Unit 4: Laboratory Techniques and their Application

Level: 3
Unit type: Internal
Guided learning hours: 90

Unit in brief

This unit covers the importance of health and safety in work place laboratories, how data is stored and communicated and how organic liquids and solids are made and tested industrially.

Unit introduction

In this unit, you will investigate a scientific organisation to gain an understanding of how it operates. You will investigate health and safety practices in the organisation’s laboratories and consider related primary and secondary legislation. You will also have the opportunity to compare the approach taken to hazards and risk management in different part of the organisation, for example production, the warehouse, the office. It is important to realise that, whether you progress to employment in the science industry or to higher education in science, you will have to be aware of the relevant hazards and to follow the practices that have been developed for your safety.

You will gain a valuable insight into the operation of the pharmaceutical and bulk chemistry industries by making and testing two organic compounds – a liquid and a solid – exploring how industrial production differs from the process that you carry out in the laboratory. You will also investigate the different methods for testing the purity of the products.

Management of data/information is becoming increasingly sophisticated. You will investigate how data/information within the organisation is stored, used and communicated. You will learn about the procedures used for recording laboratory information that ensure it is sufficiently detailed, accessible and traceable. Large amounts of data are available for others to use for research purposes, for example by organisations interested in DNA sequencing or in healthcare. You will explore how these data may be used and consider the benefits and issues associated with accessing and with making large quantities of data available for research.

Not only will this unit give you some understanding of the workplace environment you may enter after finishing this course or after completing a scientific higher education programme, it will also allow you to develop an appreciation of how laboratory preparation and testing of compounds may be scaled up by industry, and of how data is managed within the organisation.

Learning aims

In this unit you will:

A Understand the importance of health and safety in scientific organisations
B Explore manufacturing techniques and testing methods for an organic liquid
C Explore manufacturing techniques and testing methods for an organic solid
D Understand how scientific information may be stored and communicated in a workplace laboratory.
**Summary of unit**

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<tr>
<th>Learning aim</th>
<th>Key content areas</th>
<th>Recommended assessment approach</th>
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| **A** Understand the importance of health and safety in scientific organisations | A1 Application of health and safety legislation in scientific organisations  
A2 Hazards in scientific organisations | A report describing health and safety legislation relevant to an organisation, describing the hazards and discussing aspects of health and safety management. |
| **B** Explore manufacturing techniques and testing methods for an organic liquid | B1 Manufacturing techniques  
B2 Testing methods and techniques | A report containing:  
• notes and results from making and testing an organic liquid  
• a description of the principles behind the preparative methods and tests used  
• analysis of ways to improve yield and purity and the reliability of testing methods as a guide to purity  
• an explanation of the principles behind the industrial manufacture and testing of the liquid  
• an observation report by the teacher of making and testing the liquid safely. |
| **C** Explore manufacturing techniques and testing methods for an organic solid | C1 Manufacturing techniques  
C2 Industrial manufacturing techniques  
C3 Estimation of purity | A report containing:  
• notes and results from making and testing an organic solid  
• a description of the principles of preparative methods and tests used  
• analysis of ways to improve yield and purity and of the reliability of testing methods as a guide to purity  
• an explanation of the principles behind the industrial manufacture and solid  
• an observation report by teacher of making and testing the solid safely. |
| **D** Understand how scientific information may be stored and communicated in a workplace laboratory | D1 Systems for managing laboratory information  
D2 Communicating information in a scientific organisation  
D3 Use of informatics for storage and retrieval of scientific information | A report containing:  
• a description of the information stored and used in the laboratory  
• a description of how useful information can be obtained from large data sets  
• analysis of the communication channels in the organisation  
• evaluation of the benefits and issues involved in making large volumes of data available to others. |
Content

Learning aim A: Understand the importance of health and safety in scientific organisations

A1 Application of health and safety legislation in scientific organisations
- Health and safety at work legislation, including:
  - management of health and safety
  - personal protective equipment (PPE)
  - use and control of hazardous substances
  - manual handling operations
  - display screen, classification, labelling and packaging regulations
  - reporting of injuries, diseases and dangerous occurrences.
- Health and safety policy or health, safety and environmental policy – scrutiny of examples from the workplace.
- Consequences of not complying with health and safety legislation.

A2 Hazards in a scientific organisation
- Control of Major Accident Hazards (COMAH) sites.
- Explosive atmospheres.
- Electrical hazards.
- Working at height.
- Lone working.
- Vehicles.
- Sensitisers.
- Noise.
- Working environments in scientific settings:
  - laboratories
  - educational settings.

Learning aim B: Explore manufacturing techniques and testing methods for an organic liquid

B1 Manufacturing techniques
- Reflux:
  - principles
  - equipment in the laboratory and in industry.
- Distillation:
  - simple and fractional
  - laboratory distillation equipment
  - distillation towers used in industry.
- Solvent extraction:
  - liquid to liquid.
- Use of chemicals to remove impurities:
  - anhydrous sodium carbonate to react with unreacted acid
  - anhydrous calcium chloride to remove water
  - molecular sieves to remove water and other impurities (depending on pore size)
  - addition of water to remove impurities soluble in water.
- Manufacture of either ethyl ethanoate or 3-methylbut-1-yl ethanoate (banana oil) – one method to be selected:
  - laboratory scale – from ethanol and ethanoic acid (for ethyl ethanoate)
  - industrial scale – from ethanol and ethanoic acid (for ethyl ethanoate)
  - other commercial methods.
B2 Testing methods and techniques

- Measurement of boiling point:
  - relation of boiling point of pure substances to intermolecular forces
  - measurement of boiling point with distillation apparatus
  - Siwoloboff method for small quantities
  - reliability of boiling point as a measure of purity.

- Infrared spectroscopy:
  - comparison of infrared spectrum with that of a pure sample.

- Other methods used in industry:
  - high-performance liquid chromatography (HPLC)
  - gas chromatography (GC).

Learning aim C: Explore manufacturing techniques and testing methods for an organic solid

C1 Manufacturing techniques

- Precipitation crystallisation and recrystallisation:
  - terms relating to saturated solutions and supersaturated solutions
  - influence of temperature on solubility
  - influence of polarity of solvent on solubility
  - crystallisation – supersaturation, nucleation, growth
  - recrystallisation used as a means of purifying solids, particularly organic solids – choice of solvent for recrystallization, the minimum amount of solvent is used, influence of rate of cooling on size of crystals and presence of impurities.

- Filtration:
  - gravity filtration: fluted and non-fluted filter paper
  - hot filtration
  - vacuum filtration using Büchner funnels, Hirsch funnels and sintered glass crucibles.

- Evaporation and drying:
  - evaporation from a crystallisation dish or other suitable container
  - oven drying
  - use of a desiccator
  - use of chemical drying agents to remove water from a solution in an organic solvent
  - distillation
  - rotary evaporation and the effect of reduced pressure.

C2 Industrial manufacturing techniques

- Spray drying.
- Freeze drying.
- Use of a filter press.
- Manufacture of aspirin or paracetamol:
  - laboratory scale
  - industrial scale.
C3  Estimation of purity

- Assessment of the appearance of crystals as an indicator of purity.
- Measurement of melting point:
  - simple cooling curves
  - design of melting-point apparatus
  - choice of thermometer with an appropriate range
  - use of glass melting-point tubes
  - techniques for filling tubes
  - presence of an impurity lowering the melting point
  - identifying a substance by the mixed-melting-point technique
  - use of standard substances (benzoic acid)
  - commercial melting point apparatus
  - reliability of melting-point and mixed-melting-point measurements as an indicator of purity.
- Thin-layer chromatography (TLC) using a locating agent.
- Other methods used in industry:
  - infrared spectroscopy.

Learning aim D: Understand how scientific information may be stored and communicated in a workplace laboratory

D1  Systems for managing laboratory information

- The need for traceability:
  - signatures or unique computer logins.
- Records associated with laboratory work:
  - booking in a sample – record of origin of the sample
  - unique sample identification number
  - records relating to the analysis – readings/weights etc. on computer, sheets or in a notebook
  - results sheet (sheet or computer or notebook)
  - report of analysis/certificate of analysis (paper or electronic)
  - reporting in a format that meets the customer’s needs by a scientific organisation.
- Laboratory information management system (LIMS).

D2  Communicating information in a scientific organisation

- Types of information used in organisations:
  - customer details
  - product details
  - manufacturing data
  - warehousing data
  - standard operating procedures – for all departments
  - sample details
  - results of analysis of raw materials and products
  - maintenance records – showing when equipment was serviced or repaired
  - safety data
  - environmental records
  - ways of communicating data, including company intranet, documents, email, website.
- Channels of communication:
  - in departments
  - between departments
  - with external customers
  - with regulatory bodies
  - with the wider scientific community – to share research data.
D3 Use of informatics for storage and retrieval of scientific information

- Examples of science data stored in large databases:
  - DNA sequencing
  - healthcare records
  - data relating to population surveys (human/animal/plant)
  - fingerprints.

- Examples of uses of information from large databases:
  - personalised healthcare treatment
  - checking what research has already been done
  - evaluating the quality of existing data
  - genetic engineering.

- Advantages of storing and retrieving large quantities of data:
  - access to a much larger data set to inform conclusions
  - access to other relevant information and research.

- Issues associated with bioinformatics:
  - confidentiality
  - ethical issues.

- The need to use appropriate software effectively.
## Assessment criteria

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<tr>
<th>Pass</th>
<th>Merit</th>
<th>Distinction</th>
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<td><strong>Learning aim A: Understand the importance of health and safety in scientific organisations</strong></td>
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<tr>
<td>A.P1 Explain how health and safety measures in a scientific organisation comply with legislation.</td>
<td>A.M1 Compare the health and safety measures taken in relation to legislation for different scientific working environments, referencing potential hazards.</td>
<td>A.D1 Evaluate the measures taken for different working environments to ensure high standards of health and safety that comply with legislation.</td>
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<td>A.P2 Describe the potential hazards relevant to different scientific working environments.</td>
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<td>B.P3 Correctly prepare and test the purity of an organic liquid and draw conclusions.</td>
<td>B.M2 Demonstrate skilful application of techniques in preparing and testing the purity of an organic liquid and draw detailed conclusions.</td>
<td>B.D2 Analyse the factors affecting the yield and purity of an organic liquid in the laboratory and their relevance to its industrial manufacture.</td>
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<td>B.P4 Describe the industrial manufacture and testing of an organic liquid.</td>
<td>B.M3 Compare the laboratory and industrial manufacture and testing of an organic liquid.</td>
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<tr>
<td>C.P5 Correctly prepare and test the purity of an organic solids and draw conclusions.</td>
<td>C.M4 Demonstrate skilful application of techniques in preparing and testing the purity of an organic solid and draw detailed conclusions.</td>
<td>C.D3 Analyse the factors affecting the yield and purity of an organic solid in the laboratory and their relevance to its industrial manufacture.</td>
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<tr>
<td>C.P6 Describe the industrial manufacture and testing of an organic solid.</td>
<td>C.M5 Compare the laboratory and industrial manufacture and testing of an organic solid.</td>
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<th><strong>Learning aim D: Understand how scientific information may be stored and communicated in a workplace laboratory</strong></th>
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<td>D.P7 Explain how scientific information in a workplace laboratory is recorded and processed to meet the needs of the customer and to ensure traceability.</td>
<td>D.M6 Analyse the differences in the storage and communication of scientific information in different workplace laboratories.</td>
<td>D.D4 Evaluate the challenges to organisations in making available large volumes of scientific information.</td>
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<td>D.P8 Explain how useful scientific information is obtained from large data sets and the potential issues and benefits.</td>
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Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. Section 6 gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)
Learning aim: B (B.P3, B.P4, B.M2, B.M3, B.D2)
Learning aim: C (C.P5, C.P6, C.M4 C.M5, C.D3)
Learning aim: D (D.P7, D.P8, D.M6, D.D4)
Further information for teachers and assessors

Resource requirements
For this unit, learners must have access to:
• a well-equipped laboratory with a fume cupboard
• vacuum filtration and sufficient sinks and power sources to allow reflux and distillation to be carried out
• Quickfit™ apparatus for reflux and distillation
• melting-point apparatus
• an infrared spectrometer or specimen infrared spectra
• examples of health and safety policies.

Essential information for assessment decisions

Learning aim A
For distinction standard, learners will explain why following the organisation’s specific health and safety management system improves the standard of health and safety and allows the company to comply with legislation. They will evaluate the measures taken for two work environments, and one of these could include the science laboratory in an educational setting or two departments in a scientific organisation. The benefits to employees and to the company of following the systems should be clear. Learners will show an awareness of different safety constraints being in place. Learners will recognise that hazards in the working environments chosen may be different, although there will be commonality too.

For merit standard, learners will compare specific measures taken in two working environments in order to keep its workforce safe and to comply with legislation. One of these could include the science laboratory in an educational setting or two departments in a scientific organisation. Some measures may be part of the management system that applies to the whole site – for example having a health and safety policy/committee, health and safety audits, risk assessment, use of standard procedures and training employees how to follow procedures. Differences may include procedures for wearing specific PPE for dealing with spillages, specific substances used, quantities of substances used, danger from vehicles, the extent of training on how to lift things, designated walkways in warehouses, permit to work systems, lone working arrangements.

For pass standard, learners will identify a specific science-based organisation. They will describe the main activities of the organisation and why specific pieces of legislation are relevant to that organisation. The list of relevant legislation described does not need to be exhaustive. Learners will also identify two different scientific working environments – for example, laboratory and production or a laboratory in an educational setting – and describe the main hazards associated with each environment. At this standard, learners will give a limited description of some hazards common to both environments in addition to hazards specific to the environments.

Learning aim B
For distinction standard, learners will analyse the factors to give thorough explanations of how they affect the yield and purity of an organic liquid. This should be in the context of the practical work that they have carried out rather than for the industrial process. However, they must explain how those factors will be relevant in the industrial context. Learners should analyse whether boiling point measurement and infrared spectroscopy are effective ways to assess whether the liquid is pure and comment on the reliability of the test methods used. Learners will also conclude using research, whether any of the methods used industrially are more reliable.
For merit standard, learners will demonstrate skilful application of techniques and procedures to prepare and test their organic liquid. Learners will independently assemble equipment safely. This could be knowing how certain equipment should be clamped securely without causing any strain on the set-up and also consider correct positioning of the equipment used. Learners will draw detailed scientific conclusions about the purity of their samples from the tests carried out and provide explanations based on the principles behind the techniques to support their conclusions.

Learners will research how the liquid is made industrially and will compare the similarities and differences in the equipment and techniques used to manufacture and test the liquid on an industrial scale.

For pass standard, learners will correctly and competently follow given techniques and procedures to prepare and test their organic liquid. Learners should use the techniques of reflux and distillation, and add chemicals to purify the liquid they have made. Making the organic liquid will involve assembling Quickfit apparatus in reflux and distillation configurations. It is expected that, at pass standard, learners will be given support to assemble the equipment associated with these techniques safely.

Learners will draw simple conclusions about the purity of the samples based on the tests carried out.

Learners will research the industrial production and testing of the liquid and describe the scale, equipment, testing and the raw materials used to produce the liquid. The information should be in the learners’ own words and all reference sources should be acknowledged.

Learning aim C

For distinction standard, learners will analyse the factors to give thorough explanations of how they affect the yield and purity of an organic solid prepared by reaction and by extraction. This should be in the context of the practical work that they have carried out rather than in the industrial process. However, learners must analyse how those factors will be relevant in the industrial context to ensure scalability. Learners will comment on the reliability of the techniques used in terms of whether melting-point measurement, mixed-melting-point measurement and thin-layer chromatography (TLC) are effective ways to assess whether the solid is pure and explain the effectiveness of alternative testing methods used industrially.

For merit standard, learners will demonstrate skilful application of techniques and procedures to prepare and test their organic solid. Learners will independently assemble equipment safely. Learners will be able to draw detailed scientific conclusions about how pure the samples are based on the tests that been carried out. Learners will reference their sources of information and explain the principles behind the techniques to support their conclusions.

Learners will research the industrial production and testing of an organic solid and compare the similarities and differences in terms of the scale, the equipment, the testing and the raw materials used to produce the organic solid, with the techniques and methods used to prepare and test their sample.

For pass standard, learners will correctly and competently follow given techniques and procedures to prepare and test their organic solid. Learners will use the techniques of vacuum filtration, filtration through filter paper, solvent extraction and recrystallisation. They will measure the melting point of the organic solid prepared from reaction and extraction, and carry out a mixed-melting-point measurement on the two samples, using a pure sample as a comparison. It is expected that at pass standard learners will be given support to assemble the equipment associated with these techniques safely. Learners will draw simple conclusions about the purity of the samples based on the tests carried out.

Learners will research the industrial production and testing of the solid and describe the scale, equipment, testing and the raw materials used to produce the solid. The information should be in learners’ own words and all reference sources should be acknowledged.
Learning aim D

For distinction standard, learners will evaluate the benefits of and issues with storing large quantities of information so that they can be retrieved and used. Learners should explain the benefits gained from pooling and sharing a specific type of information. Learners should contrast those benefits with the issues involved in organising information so that it may be retrieved and shared. They should include the ethical and bioethical considerations associated with storage of information that may be made available to a third party. Learners will be able to evaluate how scientific information is stored and communicated in different working environments.

For merit standard, learners will analyse how different workplace laboratories (these could be within an organisation or in different organisations) communicate and why and how they may communicate with external customers or regulatory bodies.

Learners could, for example, focus on the communication associated with the manufacture, testing and distribution of a single product, including communication with one body (customer or regulator) external to the company. Alternatively, they could focus on the development and manufacture of a new product, for which their sales team thinks there is a need. They should analyse the sort of information communicated, why it is needed and how that information may be shared between different departments.

Learners could comment on whether the way information communicated is fit for purpose and how it may be improved.

For pass standard, learners will investigate a workplace laboratory and gather information about the day-to-day recording systems used by the laboratory technicians as they generate routine data on a day-to-day basis. They should know whether paper worksheets, laboratory notebooks or computer forms are used to record data relevant to analysis. Learners should explain what they know about how the information is processed and made traceable, for example by using signatures or by analysts having a computer login unique to them.

Learners will understand the process of analysis in an analytical laboratory (from booking in samples through to producing a certificate of analysis) or the process of carrying out industrial development project work (from planning the project through to producing the report). Learners must use this understanding to explain how the information collected is transformed into documents that are useful to the customer (external or internal).

Learners must research and explain a specific example of one way in which useful scientific information is obtained, for example in healthcare. This does not need to be in the context of the organisation(s) investigated.

Links to other units

This unit links to:
- Unit 2: Practical Scientific Procedures and Techniques
- Unit 18: Industrial Chemical Reactions
- Unit 19: Practical Chemical Analysis.
Employer involvement

For this unit, learners must have access to one or more scientific organisations to investigate, for example organisations involved in manufacturing, contract analysis or providing a technical service such as water treatment. Ideally, learners should have the opportunity to visit and communicate with the organisation, but the unit could be successfully supported by the provision of case study material from the organisation. The organisation should have at least one laboratory with an established laboratory information and management system (paper based or electronic).

Visits to, or speakers from, manufacturing industry will be invaluable when learners are researching health and safety practices in the laboratory and elsewhere in the organisation. Visits or speakers will also provide insight into data-management systems. Suitable companies could come from the following list of industries: pharmaceuticals, biopharmaceuticals, metals, printed circuits, bulk chemicals, paints and coatings, agrochemicals, food and drink, refractories, nuclear fuel or reprocessing, water treatment, polymers, textiles. A speaker from the local NHS trust may explain how the organisation uses large data sets.