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

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** **The RSC online resource *Practical Chemistry for Schools and Colleges* is very useful here 💻**
Candidates should be familiar with and be able to carry out calculations based on the following skills and techniques, where appropriate.	
(a) Gravimetric analysis/Use of an accurate electronic balance	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: ♦ Gravimetric determination of water in hydrated barium chloride. ♦ Gravimetric determination of water in hydrated magnesium sulfate. ♦ Determination of Ni using butanedioxime (dimethylglyoxime).
(b) Volumetric analysis/Preparation of a standard solution/Primary standard/ Standardising solutions	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: ♦ high state of purity ♦ stability in air and in solution ♦ solubility ♦ reasonably high formula mass Examples of primary standards include ♦ sodium carbonate, Na_2CO_3 ♦ oxalic acid, $H_2C_2O_4.2H_2O$ ♦ potassium hydrogen phthalate, $KH(C_8H_4O_4)$ ♦ silver nitrate, $AgNO_3$ ♦ potassium iodate, KIO_3 ♦ potassium dichromate, $K_2Cr_2O_7$

Skills and techniques	Notes/Possible contexts and activities
(b) (cont)	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. Possible experiments include: ♦ 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. Animation of titration and titrations with corresponding calculations can be found on the internet 💻
(c) Use of a control/reference/ blank analysis	A control determination consists of carrying out a determination on a solution of known concentration to establish the validity of the results. A blank determination consists of carrying out a separate determination without the substance being tested for being present. Possible experiments include: ♦ 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	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. A possible experiment includes ♦ Determination of the percentage Ni in a nickel salt using EDTA

Skills and techniques	Notes/Possible contexts and activities
(e) Back titration	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. Possible experiments include: ♦ Determination of aspirin ♦ Determination of purity of marble by back titration
(f) Colorimetry/ Accurate dilution	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. Possible experiments include: ♦ Colorimetric determination of manganese in steel ♦ Determination of nickel using colorimetric analysis

Skills and techniques	Notes/Possible contexts and activities
(g) Distillation	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. 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. This technique provides opportunities for candidates to become familiar with glassware containing ground glass joints. Possible experiments include: ♦ Preparation of benzoic acid by hydrolysis of ethyl benzoate ♦ Preparation of ethyl ethanoate ♦ Preparation of cyclohexene from cyclohexanol A video showing simple, fractional and steam distillation is available on the internet 💻
(h) Refluxing	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. This technique provides opportunities for candidates to become familiar with glassware containing ground glass joints. Possible experiments include: ♦ Preparation of benzoic acid by hydrolysis of ethyl benzoate ♦ Preparation of ethyl ethanoate Different videos showing heating under reflux are available on the internet. 💻

Skills and techniques	Notes/Possible contexts and activities
(i) Vacuum filtration	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. Possible experiments include: ♦ Preparation of potassium trioxolatoferrate(III) ♦ Preparation of aspirin ♦ Preparation of benzoic acid by hydrolysis of ethyl benzoate ♦ Identification by derivative formation. A video on vacuum filtration showing use of a Buchner funnel and a Hirsch funnel is available on the internet. 💻
(j) Experimental determination of percentage yield	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. Possible experiments include: ♦ Preparation of aspirin ♦ Preparation of potassium trioxolatoferrate(III) ♦ Preparation of benzoic acid by hydrolysis of ethyl benzoate ♦ Preparation of ethyl ethanoate
(k) Recrystallisation	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. Possible experiments include: ♦ Preparation of benzoic acid by hydrolysis of ethyl benzoate ♦ Preparation of potassium trioxalatoferrate(III) ♦ Preparation of acetylsalicylic acid Videos on recrystallisation are available on the internet. 💻

Skills and techniques	Notes/Possible contexts and activities
(l) Use of thin-layer chromatography to assess product purity	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. 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. Possible experiments include: ♦ Preparation of Aspirin ♦ Hydrolysis of ethyl benzoate. Videos of thin-layer chromatography are available on the internet. 💻
(m) Determination of melting point and mixed melting point	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. 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 Possible experiments include: ♦ Preparation of benzoic acid by hydrolysis of ethyl benzoate ♦ Identification by derivative formation ♦ Preparation of aspirin Videos on melting point determination are available on the internet. 💻

Skills and techniques	Notes/Possible contexts and activities
(n) Solvent extraction/ Use of a separating funnel	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 CO_2 is used in the preparation of decaffeinated coffee. Possible experiments include: ♦ Preparation of ethyl ethanoate ♦ Extraction of caffeine from tea Videos on solvent extraction are available on the internet. 💻
(o) Carrying out stoichiometric calculations	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.

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 Ni^{2+} 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.