Unit 2: Materials science (LEVEL 2)

Learning outcomes

By completing this unit candidates will develop knowledge and understanding of how to identify and test materials to ensure that they have suitable properties to meet the fitness for purpose of a product. They will also be able to perform laboratory activities in order to obtain and manufacture materials and show understanding of how the properties of materials relate to their structures.

Candidates will produce evidence to meet the unit assessment objectives in order to show that they understand:

- the structure of materials and their resulting properties
- that scientific theories and models can predict the development and of usage of materials
- that as scientific knowledge changes, new technologies and materials can be developed
- how materials are obtained and manufactured
- how to test the physical properties and the usability of materials
- the ways in which materials can be used in the production of specific artefacts
- how the production of materials affects the environment and the ethical issues that result.

Assessment objectives	**Knowledge, understanding and skills**
1 Describe the structure and bonding of materials	Explanations of materials can be developed using scientific theories, models and ideas Atomic structure • structure of the atom in terms of protons, neutrons and electrons • relative atomic mass • relative atomic number • formation of ions from atoms, or groups of atoms, in terms of gain or loss of electrons • electronic configuration of elements • construction of the Periodic Table based on groups and periods Structure and bonding • ionic bonding as ions of opposite charge being attracted to each other • covalent bonding as atoms held together by sharing electrons • metallic bonding • a chemical reaction is needed to obtain elements from a compound Elements, compounds and mixtures • elements contain all the same type of atoms • compounds contain two or more elements chemically bonded together • mixtures contain more than one material that are not chemically bonded together • amounts of substances can vary in a mixture • mixtures can be in the form of foams, emulsions, aerosols, gels and composites (continued overleaf)

Assessment objectives	Knowledge, understanding and skills
1 Cont. Describe the structure and bonding of materials	• a physical process is used to separate mixtures – filtration, distillation, evaporation • alloys are mixtures of a metal with other elements • mixtures can be a mixture of several compounds (such as concrete, glass)
2 Describe properties and uses of solid materials	Describe the characteristics of solid materials and match the properties to their uses in the commercial world. Coverage of: • the wide range of specialist uses of manufactured materials (for example in building, transport, furniture and flooring, clothing, sport) • natural fibres (such as wool, silk, cotton) • polymers (such as nylon, polyester, poly(ethene), lycra) • ceramics (such as glass, pottery, china) • metals and alloys (such as aluminium, copper, iron, steel) • composites (such as fibreglass, plywood, laminate flooring) • "smart materials"(such as carbon nanotubes, organic electronic chips)
3 Perform laboratory activities to process and manufacture one material and extract and manufacture one material	Process and manufacture: • process a material (such as wool, silk, cotton, linen, mud); **and** then manufacture a product with the material (such as a textile, paper, cardboard or bricks) Extract and manufacture: • extract a material (such as a metal from an ore, oil fraction from a crude oil, oil from rape seed); **and** then manufacture a material (such as a metallic artefact, bio fuel or soap) Evaluate the success of the activities by considering the quality and yield of the materials
4 Relate laboratory activities for obtaining and manufacturing materials to activities for the commercial production of materials	Report on an organisation that produces **ONE** of the materials/products that was manufactured in AO3. Report should include: • the location of the organisation • job roles within the organisation • the manufacturing process involved • health and safety regulations • approaches to minimise environmental damage
5 Carry out tests to determine whether materials are fit for purpose	Choose and carry out at least **THREE** appropriate tests on materials Tests: • density • hardness • brittleness • stiffness • tensile strength • electrical resistance • thermal conductivity • optical properties (continued overleaf)

Assessment objectives	Knowledge, understanding and skills
5 Cont. Carry out tests to determine whether materials are fit for purpose	• durability • permeability • texture
6 Examine the environmental, ethical and economic issues related to the production of materials	Be aware of the advantages and disadvantages when examining environmental issues in manufacture. For example: • why materials need to be recycled (conservation of finite resources) • how extraction and manufacturing processes are run to be non-polluting and as unobtrusive as possible • the importance of finding uses for side products and waste • the effects on local people (housing, transport, jobs, public health, landscaping) • impact of new materials Be aware that science cannot answer ethical questions Use ICT sources or tools to either gather or present data

Assessment

This unit is centre-assessed and externally moderated.

In order to achieve this unit candidates must produce a portfolio of evidence showing that they can meet all of the assessment objectives.

Portfolios of work must be produced independently. They will need to be made available, together with witness statements and any other supporting documentation, to the OCR Visiting Moderator when required.

Centres must confirm to OCR that the evidence produced by candidates is authentic. An OCR Authentication Form is provided in the Centre Handbook and includes a declaration for assessors and candidates to sign. It is a requirement of the QCA Common Criteria for all Qualifications that proof of authentication is received.

Guidance on assessment and evidence requirements

Tutors should at all times make sure that candidates comply with any safety considerations that have been published by any regulatory body (refer to COSHH regulations, CLEAPPS handbook and CLEAPPS: hazard and student safety sheets). There may also be relevant safety regulations issued by the DfES or local LEAs, as well as by the institution that the course is being carried out in, that need to be considered.

Throughout this unit, candidates need to consider their own safety and that of others. They should be aware of the appropriate parts of the Health and Safety at Work Act and the Control of Substances Harmful to Health (COSHH). They should also be aware of the wider implications of their actions to the environment and to society. Consequently, this unit could be linked with *Unit 1: Best Practice in Science.*

An OCR model assignment is available for this unit. It can be downloaded from our website: www.ocr.org.uk and can also be found in the Model Assignments folder on this CD Rom.

Describe the structure and bonding of materials (AO1)

This assessment objective focuses on the theories, models and ideas that underpin the application of material science. Tutors may prefer to map to it, when delivering and assessing other assessment objectives in the unit, rather than teaching it in 'one block'. The theory could be framed in the context of how the materials that surround us every day behave. This would give more relevance and interest to the theory and could increase the motivation of learners.

Candidates should recognise that there is a huge range of materials, each with specific properties. These properties depend on the atomic structure of the material. Candidates should show that they understand what elements are, and that different elements have different characteristics because of their electronic configurations. Candidates should also be aware that most solid materials are held together in regular arrangements of atoms bonded together. Mixtures are much harder to describe chemically than elements or compounds, but in everyday life they are more common. Concrete is a mixture of compounds (sand, cement and gravel) but it can be mixed in varying amounts and so changes its characteristics.

Candidates should know the symbols of the elements and the formulae of the compounds they use. To demonstrate this knowledge, candidates could cross-reference evidence from other assessment objectives. Alternatively, if this assessment objective is delivered holistically, candidates could produce a summary (for example using spider diagrams, glossary, electronic presentation, poster) giving examples of:

- elements, compounds and mixtures
- ionic, covalent and metallic bonding
- a comparison of general properties of elements, compounds and mixtures.

Describe properties and uses of solid materials (AO2)

Candidates should identify materials with properties that satisfy the design specifications of particular products. This is also an opportunity for candidates to realise that new materials are being developed to meet specific requirements such as:

- "smart materials", which are used in the twisting Stealth Bomber's wing
- nanotechnology such as carbon nanotubes which are 1000 times smaller than the cross-section of a hair.

Candidates should recognise that whilst at present science might not have all the answers, with the use of modelling and simulation, it is likely that new materials will be manufactured in the future.

Using secondary sources, candidates should group materials, giving examples of their properties and uses. They should cover all appropriate knowledge, understanding and skills. This information gathering could be demonstrated in a table.

This assessment objective could be linked to AO1, 2 and 3. Candidates could choose two materials that they plan to process or manufacture in AO3 and in a report explain in-depth their properties, uses, structure and bonding.

Perform laboratory activities to process and manufacture one material and extract and manufacture one material (AO3)

Candidates should understand that naturally occurring materials, such as metals, rocks and minerals, could be made into products that are more useful, by physical or chemical change. They should also recognise that some manufacturing processes are based on reversible reactions and

that the conditions of these reactions affect the yield of the product. Pass level students should make a qualitative statement on the success of their process in producing a yield. Higher level candidates are expected to comment on how the yield of a material could be improved. So that candidates have an appreciation of the need for industrial chemists to understand the efficiency of their processes, this would also involve calculating the percentage yield from the amounts of reactants used. To do this, candidates would need to:

- write balanced chemical equations to describe reactions
- calculate the theoretical yield to be obtained from specified amount of reactant
- calculate the percentage yield from the actual yield produced and the theoretical yield.

However, the main focus of the unit is the practical activities. The information gathering exercises are designed to put the practical activities into context.

Candidates will be required to obtain two materials. This is done by:

- processing a natural material (such as wool, silk, cotton, linen, wood or clay)
- extracting a material (such as a metal from a ore, oil fraction from crude oil or oil from rape seed).

Then candidates will be required to manufacture two products:

- a physical product (such a textile, paper, cardboard or bricks)
- a complex material (such as a metallic artefact, bio fuel or soap).

It is recognised that the amount and quality of the material processed or extracted by the candidate may not be sufficient to manufacture a product from it. To meet the requirements of the assessment objective, it would be sufficient to supply similar materials, to those produced in the first part of the assessment objective, to the candidate to use in the manufacturing part of the assessment objective.

Evidence could be the laboratory notes of the candidate.

Relate laboratory activities for obtaining and manufacturing materials to activities for the commercial production of materials (AO4)

Candidates should compare their activities in the laboratory to commercial processes. This is an opportunity to research the history and development of products, showing the economic and regulatory constraints that scientists work under.

To demonstrate the vocational linkage, candidates could write a report or presentation on an organisation that produces one of their products.

Information on organisations can be gathered from the Engineering Council, the Education Liaison Unit of the Institute of Chemical Engineers and the Institute of Materials. Information on these organisations can be found in: Partners in Science Education. CRAC also publishes a Casebook for Schools – *Science and Technology in the Environment* - in which science organisations outline how they have overcome practical difficulties. The Times 100 case studies with Business News cover the operation of many different companies and organisations.

Carry out tests to determine whether materials are fit for purpose (AO5)

Having manufactured their two products, candidates need to carry out at least three appropriate tests and record the physical properties and usability of the materials they have made.

Alternatively, candidates can be provided with materials of a similar type. The usability of the material will depend on the artefact that the materials are intended for and it may be more appropriate to test the product rather than the material. Candidates should select the tests that are appropriate, and that reflect the main function of the product or material, from the tests listed under knowledge understanding and skills. When choosing a material for its function, candidates need to ask themselves 'what does the product, that the material is going to be used in, do?' Does the material need to be waterproof, rigid and light to make a small rowing boat or does it have to be transparent, rigid and take compressive strains such as a glass window?

It is recognised that some tests will produce a qualitative rather than a quantitative result. In order to achieve the higher grades, candidates have to obtain quantitative results.

The evidence could be presented as a report, for a specified end user, explaining the choice of materials used in the product and their fitness for purpose in the specified artefact.

Examine the environmental, ethical and economic issues related to the production of materials (AO6)

Finally, candidates should examine the environmental and ethical issues that arise in the production of materials. They should be aware that there are both advantages and disadvantages when considering these issues. Candidates should have the opportunity to debate the development of new materials. As materials are developed and used, the economic and environmental side effects may not be fully understood or even questioned. A pertinent example in recent history is the use of asbestos in buildings. In the future, the use of nanotechnology and smart materials may also result in side effects that we are not yet aware of. However, whilst science can help us uncover facts it cannot directly answer ethical questions.

Candidates **must** use ICT sources or tools to either gather or present their data.

Evidence could be a written report or an electronic presentation on the environmental, ethical and economic issues related to the production of materials. Candidates should comment on the issues outlined in knowledge, understanding and skills.

Signposting to Key Skills

✓ The unit contains opportunities for developing the Key Skill, and possibly for generating portfolio evidence, if teaching and learning is focused on that aim. Assessing staff will need to check each candidate's evidence against the specifications to ensure all evidence requirements have been met. Additional evidence may also be required.

Key Skill reference		**Key Skill reference**		**Key Skill reference**	
C2.1		N2.1	✓	ICT2.1	✓
C2.2a	✓	N2.2a	✓	ICT2.2	✓
C2.2b	✓	N2.2b	✓	ICT2.3	✓
C2.3	✓	N2.2c	✓		
		N2.2d			
		N2.3	✓		

Mapping to National Occupational Standards

Occupational Standards	Unit number	Title
LATA	1.01	Complying with Statutory regulations and Safety requirements
LATA	1.04	Take laboratory measurements
LATA	1.05	Perform basic laboratory activities
LATA	2.03	Carry out simple testing operations
LATA	2.04	Carry out simple sampling operations
LATA	2.05	Prepare laboratory materials, equipment and resources
LATA	2.06	Calibrate equipment

Resources

The following are suggestions of resources that could be useful when delivering the unit. They are neither prescriptive nor exhaustive, and candidates should be encouraged to gather information from a variety of sources.

Books

DfES (1996)	*Safety in science education* The Stationery Office Books
CLEAPSS Laboratory Handbook (updated 2005)	See URL:http://www.cleapss.org.uk/ for details
CLEAPSS Hazcards (updated 2005)	See URL:http://www.cleapss.org.uk/ for details
Association for Science Education (1996)	*Safeguards in the school laboratory* ASE
Hubbard, L. & Mapletoft, M. (editors) (1993)	*Partners in science education* Chemical Industry Education Centre

Journals/Magazines/Newspapers

Business case studies are collated in The Times 100 Casestudies with Business News published on behalf of Times Newspapers by MBA Publishing Limited

Websites

Royal Society of Chemistry. URL:http://www.rsc.org/
The RSC is the largest organisation in Europe for advancing the chemical sciences and activities span education, conferences, science policy and the promotion of chemistry to the public.

CRAC Career development for life. URL:http://www.crac.org.uk/
The Careers Research and Advisory Centre aims to advance the education of the public, and young persons in particular, in lifelong career-related learning.

Corus Education Service. URL:http://www.corusgroup.com/en/responsibility/education/
Corus provides a range of activities, including providing advice and resources for teaching.

Steel Matter. URL:http://www.matter.org.uk/steelmatter/
Develops interactive educational software resources to help students understand the key concepts and relationships in ferrous metallurgy.

Schoolscience. URL:http://www.schoolscience.co.uk/content/index.asp
Free online resources showing the applications of science learnt in schools.

Chemical industry education centre. URL:http://www.ciec.org.uk/
Publications, training and information service.

Trotman Publishing. URL:http://www.trotman.co.uk/default.asp?action=article&ID=103
Careers portal provides details on careers and higher education information on the web.

Grading

Assessment Objective	Pass	Merit	Distinction
AO1 Describe the structure and bonding of materials	Candidates describe in **basic terms** the atomic structure and bonding of elements, compounds and mixtures. They present their evidence in a format which is **brief**.	Candidates describe in **detail** the atomic structure and bonding of elements, compounds and mixtures. Their evidence is **clearly structured**.	Candidates describe in **great detail** the atomic structure and bonding of elements, compounds and mixtures. Their evidence is **very well structured**.
AO2 Describe properties and uses of solid materials	Candidates describe in **basic terms** the properties and uses of solid materials. They **link in places** the materials' properties to their commercial applications.	Candidates describe in **detail** the properties and uses of solid materials. They **link** the materials' properties to their commercial applications.	Candidates describe in **great detail** the properties, and uses of solid materials. They **thoroughly link** the materials' properties to their structure and commercial applications.
AO3 Perform laboratory activities to process and manufacture one material and extract and manufacture one material	Candidates demonstrate a **basic competence** in processing/extracting two materials and in manufacturing two materials. They **comment** on the yield and quality of their output. Candidates **use qualitative data** or the most obvious and easily obtainable **quantitative data** to back up their findings. They also comment in **basic** terms on the validity and reliability of the collected data.	Candidates **demonstrate competence** in processing/extracting two materials and in manufacturing two materials. They **comment in detail** on the yield and quality of their output and use **quantitative data**, which is **generally accurate**, to back up their findings. They also comment in **detail** on the validity and reliability of the collected data.	Candidates **demonstrate a high level of competence** in processing/extracting two materials and in manufacturing two materials. They **comment in great detail** on the yield and quality of their output using accurate quantitative data to back up their findings. They also comment in **great detail** on the validity and reliability of the collected data. Their evidence is **very well structured**.
AO4 Relate laboratory activities for obtaining and manufacturing materials to activities for the commercial production of materials	Candidates make a **basic comparison** between laboratory and commercial manufacturing activities. In their report, they provide a **narrow range** of information on the commercial organisation. They present their evidence in a format which is **brief**.	Candidates make a **detailed comparison** between laboratory and commercial manufacturing activities. In their report, they provide a **wide range** of information on the commercial organisation. Their evidence is **clearly structured**.	Candidates make a **highly detailed comparison** between laboratory and commercial manufacturing activities. In their report, they provide a **full range** of information on the commercial organisation. Their evidence is **very well structured**.

Assessment Objective	Pass	Merit	Distinction
AO5 Carry out tests to determine whether materials are fit for purpose	Candidates provide a **basic** description of the proposed function of their two materials. They carry out three tests on their materials, demonstrating a **basic level of competence** and **link in places** the chosen tests to the proposed function of the materials.	Candidates provide a **good description** of the proposed function of their two materials. They carry out three tests on their materials, demonstrating **competence**, and **link** the chosen tests to the proposed function of the materials.	Candidates provide a **full description** of the proposed function of their two materials. They carry out three tests on their materials, demonstrating competence, and they **comprehensively link** the chosen tests to the proposed function of the materials.
AO6 Examine the environmental, ethical and economic issues related to the production of materials	Candidates **briefly describe** some of the ethical issues and environmental issues related to material production and they make **basic** ethical judgements. Candidates **use** ICT sources or tools to either gather or present their data.	Candidates **describe in detail** a wide range of the ethical and environmental issues related to material production and they make **sound** ethical judgements. Candidates **use** ICT sources or tools to either gather or present their data.	Candidates **describe in great detail** many of the ethical and environmental issues related to material production and they **make ethical judgements that are fully reasoned.** Candidates **use** ICT sources or tools to either gather or present their data. Their evidence is **well structured**.