# Unit 40 Scientific Practical Techniques

**Unit code:** M/502/5544

**QCF Level 3:** BTEC National

**Credit value:** 10

**Guided learning hours:** 60

## Aim and purpose

The aim of this unit is to enable learners to use a range of practical techniques used in science such as the analysis of substances, the separation of substances and the use of instruments/sensors. The variety of techniques in the content allows the unit to be tailored to reflect the focus of different areas of study, for example forensic science, biology, chemistry, physics, electronics and environmental science.

## Unit introduction

The ability to sample and test substances and materials is important in many branches of industry, in research work, forensic science and in the hair and beauty sector. To do this, learners need to be able to select and use appropriate instruments for the work being carried out. In this unit they will gain experience of a range of instruments and their use.

As a result of scientific advances, new drugs have revolutionised healthcare, and new forensic techniques have led to the accurate and swift conviction of criminals and solved crimes from the past. In sport, new materials developed by scientists have enabled athletes to break world records, going faster, higher and further than ever before. Practical techniques are the basis of many other science-related industries, including environment, conservation, animal health and breeding, food manufacturing, engineering and aerospace.

In all of these areas the ability to work safely and accurately, and to appreciate the properties of materials, is important. When scientists undertake investigations, they may need to know what substances are present. For example, an investigator of a pollution incident may need this information to identify the cause of the pollution. A scientist checking the purity of a pharmaceutical product may also need to know the nature and quantities of impurities present. Learners will gain experience of both these types of analytical method: qualitative and quantitative.

## Learning outcomes

**On completion of this unit a learner should:**

1 Be able to use analytical techniques

2 Be able to use scientific techniques to separate and assess purity of substances

3 Be able to use instruments/sensors for scientific investigations.

# Unit content

## 1 Be able to use analytical techniques

*Quantitative analysis*: preparation and use of standard solutions; titration

*Qualitative analysis:* test for cations eg sodium, potassium, copper, calcium, barium; test for anions eg chloride, sulphate, carbonate; tests for proteins, starch and reducing sugars

## 2 Be able to use scientific techniques to separate and assess purity of substances

*Separation techniques:* precipitation; crystallisation; filtration; drying; distillation; solvent extraction; chromatography; electrophoresis; centrifugation

*Sampling*: importance of sampling; techniques for solids, liquids, gases; representative sampling eg homogenisation, selection of appropriate sampling points, number of samples, isokinetic sampling of gases; importance of correct labelling and storage

*Estimation of purity*: measurement of melting point and boiling point; chromatography eg paper, thin layer, gas liquid, HPLC; spectroscopy eg ultraviolet, infrared; appropriate reference data; other techniques eg refractive index, polarimetry

## 3 Be able to use instruments/sensors for scientific investigations

*Use of a variety of basic instruments*: microscope, pH meter, balance, colorimeter, pipette

*Selection of instruments/sensors*: measure scientific parameters; appropriate choice of instruments/sensors; safety; calibration; consideration of the required accuracy eg linearity, percentage error

*Measurement*: techniques for measuring material properties eg melting point, boiling point, resistance, conductivity, tensile strength, compressive strength, elasticity, refractive index, turbidity, viscosity

# Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

| Assessment and grading criteria | | |
|---|---|---|
| **To achieve a pass grade the evidence must show that the learner is able to:** | **To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:** | **To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:** |
| **P1** carry out quantitative and qualitative analytical techniques [IE2] | **M1** explain how accuracy may be ensured in the techniques used | **D1** evaluate the quantitative and qualitative analytical techniques used, suggesting improvements for future investigations |
| **P2** demonstrate use of scientific techniques to separate substances [EP2, EP3, SM2, SM4] | **M2** describe the factors that influence purity | **D2** evaluate the accuracy of the methods used to estimate the purity of the samples |
| **P3** estimate the purity of samples using scientific techniques [IE5, IE6] | | |
| **P4** use instruments/sensors to test substances or materials. [IE5, IE6] | **M3** justify the choice of instruments in the practical exercises. | **D3** evaluate the accuracy of the measurements taken. |

**PLTS**: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

| Key | | | |
|---|---|---|---|
| | IE – independent enquirers | RL – reflective learners | SM – self-managers |
| | CT – creative thinkers | TW – team workers | EP – effective participators |

# Essential guidance for tutors

## Delivery

This unit should be delivered using a series of practical exercises, complementing the content of the other beauty therapy and science units. Each centre is likely to have a unique learning plan for the unit. Essentially, there are several themes: safety, quantitative and qualitative analysis, preparative techniques used in chemistry, testing the purity of substances, representative sampling, use of appropriate instrumentation and justifying the use of particular instruments. It is possible to vary the order of these topics depending on the context of the assignments, the centre, its facilities and the ability of learners. Since safety is important in all practical work, the common laboratory hazards and ways of minimising risk should be introduced at the start of the unit. Although safety is not specifically assessed, learners will be expected to make justifiable decisions on risk minimisation once they are confident with risk minimisation strategies devised by tutors and support staff.

The timing of delivery of good volumetric technique, for example titrations and preparation of standard solutions, should fit in with when formulae, balanced equations and mole calculations are being taught. The importance of accurate measurement of volume and mass should be stressed. If it is desirable that learners gain confidence quickly in using a range of preparative techniques, eg to highlight the inherent value of developing the range of manipulative skills needed in science, it may be more appropriate to begin with preparative techniques. This unit gives learners the opportunity to use and understand the principles behind preparative techniques before the techniques are used in the context of analysis or synthesis. For example, learners can learn about choosing recrystallisation solvents and recrystallisation before the technique has to be applied as part of a synthesis.

Techniques, such as measurement of melting point, used to estimate purity could be used in relation to straightforward measurements before being applied in context. Similarly, instrumental techniques may be used in simple measurements before learners need to select suitable instrumental techniques for a purpose. Instrumental techniques may be chosen because of their relevance to units involving, for example, chemical syntheses, biochemical techniques, physiological measurement or electrical circuits. Alternatively, the tutor may choose to use certain instruments in stand-alone exercises because technicians in industry may use these instruments routinely, for example pH meters.

Since measuring the properties of materials depends on the samples being representative, although not specifically assessed, representative sampling should be discussed/carried out in relation to meaningful contexts. For example, in the synthesis of aspirin, aspirin crystals may be produced mixed with impurities and random sampling may give different measurements of melting points to sampling of product which is ground up together. Sampling may be undertaken on commercial products for example clingfilm, road grit, sweet and sour sauce, savoury rice and pineapple juice. Measurements made may be inconsistent, depending on the sampling point (bottom or top of a bag of gravel or savoury rice) or direction of measurement (strength testing of cling film). The features of the sampling plan should be discussed with learners, for example the need to blend/grind an inhomogeneous matrix to ensure that it is sampled in a representative manner, labelling, date the sample was taken, person carrying out the sampling, prevailing weather conditions (environmental sampling), nature of sample containers chosen, rinsing out sample containers appropriately before filling, correct storage of samples. If the features of a given sampling plan are discussed, it will be easier for learners to understand the need for a representative, stable and traceable sample. This could be from the point of view of what would happen if each of the conditions is not applied, for example if the sample is not labelled, if the sample container is not rinsed. Learners need to be presented with industrial contexts for sampling, relevant to their needs and to the needs of the programme that they are following, eg analysis of a manufactured product, environmental water samples, forensic samples, medical specimens.

Results should be recorded accurately and completely. This may often involve use of a pro forma because writing full laboratory reports for each practical undertaken is likely to take too much time. Alternatively, learners may have a notebook in which to record results. Learners should be encouraged to write accurate details of their practical work in these notebooks, for example dates, procedures, sample details.

## Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

| Topic and suggested assignments/activities and/assessment |
|---|
| Introduction to unit and assignment programme. |
| Introduce safety in the laboratory – hazards – card activity matching symbols to definitions. |
| COSHH regulations, risk minimisation and available and accessible sources of information. Reading through given risk assessments and discussion of what would happen if guidance was not followed. |
| Introduction to standard operating procedures relating to procedures to be carried out in this unit. |
| Identification of a range of glassware – assigning correct labels, diagrammatic representation of a range of glassware, accuracy of volumes measured using different types of glassware. |
| Sodium hydroxide/hydrochloric acid titration using phenolphthalein as an indicator. Discussion of error sources. Calculation of results via a template. |
| Titration of the primary standard, potassium hydrogen phthalate, with sodium hydroxide to determine the concentration of sodium hydroxide (uses accurate balance – discussion of the need to calibrate balances). Discussion of error sources. Calculation of results via a template. (performance and safety assessed). |
| Titration of the primary standard, sodium carbonate with hydrochloric acid to determine the concentration of the hydrochloric acid (uses accurate balance). Discussion of error sources. Calculation of results via a template (performance and safety assessed). |
| Sampling water from a local source. Titration of the chloride content with standardised silver nitrate solution. |
| Use of microscope to study the water sampled. |
| Discussion of other analytes, eg dissolved oxygen, trace metals, bacteria, fungi and the sorts of container and sample storage that would be needed to avoid contamination. |
| **Assignment 1 : Quantitative Analysis (P1, M1, D1) stage 1.**<br>Learners carry out the above titrimetric exercises and explain how accuracy is ensured. Learners evaluate the equipment used and the way the techniques are presented. |
| Flame tests for cations. Discussion of the need to avoid cross-contamination (performance and safety assessed). |
| Test tube reactions to identify chloride, bromide, iodide, carbonate and sulphate. Gap-fill exercise to ensure understanding. |
| Identification of an inorganic salt using cation and anion tests. Discussion.<br>Identification of the anions and cations present in road grit. |
| Tests on food for protein, starch and reducing sugars. Discussion of results. |
| **Assignment 2: Qualitative Analysis (P1, M1, D1) stage 2.**<br>Learners carry out the above tests to identify ions. |
| Simple filtration and evaporation – road grit, mixing with water, filtering of insoluble material, evaporation of water to leave white solid. Weigh this before and afterwards and calculate percentage recovery of white solid, label sample for further analysis, TLC of halides to identify which are present. |
| Soil suspension – comparison of fluted filter paper and glass-fibre filter paper and vacuum filtration. |

| Topic and suggested assignments/activities and/assessment |
|---|
| Melting point of known substances and mixed melting point to identify an unknown substance – melting point and mixed melting point as indicators of purity. |
| Recrystallisation of a solid from water/vacuum filtration. |
| Choice of a solvent for recrystallisation of solids. |
| Hot filtration technique as part of recrystallisation of an impure solid (eg organic compound like acetanilide mixed with sand). Vacuum filtration. Measurement of melting point. |
| Solvent extraction of pigment from dried herbs using Soxhlet extractor – distil to remove most of the solvent – BPT and refractive index of the solvent – similar to what was used initially? – carry out paper or TLC of extract. |
| Solvent extraction using a separating funnel – eg fat from full fat milk. Evaporation of the residue with a rotary evaporator or by distillation – and find percentage of fat. |
| Extraction of sugars from fruit (ground up) – mix with water, centrifuge, carry out chromatography in relation to standard sugars. Identify sugars present in a mixture. Explain relevance of this technique in identifying pure compounds. |
| Paper chromatography of amino acids. Identify amino acids in a mixture. Explain relevance of this technique in identifying pure compounds.<br>Electrophoresis of amino acids. |
| **Assignment 3:Separating and Estimating Purity (P2, P3, M2, D2).**<br>Learners collate the results from the practical work listed above. |
| Calibration of a pH meter. Measurement of pH of a range of substances. |
| pH titration of ethanoic acid with sodium hydroxide to allow learners to calibrate pH meters. Use of appropriate software to plot results. Differential plot. |
| pH titration of river (or 'water from an industrial treatment pond') water with 0.01 mol $dm^{-3}$ HCl. |
| Measure conductivity of three water samples. Find total dissolved solids by evaporation – is there a relationship between conductivity and dissolved solids? |
| Preparation of standards and use of colorimeter to find the concentration of a copper sulphate solution. Produce a graph. Equation used to find concentration. Discussion of errors associated with preparing standards and using a colorimeter to make measurements. |
| Learners select colorimeter as a suitable instrument for finding the concentration of a solution of cobalt chloride. Preparation of standards and use of colorimeter to find the concentration of a cobalt chloride solution. Produce a graph. Equation used to find concentration (assessed). |
| Use of multimeters to measure current and voltage, vernier calliper in order to determine resistivity of a wire – identification of the material wire is made from (as an example of an alternative to one of the other exercises above). |
| **Assignment 4: Selecting and Using Instruments/Sensors to Test Materials (P4, M3, D3).**<br>Learners carry out the above practical work, keep a portfolio of results and assess how effective the techniques are. |
| Review of unit and assignment programme. |

## Assessment

The unit is assessed by the centre and will be subject to external verification by Edexcel.

Achievement of the assessment and grading criteria should be evidenced through contextualised, vocationally-related experiences, with tasks specifically designed with the assessment and grading criteria in mind.

The theoretical aspects of assessment for this unit can be achieved through learners completing centre-devised assignments, a portfolio of evidence or through adaptation of Edexcel assignments where available. Practical assessment criteria will require observation and completion of relevant documentary evidence by the assessor.

Assessment should be as holistic as possible, with assignments designed to cover multiple assessment criteria, even across units, where appropriate. Reference to grading criteria should be made in the assessment documentation, to ensure the criteria have been met.

The quantitative aspect of P1 is likely to be assessed separately from the qualitative aspect. Quantitative analysis in this context can be limited to titration because there are several aspects of ensuring accuracy in volumetric technique and making standard solutions which are applicable in other contexts. Assessment of the quantitative part of P1 should involve witness testimony that learners have used appropriate aspects of good technique, supported by associated records of weight, titrimetric volumes and calculations. Learners should follow a given method for calculating results. Awarding P1 does not depend on correct calculations but on accurate results, showing good technique. For the qualitative aspect of P1, learners should show evidence of accurate observations of spot tests, identifying anions, cations and reducing sugars, starch and protein. Learners will be expected to keep accurate records, either on proformas or in notebooks. Learners do not need to produce a full laboratory report for every experiment carried out.

M1 relates to ensuring accuracy in both quantitative and qualitative analysis. Aspects of good volumetric technique should be discussed and the need to avoid contamination in the spot tests explained.

To achieve D1, learners need to be critical of the way they carried out the practicals. They should explain the consequence of particular errors in technique, for example not mixing solutions, overshooting the endpoint, not cleaning the wire properly in flame tests. They may also justify improvements to the methods used to carry out the practical, highlighting features which may have confused them.

To achieve P2, learners should use all the separation techniques listed in the unit content in contexts which the tutor thinks appropriate are to the learners. For P3, purity should be estimated on at least three occasions. This could be by using a chromatographic technique, measuring boiling point or melting point or by carrying out a titration.

To achieve M2, at least one specific context should be selected to give learners the opportunity to discuss the factors influencing purity, for example during recrystallisation, filtration and drying of an organic compound. For D2, learners should evaluate the accuracy of all the methods chosen to estimate purity.

To achieve P4, learners should use at least three instruments or sensors to carry out measurements on samples. This should be made as relevant as possible to the rest of the course. Learners need to describe the principles of operation of the instruments to justify their use in particular applications for M3.

Learners often assume that instruments give more accurate measurements than wet analysis techniques. To achieve D3, learners must evaluate the accuracy of the measurements made, contrasting them with wet techniques where appropriate (for example determination of Cu2+ concentration by titration and by colorimetry).

It is essential that learners are given opportunities to achieve all the assessment and grading criteria through the assignments. The theoretical aspects of this unit can be cross unit assessed.

It is recommended good practice for tutors to hold regular assignment workshops where learners bring in their assignment work and work on it, consulting with the tutor when necessary.

Signed witness testimonies and observation records must be retained for verification purposes. Supplementary evidence in the form of photographs could also be provided.

### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

| Criteria covered | Assignment title | Scenario | Assessment method |
|---|---|---|---|
| P1, P2, P3, P4, M1, M2, M3, D1, D2, D3 | Scientific Practical Techniques Investigation | Carry out quantitative and qualitative analytical techniques and produce a report detailing the investigation. | Written report marked and authenticated by the assessor.<br>Supplementary evidence of signed witness testimony evidencing practical observation of P1. |

## Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC in Applied Science sector suite. This unit has particular links with other units in the BTEC in Applied Science suite of qualifications:

| Level 2 | Level 3 |
|---|---|
| Chemical Analysis and Detection | Fundamentals of Science |
| | Practical Chemical Analysis |
| | Chemical Laboratory Techniques |

## Essential resources

The resources required are determined by learners' specialist studies. The practical methods selected for study should be representative of those in current use in the beauty therapy industry. All learners will need access to appropriate laboratory facilities and information communication technology resources. Learners not in employment will benefit from visits to appropriate industrial facilities to see practical techniques in operation within an industrial context.

## Employer engagement and vocational contexts

Laboratory techniques are used in a variety of contexts for example, environmental, manufacturing, pharmaceutical, forensic and medical. Visits to laboratories and speakers from laboratories can help to support the important issues around safety, representative sampling, traceability and recording data accurately.

Centres can visit the STEMNET website www.stemnet.org.uk or Future Morph www.futuremorph.org

## Indicative reading for learners

### Textbooks

Coyne G S – *The Laboratory Companion: A Practical Guide to Materials, Equipment, and Technique* (Wiley-Blackwell, 2005) ISBN 9780471780861

Ennets F – *BTEC Level 3 National Applied Science Student Book* (Edexcel, 2010) ISBN 9781846906800

Jones A Reed R and Weyers J – *Practical Skills in Biology 3rd Edition* (Prentice Hall, 2003) ISBN 9780130451415

Lintern M – *Laboratory Skills for Science and Medicine: An Introduction* (Radcliffe Medical Press, 2007) ISBN 9781846190162

Reed R, Holmes D, Weyers J and Jones A – *Practical Skills in Biomolecular Sciences 3rd Edition* (Prentice Hall, 2007) ISBN 9780132391153

**Journals and magazines**

*Nature* (Nature Publishing Group)

*New Scientist* (Reed Business Information)

**Websites**

| | |
|---|---|
| www.rsc.org/ | Royal Society of Chemistry |
| www.virtlab.com/main.aspx | Virt Lab |

## Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

| Skill | When learners are ... |
|---|---|
| **Independent enquirers** | carrying out quantitative and qualitative analytical techniques [IE2]<br>considering the influence of circumstances and supporting conclusions, estimating the purity of samples using scientific techniques and instruments/sensors to test substances or materials [IE5, IE6] |
| **Self-managers** | working towards goals and anticipating risks, demonstrating use of scientific techniques to separate substances [SM2, SM4] |
| **Effective participators** | presenting a persuasive case and proposing practical ways forward, demonstrating use of scientific techniques to separate substances. [EP2, EP3] |

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

| Skill | When learners are ... |
|---|---|
| **Independent enquirers** | explaining the importance of the choice of sample containers and methods for preserving and storing samples [IE1]<br>evaluating the accuracy of the methods used to estimate and to measure the purity of the compounds prepared [IE4] |
| **Reflective learners** | explaining how accuracy may be ensured in the techniques used and optimised [RL5] |
| **Team workers** | sharing data/comparing analysis data [TW1, TW4] |
| **Self-managers** | handing in assignment work to meet deadlines. [SM2] |

## Functional Skills – Level 2

| Skill | When learners are ... |
|---|---|
| **ICT – using ICT** | |
| Select, interact with and use ICT systems safely and securely for a complex task in non-routine and unfamiliar contexts | using ICT systems to find information for the unit<br>constructing diaries/mindmaps in appropriate packages, and discussing the effectiveness of what is carried out |
| Manage information storage to enable efficient retrieval | saving information in suitable files and folders |
| **ICT – finding and selecting information** | |
| Use appropriate search techniques to locate and select relevant information | obtaining experimental data<br>collecting health and safety information from books and websites |
| Select information from a variety of sources to meet requirements of a complex task | collecting information from suitable websites<br>highlighting suitable information and discussing whether it meets the purpose |
| **ICT – developing, presenting and communicating information** | |
| Enter, develop and refine information using appropriate software to meet requirements of a complex task | ensuring all necessary information for the unit is available electronically, eg tests from websites, experimental methods, tables of information about chemical hazards, tables of numerical data, pictures of equipment |
| Combine and present information in ways that are fit for purpose and audience | creating documents which have the necessary information for a report on a piece of practical work, say in one document so that it is easy to edit<br>presenting information as a report or other document as requested in the brief |
| Evaluate the selection, use and effectiveness of ICT tools and facilities used to present information | discussing the layout of the documents produced and how they may be improved |
| **Mathematics – representing:** | |
| Understand routine and non-routine problems in familiar and unfamiliar contexts and situations | calculating concentrations |
| Identify the situation or problems and identify the mathematical methods needed to solve them | planning to calculate by rearranging equations involving concentration, volume and number of moles; number of moles, mass and mass of one mole; plotting calibration graphs<br>planning to use simple statistics to evaluate the accuracy of a result by comparing with classmates' results |
| **Mathematics – analysing** | |
| Apply a range of mathematics to find solutions | calculating by rearranging equations involving concentration, volume and number of moles; number of moles, mass and mass of one mole; plotting calibration graphs<br>calculating mean result for the class and comparing results to it |
| Use appropriate checking procedures and evaluate their effectiveness at each stage | calculating backwards to obtain the initial numbers |

| Skill | When learners are ... |
|---|---|
| **Mathematics – interpreting** | |
| Interpret and communicate solutions to multistage practical problems in familiar and unfamiliar contexts and situations | writing final reports or other documents as suggested in assignment briefs<br>communicating in appropriate ways |
| Draw conclusions and provide mathematical justifications | drawing conclusions about final calculated results and their reliability<br>justifying these conclusions in terms of the quality of the data collected and its number of significant figures |
| **English – Speaking, Listening and Communication** | |
| Make a range of contributions to discussions in a range of contexts, including those that are unfamiliar, and make effective presentations | discussing risk assessment and representative sampling |
| **English – Reading** | |
| Select, read, understand and compare texts and use them to gather information, ideas, arguments and opinions | reading documents about representative sampling and risk assessment |
| **English – Writing** | |
| Write a range of texts, including extended written documents, communicating information, ideas and opinions, effectively and persuasively | writing reports, leaflets and other documents as suggested by the assignment briefs. |