as colours, colour changes, physical features of crystalline products should also be recorded.

Guidance on learning and teaching approaches for this Unit

Candidates may consider a variety of approaches to the activities associated with the Unit. Independent management of both time and resources should be encouraged although candidates may need considerable support in the early stages of their planning. Furthermore, it is recommended that candidates are given support as they make a record of their plan and then record their results. Teachers/lecturers should discuss the results during and after the collection of data and if necessary experimental procedures can be repeated or modified to generate further data.

It may also be good practice to carry out an initial analysis of results obtained to check for trends, unexpected results, etc but this is not part of the assessment of this Unit. This will avoid the situation where inappropriate procedures and techniques are not discovered until a later stage in the work when it may be difficult or even too late to make the necessary corrections.

Candidates should be encouraged to select topics for investigation that they are interested in. However, important considerations are the chemicals and equipment available and teachers/lecturers may need to offer advice on the suitability a particular topic, given local considerations. It is recommended that candidates from any one class should not undertake the same Investigation.

Whilst centres are free to deliver this Unit at any point during the Advanced Higher Chemistry Course, the '*Possible contexts and Activities*' associated with the other Units of the Course may be used to provide real-life contexts within which candidates can become familiar with all the practical skills, apparatus and procedures listed above. Many teachers/lecturers may wish to delay the Investigation part of the Unit until the later stages of the Course in recognition of the considerable exposure to relevant experimental techniques candidates may experience whilst undertaking the other Advanced Higher Chemistry Units. This Unit allows candidates to link and apply different kinds of learning in new situations.

National Unit specification: support notes (cont)

Unit title: Researching Chemistry (SCQF level 7)

Guidance on approaches to assessment for this Unit

Outcome 1 is assessed by a written or electronic record of the candidate's aim and plan. This record must be the result of the candidate's individual work. The record may be in the form of a paper based daybook or stored electronically.

Candidates should follow good practice and maintain this record of work or daybook in which they must record the aim and plan of the Investigation. Any modifications in the light of experience may be included. A risk assessment of the procedure(s) and of all the chemicals to be used should also be included. This record of work may be used as evidence for the achievement of Outcome 1.

Outcome 2(a) requires candidates to carry out procedures effectively. Procedures, equipment and chemicals used should be appropriate to the aim(s) of the investigation. Candidates should be encouraged to carry out control experiments and to carry out each procedure in duplicate.

In relation to Outcome 2(a), the candidate should have regular discussions with teachers/lecturers on the difficulties and challenges of carrying out the practical work. By observation and discussion, teachers/lecturers should attest that the candidate has carried out the experimental procedures effectively. They may like to consider the following in making their judgement.

- ◆ Candidates should use equipment and chemicals properly, taking account of risk assessments.
- ◆ Candidates should take responsibility for collecting and putting away equipment and chemicals as appropriate.

In relation to Outcome 2(b), experimental results must be recorded and this may be paper based in a day book or in an electronic format. All raw results, measurements and observations should be recorded. Tables should normally include headings and Units as appropriate.

Candidates must maintain this record of their work and experimental results as evidence for achievement of Outcome 2.

Appropriate formative assessment methods may be used here. It is good practice when the assessor checks the record of work/day book of each candidate on a regular basis and signs and dates the relevant part when each performance criterion has been overtaken. Candidates should use the record of work/day book to record aims, planning, risk assessments, observations and results of the Investigation. It is also good practice for the assessor to take this opportunity to write appropriate comments and advice in the candidate's record of work/ day book.

National Unit specification: support notes (cont)

Unit title: Researching Chemistry (SCQF level 7)

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003)*, *SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

This Unit provides opportunities to develop *Communication, Numeracy, Information and Communication Technology (ICT)* and *Problem Solving* skills in addition to providing contexts and activities within which the skills associated with *Working with Others* can be developed.

Outcome 1 focuses upon a candidate's ability to plan how to carry out a chemistry investigation. *Communication* skills and skills of *Working with Others* are developed during discussion with technicians and teachers/lecturers in considering equipment and chemical requirements and developing suitable experimental procedures and techniques to carry out the investigation.

The collection and recording of experimental results for Outcome 2 provides a highly effective context within which candidates can develop both *Numeracy* and *Information and Communication Technology* skills.

This Unit has the Using Graphical Information component of Numeracy and the Critical Thinking and Planning and Organising components of Problem Solving, embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show that they have achieved Using Graphical Information, Critical Thinking and Planning and Organising at SCQF level 6.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

History of changes to Unit

Version	Description of change	Date

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The table below gives further details on the skills and techniques to be developed as listed on page 76. The right hand column contains notes, which give further details of the breadth and depth expected and is examinable in the Course assessment. Some bullet points indicate possible contexts and activities which could be used to develop these practical skills and techniques. Further details on many of the activities mentioned in the right hand column can be obtained from **National Qualifications Online**, part of the Education Scotland online service. Where such online support exists the  symbol appears in the text.

Skills and techniques	Notes/Possible contexts and activities
<p>Candidates should be familiar with and be able to carry out calculations based on the following skills and techniques, where appropriate.</p>	
<p>(a) Gravimetric analysis/Use of an accurate electronic balance</p>	<p>In gravimetric analysis the mass of an element or compound present in a substance is determined by chemically changing that substance into some other substance of known chemical composition, which can be readily isolated, purified and weighed to constant mass. Candidates should be aware of the techniques of weighing by difference and heating to constant mass. Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Gravimetric determination of water in hydrated barium chloride. ◆ Gravimetric determination of water in hydrated magnesium sulfate. ◆ Determination of Ni using butanedioxime (dimethylglyoxime).
<p>(b) Volumetric analysis/Preparation of a standard solution/Primary standard/Standardising solutions</p>	<p>A solution of accurately known concentration is known as a standard solution. A standard solution can be prepared directly from a primary standard. A primary standard must have, at least, the following characteristics:</p> <ul style="list-style-type: none"> ◆ high state of purity ◆ stability in air and in solution ◆ solubility ◆ reasonably high formula mass <p>Examples of primary standards include</p> <ul style="list-style-type: none"> ◆ sodium carbonate, Na_2CO_3 ◆ oxalic acid, $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ◆ potassium hydrogen phthalate, $\text{KH}(\text{C}_8\text{H}_4\text{O}_4)$ ◆ silver nitrate, AgNO_3 ◆ potassium iodate, KIO_3 ◆ potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$

Skills and techniques	Notes/Possible contexts and activities
(b) (cont)	<p>Candidates should appreciate why certain compounds such as sodium hydroxide are not acceptable as primary standards. Candidates should also be aware that, where practicable, titrations should be repeated until concordant results are obtained.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Prepare a standard solution of 0.1 mol l⁻¹ oxalic acid ◆ Standardisation of approx 0.1 mol l⁻¹ NaOH(aq). ◆ Determination of the ethanoic acid content of vinegar ◆ Preparation of a standard solution of 0.1 mol l⁻¹ sodium carbonate solution ◆ Standardisation of approximately 0.1 mol l⁻¹ HCl(aq) ◆ Determination of the purity of marble by back titration. <p>Animation of titration and titrations with corresponding calculations can be found on the internet </p>
(c) Use of a control/reference/blank analysis	<p>A control determination consists of carrying out a determination on a solution of known concentration to establish the validity of the results.</p> <p>A blank determination consists of carrying out a separate determination without the substance being tested for being present.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Determination of the percentage acetyl salicylic acid in a commercial tablet, using “pure” aspirin as a control ◆ Determination of vitamin C in a fruit juice using pure ascorbic acid as a control
(d) Complexometric titration	<p>Complexometric titrations are based on reactions in which complexes are formed. EDTA is an important complexometric reagent and can be used to determine the concentration of metal ions in solution.</p> <p>A possible experiment includes</p> <ul style="list-style-type: none"> ◆ Determination of the percentage Ni in a nickel salt using EDTA

Skills and techniques	Notes/Possible contexts and activities
(e) Back titration	<p>Back titration is used to find the number of moles of a substance by reacting it with an excess volume of reactant of known concentration. The resulting mixture is then titrated to work out the number of moles of the reactant in excess. From the initial number of moles of that reactant the number of moles used in the reaction can be determined, making it possible to work back to calculate the initial number of moles of the substance under test. A back titration is useful when trying to work out the quantity of substance in an insoluble solid.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Determination of aspirin ◆ Determination of purity of marble by back titration
(f) Colorimetry/ Accurate dilution	<p>Colorimetry uses the relationship between colour intensity of a solution and the concentration of the coloured species present. A calibration curve must be prepared using solutions of known concentrations (standard solutions). The concentration of the 'unknown' solution is determined from its absorbance and by referring to the calibration curve. The calibration graph should cover the dilution range likely to be used in the determination.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Colorimetric determination of manganese in steel ◆ Determination of nickel using colorimetric analysis

Skills and techniques	Notes/Possible contexts and activities
(g) Distillation	<p>Distillation is the process of heating a liquid until it boils, capturing and cooling the resultant hot vapours, and collecting the condensed vapours. In the modern organic chemistry laboratory, distillation is a powerful tool, both for the identification and the purification of organic compounds. The boiling point of a compound—determined by distillation—is well-defined and thus is one of the physical properties of a compound by which it is identified.</p> <p>Distillation is used to purify a compound by separating it from a non-volatile or less-volatile material. When different compounds in a mixture have different boiling points, they separate into individual components when the mixture is carefully distilled.</p> <p>This technique provides opportunities for candidates to become familiar with glassware containing ground glass joints.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of benzoic acid by hydrolysis of ethyl benzoate ◆ Preparation of ethyl ethanoate ◆ Preparation of cyclohexene from cyclohexanol <p>A video showing simple, fractional and steam distillation is available on the internet </p>
(h) Refluxing	<p>Refluxing is a technique used to apply heat energy to a chemical reaction mixture over an extended period of time. The liquid reaction mixture is placed in a round-bottomed flask with a condenser connected at the top. The flask is heated vigorously over the course of the chemical reaction; any vapours given off are immediately returned to the reaction vessel as liquids when they reach the condenser.</p> <p>This technique provides opportunities for candidates to become familiar with glassware containing ground glass joints.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of benzoic acid by hydrolysis of ethyl benzoate ◆ Preparation of ethyl ethanoate <p>Different videos showing heating under reflux are available on the internet. </p>

Skills and techniques	Notes/Possible contexts and activities
(i) Vacuum filtration	<p>Using a Buchner, Hirsch or sintered glass funnel. These methods are carried out under reduced pressure and provide a faster means of separating the precipitate from the filtrate. The choice of filtering medium depends on the quantity and nature of the precipitate.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of potassium trioxalatoferrate(III) ◆ Preparation of aspirin ◆ Preparation of benzoic acid by hydrolysis of ethyl benzoate ◆ Identification by derivative formation. <p>A video on vacuum filtration showing use of a Buchner funnel and a Hirsch funnel is available on the internet. </p>
(j) Experimental determination of percentage yield	<p>Percentage yields can be calculated from the number of moles of limiting reagent used and the number of moles of product formed. Mass transfer or mechanical losses and purification of product inevitably lowers the percentage yield.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of aspirin ◆ Preparation of potassium trioxalatoferrate(III) ◆ Preparation of benzoic acid by hydrolysis of ethyl benzoate ◆ Preparation of ethyl ethanoate
(k) Recrystallisation	<p>Recrystallisation is a laboratory technique used to purify solids, based upon solubility. The solvent for recrystallisation must be carefully selected such that the impure compound is insoluble at lower temperatures, yet completely soluble at higher temperatures. The impure compound is dissolved gently in the minimum volume of hot solvent then filtered to remove insoluble impurities. The filtrate is allowed to cool slowly to force crystallisation. The more soluble impurities are left behind in the solvent.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of benzoic acid by hydrolysis of ethyl benzoate ◆ Preparation of potassium trioxalatoferrate(III) ◆ Preparation of acetylsalicylic acid <p>Videos on recrystallisation are available on the internet. </p>

Skills and techniques	Notes/Possible contexts and activities
(l) Use of thin-layer chromatography to assess product purity	<p>Instead of chromatography paper, thin-layer chromatography (TLC) uses a fine film of silica or aluminium oxide spread over glass or plastic. Separation is usually faster and better than with paper chromatography. R_f values can be calculated and under similar conditions a compound will always have the same R_f value within experimental error.</p> <p>Since a pure substance will show up as only one spot on the developed chromatogram, TLC can be used to assess the purity of a product prepared in the lab.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of Aspirin ◆ Hydrolysis of ethyl benzoate. <p>Videos of thin-layer chromatography are available on the internet. </p>
(m) Determination of melting point and mixed melting point	<p>The melting point of an organic compound is one of several physical properties by which it can be identified. A crystalline substance has a sharp melting point falling within a very small temperature range. Determination of the melting point can also give an indication of the purity of an organic compound, as the presence of impurities lowers the melting point and extends its melting temperature range.</p> <p>Since impurities lower the melting point, the technique of mixed melting point determination can be used as a means of identifying the product of a reaction</p> <p>Possible experiments include:</p> <ul style="list-style-type: none"> ◆ Preparation of benzoic acid by hydrolysis of ethyl benzoate ◆ Identification by derivative formation ◆ Preparation of aspirin <p>Videos on melting point determination are available on the internet. </p>

Skills and techniques	Notes/Possible contexts and activities
(n) Solvent extraction/ Use of a separating funnel	<p>Solvent extraction is an application of the partition of a solute between two liquids. It is based on the relative solubility of a compound in two different immiscible liquids, usually water and an organic solvent. The two solvents form two separate layers in the separating funnel and the lower layer is run off into one container and the upper layer is poured out into another container. The quantity of solute extracted depends on the partition coefficient and on the number of times that the process is repeated. Selection of suitable solvents can be discussed. For example, supercritical CO₂ is used in the preparation of decaffeinated coffee.</p> <p>Possible experiments include:</p> <ul style="list-style-type: none">◆ Preparation of ethyl ethanoate◆ Extraction of caffeine from tea <p>Videos on solvent extraction are available on the internet. </p>
(o) Carrying out stoichiometric calculations	<p>Stoichiometry is the study of quantitative relationships involved in chemical reactions. The ability to balance and interpret equations enabling calculations to be carried out involving any of the above skills/techniques is an important part of chemistry at this level and is examinable in the Course assessment.</p>

Matrix showing possible experiments covering all the skills/techniques.

Advanced Higher Chemistry						Skills/techniques to be covered in the Researching Chemistry Unit								
(a) Use of a Balance	(b) Standardisation	(c) Control/ Reference	(d) Complexometric titration	(e) Back titration	(f) Colorimetry/ serial dilution	(g) Distillation	(h) Refluxing	(i) Vacuum filtration	(j) Recrystallisation	(k) % yield	(l) TLC	(m) Melting point determination	(n) Separating funnel	(o) Stoichiometric Calculations
1	1			1										1
2	2													2
3			3											3
4														4
5								5	5	5				5
6	6	6												6
7		7		7				7	7	7	7	7		7
8						8	8	8	8	8	8	8		8
9						9	9			9			9	9
10		10			10									10
11						11				11			11	11

Possible experiments to cover these skills

Experiment 1

- ◆ Prepare a standard solution of 0.1 mol l⁻¹ oxalic acid
- ◆ Standardisation of approx 0.1 mol l⁻¹ NaOH(aq)
- ◆ Determination of the ethanoic acid content of vinegar

Experiment 2

- ◆ Preparation of a standard solution of 0.1 mol l⁻¹ sodium carbonate solution
- ◆ Standardisation of approximately 0.1 mol l⁻¹ HCl(aq)
- ◆ Determination of purity of marble by back titration

Experiment 3

- ◆ Determination of Ni²⁺ in a nickel(II) salt

Experiment 4

- ◆ Determination of water in hydrated barium chloride
- ◆ Gravimetric determination of nickel using butanedioxime

Experiment 5

- ◆ Preparation of trioxalatoferrate(III)

Experiment 6

- ◆ Determination of vitamin C in a tablet

Experiment 7

- ◆ Preparation of aspirin (acetyl salicylic acid)
- ◆ Determination of acetyl salicylic acid in a commercial tablet, using prepared aspirin as a control

Experiment 8

- ◆ Hydrolysis of ethyl benzoate

Experiment 9

- ◆ Preparation of ethyl ethanoate

Experiment 10

- ◆ Colorimetric determination of manganese in steel

Experiment 11

- ◆ Preparation of cyclohexene from cyclohexanol

Candidates should be exposed to these skills/techniques by carrying out a variety of experiments such as those suggested above. For example, doing experiments 1, 3 and 10 followed by 8 and 11 would cover all the skills/techniques. However the list above is neither prescriptive nor exhaustive.

Candidates may also carry out experiments based on these skills/techniques as part of their Chemical Investigation. There will be no formal internal assessment of these skills but candidates should be given opportunities to become secure in each skill. Questions in the examination paper relating to these techniques, including calculations, will be the means of external assessment.