Unit 4: 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, eg 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 and in forensic science. In order 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 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 the 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 [EP, SM]	**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 [EP, SM]	**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 [EP, SM]				
P4	use instruments/sensors to test substances or materials. [EP, SM]	**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 through a series of practical exercises, complementing the content of the other unit. 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 the 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, eg 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 quickly gain confidence 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 straightforward measurements before being applied in context. Similarly, instrumental techniques may be used in simple measurements before the learner is required to select suitable instrumental techniques for a purpose. Instrumental techniques may be chosen because of their relevance to units involving, eg chemical syntheses, biochemical techniques, physiological measurement or electrical circuits. Alternatively the centre may elect to use certain instruments in stand alone exercises because technicians in industry may use these instruments routinely, eg 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 eg clingfilm, road grit, sweet and sour sauce, savoury rice, 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, eg 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 done from the point of view of what would happen if each of the conditions is not applied, eg if the sample is not labelled, if the sample container is not rinsed etc. 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 accurately and completely recorded. 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 practical work in these notebooks, eg dates, procedures, sample details etc.

This unit may be delivered in conjunction with other units, for example *Unit 22: Chemical Laboratory Techniques*.

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 were 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 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. Identification of the anions and cations present in road grit.
Tests on food for protein, starch and reducing sugars. Discussion of results.
Assignment 1 – Qualitative Analysis (P1, M1, D1) Stage 2 Learners carry out the above tests to identify ions.

Topic and suggested assignments/activities and/assessment
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.
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. Electrophoresis of amino acids.
Assignment 2 – Separating and Estimating Purity (P2, P3, M2, D2) 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 3 – Selecting and Using Instruments/Sensors to Test Materials (P4, M3, D3) 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

All the pass grade criteria must be met in order for a learner to achieve this unit.

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 the 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, reducing sugars, starch and protein. Learners will be expected to keep accurate records, either on proformas or in notebooks. It is not necessary for learners 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, eg not mixing solutions, overshooting the endpoint, not cleaning the wire properly in flame tests. They may also justify improvements to the methods given 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 centre thinks appropriate 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, eg 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 for learners. Learners will have to describe the principles of operation of the instruments in order to justify their use in particular applications to achieve 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 (eg determination of $Cu2+$ concentration by titration and by colorimetry).

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, M1, D1	Quantitative Analysis – Stage 1	You have started to work in the analysis laboratory of a large and diverse chemical manufacturer, called Superchem. You will need to be trained in some of the basic techniques before you are allowed to do some of the non-routine analysis. You must keep accurate records of all your work.	Analysis according to the standard methods given to find analyte concentrations. Explain how to maximise the accuracy of your results and evaluate variations in the methods which may improve the results.
P1, M1, D1	Qualitative Analysis – Stage 2	At Superchem, in order to select the most appropriate way to analyse samples quantitatively, you need to do some simple tests to work out what is in the samples. You must record the results of these tests for future reference.	Carry out simple tests, according to the standard methods given to find the concentrations. Explain how to maximise the accuracy of your results and evaluate variations in the methods which may improve the results.
P2, P3, M2, D2	Separating and Estimating Purity	You are moved to the research lab of Superchem, a laboratory which develops methods for analysing and purifying substances. You have been given several tasks to support the manufacturing side of the company. You will need to keep detailed records of your work.	Separate a range of substances in mixtures following given methods. You will have to calculate the percentage of different substances present in some cases. Carry out measurements of some of the properties of the substances separated. Record your results. As a guide for people repeating your work, you need to describe the factors that will alter the purity of the substances.
P4, M3, D3	Searching and Using of Instruments/ Sensors to Test Materials	As part of your training, you have been moved into the laboratory which uses simple instruments and sensors. You will learn about the instruments so that you can select which one is the best to use in a given situation. You will then have to recommend the most appropriate instruments to use in certain situations. You must keep accurate records of all your work.	Carry out a series of measurements with instruments/sensors using given methods. Justify why these instruments are appropriate to use and evaluate how accurate the measurements and subsequent results are. Justify more appropriate alternatives if need be.

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 the learners' specialist studies. The practical methods selected for study should be representative of those in current use in the appropriate vocational area. All learners will need access to appropriate laboratory facilities and information communication technology resources. Non-employed learners 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, environmental, manufacturing, pharmaceutical, forensic, medical. Visits to laboratories and speakers from laboratories should help to support the important issues around safety, representative sampling, traceability and recording data accurately.

It would be beneficial for centres to visit the STEMNET website **www.stemnet.org.uk** or Future Morph **www.futuremorph.org** for more ideas about vocational contexts.

Indicative reading for learners

Textbooks

Foale S, Hocking S, Llewellyn R, Musa I, Patrick E, Rhodes P and Sorensen J – *BTEC Level 3 in Applied Science Student Book* (Pearson, 2010) ISBN 9781846906800

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

Dean J R et al – *Practical Skills in Chemistry* (Prentice Hall, 2001) ISBN 9780130280022

Dean J R et al – *Practical Skills in Forensic Science* (Prentice Hall, 2005) ISBN 9780131144002

Derenzo S E – *Practical Interfacing in the Laboratory: Using a PC for Instrumentation, Data Analysis and Control* (Cambridge University Press, 2003) ISBN 9780521815277

Jones A et al – *Practical Skills in Biology, 3rd Edition* (Prentice Hall, 2002) ISBN 9780130451415

Lawn R and Prichard E – *Practical Laboratory Skills Training Guide: Measurement of Mass* (The Royal Society of Chemistry, 2003) ISBN 9780854044634

Lintern M – *Laboratory Skills for Science and Medicine: An Introduction* (Radcliffe Medical Press, 2006) ISBN 9781846190162

Prichard E and Lawn R – *Practical Laboratory Skills Training Guide: Measurement of pH* (The Royal Society of Chemistry, 2003) ISBN 9780854044733

Prichard E and Lawn R – *Practical Laboratory Skills Training Guide: Measurement of Volume* (The Royal Society of Chemistry, 2003) ISBN 9780854044689

Reed R et al – *Practical Skills in Biomolecular Science, 3rd Edition* (Benjamin Cummings, 2007) ISBN 9780132391153

Journals

BluSci

Nature

New Scientist

Websites

www.chemguide.co.uk/organicprops/esters/preparation.html	Guide to esters
www.rsc.org/education/teachers/learnnet/pdf/LearnNet/rsc/Aspirin_full.pdf	A curriculum resource on aspirin
www.virtlab.com/main.aspx	A virtual laboratory

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 …
Effective participators	[EP2,3] carrying out quantitative and qualitative analytical techniques demonstrating the use of scientific techniques to carry out separation of substances estimating stance the purity of substances by using scientific techniques using instruments/sensors to test substances or materials
Self-managers	[SM3,4] organising time and resources when carrying out practical tasks anticipating, taking and managing risks when working in the laboratory.

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	[IE1] explaining the importance of choice of sample containers and methods for preserving and storing samples [IE4] evaluating the accuracy of the methods used to estimate and to measure the purity of the compounds prepared
Reflective learners	[RL5] explaining how accuracy may be ensured in the techniques used and optimised
Team workers	[TW1,4] sharing data/comparing analysis data
Self-managers	[SM2] handing in assignment work to meet deadlines.

Functional Skills – Level 2

Skill	When learners are …
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using the centre's ICT systems to find information for the unit
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	constructing diaries/mindmaps in appropriate packages, and discussing the effectiveness of what is done
Manage information storage to enable efficient retrieval	saving information in suitable files in suitable folders
Follow and understand the need for safety and security practices	keeping food and drink away from computers, not using someone else's login, and explaining how safety is addressed in the context of the tasks explaining why the IT usage policy forbids certain actions
Troubleshoot	carrying out checks to identify the source of a problem encountered, eg missing file of work
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	obtaining experimental data collecting health and safety information from books and websites
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	collecting information from suitable websites highlighting suitable information and discussing whether it meets the purpose
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	ensuring all necessary information for the unit is available electronically, eg test from websites, and experimental methods, tables of information about chemical hazards, tables of numerical data, pictures of equipment
Bring together information to suit content and purpose	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
Present information in ways that are fit for purpose and audience	presenting information as a report or other document as requested in the brief
Evaluate the selection and use of ICT tools and facilities used to present information	discussing the layout of the documents produced and how they may be improved
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	emailing material, including attached files, to tutors and classmates using contact lists storing messages and replies in appropriate folders being observed doing the above

Skill	When learners are …
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	calculating concentrations
Identify the situation or problem and the mathematical methods needed to tackle it	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 planning to use simple statistics to evaluate the accuracy of a result by comparison with classmates' results
Select and apply a range of skills 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 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
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	writing final reports or other documents as suggested in assignment briefs communicating in appropriate ways
Draw conclusions and provide mathematical justifications	drawing conclusions about final calculated results and their reliability justifying these conclusions in terms of the quality of the data collected and its number of significant figures
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	discussing risk assessment and representative sampling
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	reading documents about representative sampling and risk assessment
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	writing reports, leaflets and other documents as suggested by the assignment briefs.