National Unit specification: general information

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

Unit code: FT91 12

Superclass: RC

Publication date: August 2011

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit has been designed to provide candidates with a basic knowledge and understanding of nanotechnology and nanomaterials. The Unit will introduce candidates to the nanoscale and to the unique properties nanomaterials possess by virtue of their size. Candidates will investigate diverse types of nanomaterials such as carbon allotropes, quantum dots, quantum tunnelling composites and colloids. They will investigate the properties of these compounds and be able to explain these properties in terms of the structure of the material. They will also be able to describe uses of nanomaterials in medicine, energy sustainability and in the home.

This Unit has also been designed to provide candidates with a general knowledge of how nanomaterials are characterised and manufactured. In addition candidates will be able to identify the technical and environmental challenges posed by the use of nanomaterials. Candidates will also undertake practical work during the Unit.

The Unit is suitable for candidates who wish to obtain a basic knowledge of nanomaterials and nanotechnology. The Unit is freestanding but may be used as an optional Unit within the National Certificate in Applied Science (SCQF level 6).

Outcomes

1 Investigate nanomaterials, their uses and properties in every day and natural objects.
2 Describe the structure of nanomaterials and relate this to their properties.
3 Identify the uses and benefits of nanomaterials and relate these to their structure.
4 Describe methods of imaging, characterisation and manufacture of nanomaterials.
5 Perform an experiment involving nanomaterials and investigate their properties.

National Unit specification: general information (cont)

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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:

- Intermediate 2 in a Science subject
- National Level 5 in a Science subject

Credit points and level

1 National Unit credit at SCQF level 6: (6 SCQF credit points at SCQF level 6*)

**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

Opportunities to develop aspects of Core Skills are highlighted in the support notes of this Unit specification.

There is no automatic certification of Core Skills or Core Skill component in this Unit.

National Unit specification: statement of standards

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

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

Investigate nanomaterials, their uses and properties in every day and natural objects.

Performance Criteria

(a) Describe the nanoscale and relate this to the size of other objects.
(b) Identify the occurrence of nanoparticles in two everyday objects and one found in the natural world and describe how these particles enhance the properties of the object.
(c) Explain the way in which two properties of nanomaterials are related to their dimensions.

Outcome 2

Describe the structure of nanomaterials and relate this to their properties.

Performance Criteria

(a) Describe the structure of the following four types of nanomaterials; carbon allotropes, quantum dots, quantum tunnelling materials and colloids.
(b) Relate the properties of these nanomaterials to their structure.

Outcome 3

Identify the uses and benefits of nanomaterials and relate these to their structure.

Performance Criteria

(a) Identify two applications of nanotechnology and explain their uses in the diagnosis and treatment of disease.
(b) Identify one application of nanotechnology and explain its use in methods of sustainable energy production and storage.
(c) Identify one application of nanotechnology in a domestic or consumer product and explain the benefits of the technology.
(d) Identify potential benefits and risks associated with the use of a particular nanomaterial in a given application.

National Unit specification: statement of standards (cont)

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

Outcome 4

Describe methods of imaging, characterisation and manufacture of nanomaterials.

Performance Criteria

(a) Describe two methods of imaging and characterisation of nanomaterials.
(b) Describe one top down method of manufacture.
(c) Describe one bottom up method of manufacture.

Outcome 5

Perform an experiment involving nanomaterials and investigate their properties.

Performance Criteria

(a) Perform an experiment involving a nanomaterial in a safe manner.
(b) Investigate two properties of the nanomaterial selected and relate the properties to the material structure.
(c) Report on the results obtained clearly and concisely.

Evidence Requirements for this Unit

Evidence is required to demonstrate the candidates have achieved all Outcomes and Performance Criteria.

Written and/or recorded oral evidence should be produced to demonstrate that the candidate has achieved all the Outcomes and Performance Criteria. Candidates must produce written and or oral evidence on their own, in their own words, at appropriate points throughout the Unit. As most of the work of this Unit is project based and the candidate must carry out research for the Outcomes the evidence will be built up as the Unit progresses and a folio will be produced. This folio will be used as the evidence and no closed-book assessments will be required.

The Assessment Support Pack for this Unit provides sample assessment material. Centres wishing to develop their own assessments should refer to the Assessment Support Pack to ensure a comparable standard.

Outcomes 1–4 may be assessed on an individual basis or as a combination of outcomes, eg Outcomes 2 and 3 assessed together and Outcome 5 could run in parallel with the other Outcomes.

Alternatively, it may also be possible to use a holistic project based on individual study of a small number of specific applications reported in a way that can be used to incorporate all the PCs in the Unit.

National Unit specification: statement of standards (cont)

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

For gathering evidence for the individual Outcomes the guidelines below should be followed.

Outcome 1

Evidence for Outcome 1 will be gathered in open-book conditions at an appropriate point in the Unit.

(a) Candidates must accurately describe, with the aid of a diagram, the nanoscale and compare this to other metric units. They should also compare the size of nanoparticles to other objects such as atoms, DNA molecules, red blood cells and human hair, etc.
(b) Candidates must identify two everyday objects which contain nanoparticles and correctly describe how these particles enhance the properties of the object. They must also give one example of the occurrence of nanoparticles found in nature again describing the effect of the nanoparticles.
(c) Candidates must explain clearly the way in which two properties of nanomaterials are related to their dimensions.

Outcome 2

Evidence for Outcome 2 will be gathered in open-book conditions at an appropriate point in the Unit.

Candidates must accurately describe, with the aid of a diagram and explanation, the structure of each of the following four types of nanomaterials — carbon allotropes, quantum dots, quantum tunnelling composites and colloids and relate the properties of the material to the structure.

For carbon allotropes: the properties of four allotropes of carbon (four from graphite, diamond, graphene, buckminsterfullerene and carbon nanotubes (CNT)) can be investigated either by actual practical experiment or by a literature or web search or a combination of both. Properties to be investigated must include physical properties such as m.p and bp.s, density, electrical conductivity, crystal structure and chemical properties such as tests for double bonds, namely bromination and the permanganate test. Candidates must give a reasoned explanation of the difference in properties of the different allotropes. Evidence for this can be demonstrated in the form of a table listing the properties and structure of the allotropes.

For quantum dots candidates must:

- identify and describe the properties of quantum dots as a special class of semiconductor
- identify and explain how their properties can alter with particle size
- describe the composition of quantum dots and problems with the use of cadmium

For quantum tunnelling composites candidates must correctly describe the structure of a quantum tunnelling composite and explain the property that makes it useful as a pressure sensing device.

For colloidal suspensions candidates must investigate and correctly describe the nature of colloids and explain two properties.

National Unit specification: statement of standards (cont)

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

Outcome 3

Evidence for Outcome 3 will be gathered in open-book conditions at an appropriate point in the Unit.

(a) Candidates must correctly identify two uses of nanotechnology in the diagnosis and treatment of disease and explain with the aid of a diagram the role of the nanomaterial used in the process.
(b) Candidates must correctly identify and correctly describe one application of nanotechnology used in methods of sustainable energy production or storage and explain with the aid of a diagram the role of the nanomaterial used in the process.
(c) Candidates must correctly identify one application of nanotechnology in a domestic or consumer product and explain with the aid of a diagram how the structure of the nanomaterial benefits the product.
(d) Candidates should select a particular nanomaterial used for a specific purpose and identify the potential benefits and risks this material has over conventional materials. The candidate should submit a report of approximately 500 words or give an oral presentation on the research. The report/presentation will be assessed using a checklist to ensure all specified areas are covered to the expected standard.

Outcome 4

Evidence for Outcome 4 will be gathered in open-book conditions at an appropriate point in the Unit.

(a) Candidates must correctly describe, with the aid of a diagram and explanation, two methods of imaging and characterising nanomaterials.
(b) Candidates must describe clearly, with the aid of a diagram and explanation, one top down method of manufacture.
(c) Candidates must describe clearly, with the aid of a diagram and explanation, one bottom up method of manufacture.

Outcome 5

Candidates must perform an experiment involving a nanomaterial and investigate two properties of the material. Throughout the practical activity candidates must comply with the relevant health and safety requirements, including the safe disposal of chemicals, as appropriate. An assessor observation checklist must be used to provide evidence of candidate performance. The laboratory report produced must meet the required standards as shown on the checklist and include an explanation of the properties observed relating to the structure of the material.

National Unit specification: support notes

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

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

This Unit is part of an exemplar course — Access to STEM — produced by STEM-ED Scotland as part of a SFC funded project titled *Building a New Educational Framework to Address the STEM Skills Gap*. This course has been designed specifically to engage interest, strengthen skills, deepen understanding of the main storylines of the sciences and to take an integrative approach to the sciences. Initially only two Units are being trialled in the SQA catalogue but it is hoped that the other Units will follow.

Outcome 1

The nanoscale should be compared to the atomic, micro and metric scales including length, area and volume. Mention should be made of natural materials such as red blood cells, DNA, bacteria and viruses.

Examples of everyday products that can be investigated include sunscreen, skin products, materials that resist staining, tennis rackets, electronic goods, catalysts in cars, etc. There are many examples of nanomaterials in nature such as in the wings of a butterfly and the feet of a gecko.

The properties of nanoparticles are different from the properties of the bulk material for two main reasons, namely the much larger surface area makes them much more reactive and also there is the 'small size' effect which may give them different physical properties such as the way they react to external radiation.

Outcome 2

If possible some practical investigative work should be carried out in this Outcome. Some centres may wish to combine Outcomes 2 and 3 to deal with uses at the same time as properties are being investigated, in which case, the centre should ensure that all the Performance Criteria are covered in the two Outcomes. Content covered will depend on the examples chosen but possible content is listed below.

Carbon allotropes: graphite, graphene, buckminsterfullerene ($C_{(60)}$) carbon nanotubes and diamond; four of the five allotropes should be investigated A table could be drawn up listing the properties of the allotropes. Examples of properties are: colour, density, hardness, melting and boiling points, electrical conductivity, crystal shape and or structure and hybridisation. Models of the allotropes can be made by the candidates or shown to them. The chemical reactivity of $C_{(60)}$ can be compared with an aromatic compound and a typical alkene by bromination and the permanganate test for alkenes. A 'simulated' sample of $C_{(60)}$) can be used if none is available. The properties should be explained in relation to the allotropic structure.

Quantum dots: the following points should be covered — quantum dots as a special type of semiconductor, typical size range 2–10nm, band gap, excitons and the Exciton Bohr radius, light emitting properties and size dependence, band gap energy inversely proportional to particle size squared, can be made into films when bonded with appropriate molecules.

Quantum tunnelling composites: Structure of the composite a metal filler and elastomer binder, the ability to act as an insulator and, when pressure is applied, as a conductor. Use as pressure devices in medical instruments and security devices. An experiment can be carried out using QTC material, which can be purchased quite cheaply, investigating the way the conductivity, alters with applied pressure and looking at the accuracy and variability of results.

Colloidal suspensions: there are a wide range of metal nanomaterials and a few can be selected for study. Ferrofluids may be chosen as an example and a ferrofluid prepared, its magnetic and light scattering properties can be investigated and its uses in electronic devices and media applications can be discussed. Gold nanoparticles can also be produced in the laboratory and properties investigated, as well as its use in the diagnosis and treatment of cancer. Other nanoparticles such as silver and its use as a bacteriocide or other metals used for their catalytic activity can also be discussed.

Outcome 3

There are a huge number of applications and potential applications in the three areas below and the lecturer and or candidates are free to cover any application they choose in the given areas. Potential examples can be chosen from the list below but there are many other examples.

Uses of nanotechnology to the diagnosis and treatment of disease:

Diagnosis — biosensors including the artificial nose, microarrays, Lab-on-a -chip
Imaging: diagnostic imaging and in-situ devices
Treatment — drug development and targeted drug delivery, nanodrug carriers, externally activated therapies.

Uses of nanotechnology in methods of renewable energy production and storage — solar energy using photovoltaic devices, at present these are very inefficient and expensive. Nanotechnology is being used to improve the efficiency in two ways by developing silicon nanocrystals and by using biomimetic methods such as artificial photosynthesis, quantum dot sensitised solar cells can also be used. Energy storage; development of a material to hold compressed hydrogen, catalysts in fuel cells and in cell membranes, use in rechargeable batteries.

Nanotechnolgy in domestic and consumer products; examples improved catalysts in cars and in industrial processes, coatings on metallic surfaces, use in food industry — coatings to give flavour, colloidal silver as a disinfectant, use in manufacture of electronic goods such as lasers, DVDs, playstations, etc.

Potential benefits and risks:

Candidates should be asked to itemize the advantages and disadvantages of nanotechnology in general and then decide on the risks and benefits of this technology in relation to a particular example. Examples could be the use of nanotechnology in the food industry (doughnuts with no calories), the use of silver nanoparticles as a disinfectant, coatings to increase durability of a surface, use in medical applications, in solar panels and as catalysts in cars. Advantages of nanoparticles are the small amounts needed, their unique properties, increased reactivity and ability to penetrate membranes. Potential disadvantages are toxicity, ability to penetrate membranes and may initiate an immune response. Generally it is not known if the toxicity of a nanomaterial is different from the toxicity of the same material in its more normal form.

Outcome 4

Methods of imaging and characterisation can include two of the following: scanning electron microscope (SEM), the transmission electron microscope (TEM), the scanning tunnelling microscope (STM) and Atomic force microscope (AFM), spectroscopic methods such as X-ray methods and UV-visible absorption and emission. The limitations of visible light microscopy should be mentioned.

Top down method of manufacture — there are numerous methods which are derived from fabrication methods used in the semiconductor industry. The terms lithography, resist and mask should be covered. Types of lithography that can be covered are: conventional lithography, photolithography, scanning lithography, soft lithography and scanning probe lithography.

Bottom up method of manufacture — methods include plasma arcing, chemical vapour deposition and sol-gel synthesis.

Outcome 5

Ideally an experiment to prepare a metallic colloid should be performed. Possible experiments are the preparation of a ferrofluid and an investigation of its magnetic behaviour and its light scattering properties; or the preparation of gold nanoparticles and an investigation of its light absorption and scattering properties and colour changes in chemical reactions. If these experiments are not possible experiments on natural nanoparticles can be investigated or an investigation on super-hydrophobic materials can be conducted. Details of the last three experiments can be obtained from the Nanoyou website at **http://nanoyou.eu/**.

National Unit specification: support notes (cont)

Unit title: Nanotechnology and Nanomaterials (SQCF level 6)

Guidance on learning and teaching approaches for this Unit

The Outcomes may be delivered in the sequence presented in this Unit specification although centres may wish to use a project based approach which will combine all Outcomes. It is recommended that this Unit is delivered using a student centred approach with the candidate being given the opportunity to find information for themselves with appropriate guidance. Lectures may be given to explain the more complex theoretical aspects of the Unit. Practical work will be carried out within the Unit.

The internet contains a rich source of materials on Nanotechnology and Nanomaterials and candidates should be guided in its use.

This Unit should also be fully supported with relevant learning materials such as handouts in paper or electronic form, text books, on-line materials and relevant laboratory instructions.

Guidance on approaches to assessment for this Unit

Candidates will keep a portfolio of their work as they progress through the Outcomes and this should be regularly checked by the tutor to ensure that it is of the required standard. The material should contain evidence for all the Performance Criteria of all the Outcomes. Evidence may take the form of completed worksheets, laboratory reports and written or oral presentations. To aid verification, internal assessors should clearly indicate where, in the candidate evidence, they regard each PC to have been overtaken.

Redrafting of written reports after necessary criticism is to be encouraged both as part of the learning and teaching process and to produce evidence for assessment.

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 e-checklists. 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

There is no automatic certification of Core Skills or Core Skill component in this Unit. However there may be opportunities for the candidate to develop the Core Skills of *Problem Solving, ICT* and the Working Cooperatively with Others component of *Working with Others*.

Problem Solving — in the experimental work the candidate may be expected to plan, organise and complete an experiment, then review and evaluate the results obtained. The 'Critical Thinking' component may be developed in Outcome 3 PC d where the candidate has to identify the factors involved and assess their relevance to the issue and select an appropriate approach.

National Unit specification: support notes (cont)

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ICT — the 'Accessing Information' component of the ICT core skill should be developed as the candidate will be expected to access information from the web. The candidate may also cover Processing Information if software is used to produce reports or presentations.

Working with Others — the candidate may develop the 'Working Co-operatively with Others' component either when performing laboratory experiments as part of a team or when searching co-operatively for information on the internet.

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