Unit 26: Fundamentals of Science

Unit code: R/502/5536

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 develop the practical techniques necessary to pursue a career as a laboratory technician. Learners will investigate the quantities necessary in chemical reactions, structure and functions of cells, calorific value of different fuels and develop the skills in communicating scientific information.

Unit introduction

Learners wishing to pursue a career as a laboratory technician will need a general understanding of all the main sciences including some practical techniques.

This unit introduces learners to fundamental scientific ideas in chemistry, biology and physics.

The learning outcomes have been designed to underpin the knowledge required in fundamental concepts in biology, chemistry and physics. This should enable existing or future applied science technicians to carry out work effectively in industry and analytical services, as well as building a knowledge base from which they can study a broader range of scientific ideas.

Communication of scientific ideas is key to anyone working within the scientific community and the ability to do this clearly and concisely is a valuable skill in any subsequent career.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use the necessary skills to measure quantities for chemical reactions

2 Be able to use the correct equipment to identify structures and functions in different types of cells

3 Be able to investigate different types of energy and their transfers

4 Be able to communicate scientific information.

Unit content

1 Be able to use the necessary skills to measure quantities for chemical reactions

Periodic table: symbols and names of elements; relative atomic mass and number; arrangements of elements; physical and chemical properties of groups and periods

Atomic structure and chemical bonding: mass and charge of subatomic particles; electronic configuration; polar molecules; ionic and covalent bonding

Chemical reactions: general, empirical and structural formulae; full chemical equations; acid-base equilibria including titration curves, pH and pKa calculations; effects of buffers; volumetric calculations ($M=CV$; $M_aV_a = M_bV_b$)

Practical skills: laboratory safety symbol interpretation, use of indicators, titration, making standard solutions

2 Be able to use the correct equipment to identify structures and functions in different types of cells

Microscopy (limitations, preparation of specimens, practical techniques, scientific drawings): compound, dissection, confocal, scanning electron microscope, transmission electron microscope

Cellular ultrastructure and function: eukaryotic cells (nucleus: nucleolus, nuclear envelope, nuclear pores; ribosomes, rough endoplasmic reticulum, smooth endoplasmic reticulum, Golgi apparatus, mitochondria, microtubules, lysosomes, peroxisomes) and prokaryotic cells (nucleoid, ribosomes, storage granules, cell wall, plasma membrane, capsule; periplasmic space and outer membrane in Gram negative bacteria; pili and flagellae)

Practical skills: microscopy, scientific drawing and interpretation of electron micrographs of different tissue types

3 Be able to investigate different types of energy and their transfers

Energy types: electromagnetic, kinetic, potential (chemical, gravitational, nuclear, elastic), electrical, thermal; energy units and measurement

Energy transfer: principals of conservation of energy; thermal energy transfers (conduction, convection, radiation); energy transfer diagrams, Sankey diagrams; electricity generation; energy from fuels

Calculations: $W = fd$, $\Delta Q=mc\,\Delta\theta$ (where c is specific heat capacity); $ke= ½mv2$; $gpe=mgh$; percentage efficiency calculations

Practical skills: simple calorimetry methods

4 Be able to communicate scientific information

Scientific reports: standard layout: title, authors, abstract, summary, table of contents, report (introduction, aims/hypothesis, materials, methods, results, discussion), conclusion, references)

Scientific communication: scientific terminology, use of statistics, paper critiques, acceptance of scientific theories, referencing methods; presentation (posters, text, tables, graphs, diagrams; presentation software, mass media (newspapers, magazines, internet))

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 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 outline the key features of the periodic table, atomic structure and chemical bonding [IE, CT]	**M1** describe the uses and action of acid and alkali buffer solutions	**D1** accurately determine the identity and concentration of unknown acids by titration methods
P2 demonstrate practically the ability to prepare chemical solutions and test their accuracy [IE, RL, SM]		
P3 accurately record observances of different types of tissues from a light microscope [IE, SM]	**M2** describe the design, operation and uses of different types of microscope	**D2** compare different tissues with similar functions in terms of their structure and functions
P4 interpret electron micrographs of different types of tissues [IE, RL]		
P5 describe the key structures and functions of a eukaryotic and prokaryotic cell [IE, SM]	**M3** design and carry out a practical investigation into the theory of energy conservation	
P6 describe different types of energy transfer [IE]		
P7 carry out a practical investigation into the calorific value of different fuels [IE1, RL, SM]		

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:**	
P8	outline the methods by which scientific information is communicated [CT]	**M4**	construct accurate graphs based on results of investigations.	**D3**	evaluate the impact of the media on the communication of scientific ideas to the general public.
P9	report on a scientific investigation that has been carried out. [IE, CT, RL, SM]				

PLTS: This summary references where applicable in the pass criteria, in the square brackets, the elements of the personal, learning and thinking skills. 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

Delivery of this unit will involve practical and written assessments, visits to suitable collections and will link to industrial experience placements.

A visit to an industrial state-of-the-art laboratory is strongly recommended. If this is not possible for all learners, then tutors are strongly advised to take any opportunity to visit one themselves. This would give tutors an appreciation of the differences between industrial laboratories and centre-based laboratories and enable them to better deliver the unit. Such differences include the clear demarcation of 'clean' and 'contaminated' areas (not only in biological and animal laboratories, but even in many chemistry ones), and the separate space for computers, desks etc that learners may not be aware of.

The fundamental ideas contained in this unit should be introduced through a programme of tuition, guided learning, practical work in the laboratory and problem solving. The practical activities in this unit will develop technical skills and help learners to understand science, common scientific instruments, and the use of these instruments in a vocationally relevant context. This could be reinforced by visits to relevant industries to enable learners to relate scientific theory to applications in industry. Wherever possible, the scientific theories should be applied to the use within, for example, a research establishment, a quality control laboratory in a fine chemical or bulk chemical industry, a medical laboratory, or a forensic science laboratory.

Before any practical work is carried out, tutors must complete risk assessments and ensure that learners are aware of laboratory health and safety procedures. Personal protective equipment must be worn as and when appropriate, and learners must be made aware of any hazardous materials that may be used before starting any practical activity.

Learning outcome 1 is designed to give learners confidence in the basic theory behind their developing practical skills. Tutors should use demonstrations and experiments in addition to those that will be assessed in order to both engage learners and familiarise them with the use of laboratory equipment.

For learning outcome 2, learners would benefit from visiting an industrial microscopy laboratory or viewing footage of them in use as well as being given information about them. The Wellcome Trust is a good source of imagery that may be used in the delivery of this outcome.

Learning outcome 3 is relevant to contemporary issues about electricity generation and fuel economy: a comparison of the relative amounts of energy generated from different fuels and the efficiency of energy interconversions can be incorporated into both the practical calorimetry and scientific communication.

Learning outcome 4 should be integrated throughout for both delivery and assessment: any opportunity should be taken to gather and present data from the practical activities via science-based technologies. An awareness of the way in which science reaches the broader world from individual laboratories is important for all scientists and technicians. Analysis of how the media presents science is key to understanding how to present the results of scientific investigations effectively.

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 gives **an indication of the volume of learning it would take the average learner** to achieve the learning outcomes. It is **indicative and is one way of achieving the credit value**.

Learning time should address all learning (including assessment) relevant to the learning outcomes, regardless of where, when and how the learning has taken place.

Topic and suggested assignments/activities and/assessment
Introduction and overview of the unit.
Science in the media – personal study.
Laboratory to accepted theory – standard report writing and referencing.
Assignment 1: The Periodic Table (P1) Tutor introduces assignment brief
Periodic table: elements, mixtures, compounds, atomic structure and electron configuration; reactants, products.
Periodic table – atomic number and mass, periodicity (including practice).
Personal study.
Demonstration and discussion of chemical reactions (eg iron and sulphur, ethanoic acid and sodium dihydrogencarbonate).
Ionic and covalent bonding – dot-and-cross diagrams, independent research into giant covalent structures.
Acid and alkali chemistry – pH scale and preparation of pH standardised solutions; titration introduction and practical work; theory and practical work on the effects and uses of buffers.
Assignment 2: Acid-base Chemistry (P2, P9, M1, M4, D1) Tutor introduces assignment brief
Data collection and processing practice.
Personal study.
Individual support.
Section review.
Microscopy – cellular ultrastructure of eukaryotes and prokaryotes using electron micrographs.
Assignment 3: Microscopy (M2) Tutor introduces assignment brief
Use of the compound microscope – scientific drawing.
Different types of microscope – guided research task.
Energy – types, units and measurements; practical examination of devices that use and measure energy.
Relationship between gravitational potential energy and kinetic energy – calculations and examples. Experimental design.
Assignment 4: Histology (P3, P4,P5) Tutor introduces assignment brief
Microscope use – histology and scientific drawing practice.
Assignment 5: Comparative Tissue Structure (D2) Tutor introduces assignment brief
Personal study.
Assignment 6: Conservation of Energy (M3) Tutor introduces assignment brief
Practical investigation (and write-up) into conservation of energy – bouncing balls.
Individual support.
Thermal energy transfer – conduction, convection, radiation. (practical demonstrations and poster making).
Personal study.
Electricity generation – sources of energy, evaluation of media portrayal, debate on renewable energy sources.
Calorimetry practical introduction.

Topic and suggested assignments/activities and/assessment
Assignment 7: Energy (P6, P7) Tutor introduces assignment brief
Individual support.
Calorimetry practical: calorific value of fuels.
Personal study.
Scientific communication: topical debate.
Assignment 8: Scientific Communication (P8, D3) Tutor introduces assignment brief
Personal study.
Unit review.

Assessment

P1 requires learners to communicate the key features of the periodic table, atomic structure and chemical bonding. At least two groups and two periods should be discussed in terms of comparing physical and chemical properties; arrangement of elements must include a description of electron configuration and atomic radii. A minimum of two ionic and two covalently bonded molecules should be described and depicted. Suitable evidence would be an illustrated essay or presentation with accompanying notes and handouts. This could also be examined.

For P2, learners must prepare chemical solutions and test their accuracy. Learners could use dilution methods to prepare solutions of different pH values from 0.1moldm-3 HCl and 0.1moldm-3 NaOH, testing their accuracy using Universal Indicator and a pH meter. Photographic evidence may be used, or observation sheets completed by the tutor and the learner.

For P3, three drawings (at different magnifications) of histological samples are required, which must have the size of a relevant feature indicated along with the total magnification and calculation. The samples could be provided by the tutor or chosen by learners.

P4 requires learners to identify features of cells and tissues from electron micrographs. Learners will be provided with at least three electron micrographs of different tissues which they must label with the relevant features.

For P5, learners must describe structures and functions within prokaryotic and eukaryotic cells as per the unit content. Evidence for this may be an illustrated essay, presentation, poster or leaflet.

P6 requires the description of at least three different types of energy transfer, one of which must be thermal energy transfer – conduction, convection and radiation. A comment should be made on the percentage efficiency of transfers. A poster, illustrated essay, presentation or short film (if accompanied by a written timeline of where each energy transfer is discussed) would be suitable evidence.

P7 involves investigating the calorific value of different fuels. Learners must set up their own equipment, record their own results, process the data and draw conclusions from their results. A suitable experiment for this would be using the specific heat capacity of water and comparing the highest temperature reached by heating a constant volume of water for four different fuels. The comparison should be in terms of calculated energy transfer rather than simply the difference in highest temperature gained per fuel.

To achieve P8, learners must describe at least three different methods by which scientific information is communicated. Suitable evidence would be an essay or presentation.

P9 requires learners to report on a scientific investigation that has been carried out. The standard scientific report layout must be followed. This does not need to be set as a stand-alone assignment and should be met during the write-up of practical work assessed elsewhere in the unit. Scientific terminology will be used throughout as a matter of course.

For M1, learners must describe the uses and action of both acid and alkali buffer solutions. At least three examples of buffers must be given and their action as proton acceptors/donators described in terms of Le Chatelier's Principle. Chemical equations must be included and fully explained. Suitable evidence would be an essay, series of posters or short video (accompanied by a written timeline).

To meet M2, learners must produce a comprehensive review of microscopes used in laboratories. Compound, dissection, confocal, scanning and transmission electron microscopes must all be covered, including descriptions of comparative size, operation, specimen preparation and power as a minimum. An illustrated essay or presentation would be suitable evidence.

M3 requires learners to design and carry out an investigation into the theory of energy conservation. The investigation may be chosen by the tutor or through discussion with learners. A possible experiment is to investigate the gravitational potential energy and kinetic energy of different types of bouncing ball. Suitable evidence would be planning documents included within the practical write-up or alongside photographic evidence of the learner carrying out the investigation.

M4 may be met during write-ups of investigations or using data provided by the tutor. Two different hand-drawn line graphs are suitable evidence. The graphs must be proportionate to the results and of suitable size in relation to the paper. Axes must be titled with the independent variable on the x axis; appropriate labels and units given; at least four points plotted neatly and accurately to within 0.5mm. A smooth line of best fit should be used as appropriate.

D1 requires learners to carry out titrations in order to determine the concentration of two unknown acids. Learners must construct a titration curve and indicate the pKa and equivalence point, following with a calculation of the Ka and concentration of the unknown acid. The Ka should then be used to identify the acid from published data. The investigation must be written up following the format of a standard scientific report.

For D2, learners must compare different tissues that have similar functions, in terms of their structure. For example, learners must compare cardiac and skeletal muscle, or endocrine and exocrine glands, or two sense organs/receptors, clearly describing the differences between the tissues and explaining how both tissue types perform similar functions. This grading criterion requires a detailed review of the information learners have given for P5 so that the cellular components of the different tissue types can be identified and explained in terms of the functions of the tissue types. Scientific drawings learners have provided for P5 would be useful in developing greater understanding of cellular components of tissues and the relationship to the function of the tissue types.

For D3, a suitable subject may be chosen by the tutor or through discussion with learners. Learners must evaluate the impact of the media on the communication of scientific ideas to the general public. Suitable evidence for this would be an essay, presentation or short film (accompanied by a written timeline) covering the effects of at least three aspects of media communication regarding a controversial scientific issue.

Programme of suggested assignments

The following table shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the 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	The Periodic Table	Write an illustrated essay describing the key features of the periodic table, atomic structure and chemical bonding. Ensure you cover the arrangement of elements within the periodic table in terms of atomic structure, outline physical and chemical properties of groups and periods and describe how chemicals are bonded together. Use relevant examples and diagrams where relevant.	Written.
P2, P9, M1, M4, D1	Acid-base Chemistry	Practical work: preparation of standard pH solutions, including testing the accuracy of the solutions using Universal Indicator. You must carry out a titration exercise and construct an accurate titration curve to reflect your results. You must use titration and volumetric calculations to determine the concentration of the unknown acid, using a suitable indicator. The report must be in standard scientific format.	Practical and scientific report.
M2	Microscopy	Write an account of the different types of microscopes used in industry. Include the design, operation and uses of each microscope. Ensure you describe each of the following: compound, dissection, confocal, scanning electron and transmission electron microscopes	Written.
P3, P4, P5	Histology	Complete a circus of scientific drawing (including magnification calculations) of histology samples and cloze procedures based on electron micrographs of prokaryotic and eukaryotic cells.	Practical.
D2	Comparative Tissue Structure	Prepare a presentation (with handouts and notes) to describe the similarities and differences between cardiac and skeletal muscle structure and function.	Oral.
M3	Conservation of Energy	Design and carry out an investigation to compare the energy transfers between the environment and different types of bouncing ball, eg a ping-pong ball and a golf ball.	Practical/ written.
P6, P7	Energy	Produce a poster to describe and explain different types of energy transfer. You should include (and explain) units of energy, energy transfer diagrams, Sankey diagrams and methods of heat transfer.	Written.
P8, D3	Scientific Communication	Make a short film outlining the different ways in which scientific information is communicated to the public. For distinction, describe and evaluate the impact of the media on the issue of the MMR vaccine.	Visual.

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

This unit forms part of the BTEC land-based sector suite. This unit has particular links with:

Level 3
Understand the Principles of Inheritance and Genetic Manipulation
Understand the Principles of Chemistry for Biological and Medical Science
Chemistry for Biology Technicians

Essential resources

Learners will need access to laboratory resources including standard titration glassware, pH meters, compound microscopes and equipment for basic calorimetry. Library and internet access is also essential.

Employer engagement and vocational contexts

Learners in laboratory placements will have opportunities to develop their practical skills.

Indicative reading for learners

Textbooks

Bell S and Morris K – *An Introduction to Microscopy* (CRC Press, 2009) ISBN 9781420084504

Brake M and Weitkamp E – *Introducing Science Communication* (Palgrave Macmillan, 2009) ISBN 9780230573864

Cargill M and O'Connor P – *Writing Scientific Research Articles: Strategy and Steps* (Wiley- Blackwell, 2009) ISBN 9781405186193

Clark J – *Calculations in AS/A Level Chemistry* (Longman, 2000) ISBN 978058241 1272

Clegg F – *Simple Statistics* (Cambridge University Press, 1983) ISBN 9780521288026

Haines P (ed)_ – *Principles of Thermal Analysis and Calorimetry* (Royal Society of Chemistry, 2002) ISBN 9780854046102

Dean J, Jones A, Holmes D, Reed R, Weyers J and Jones A –*Practical Skills in Chemistry* (Prentice Hall, 2001) ISBN 9780130280022

Headstrom R – *Adventures With a Microscope* (Dover Publications, 2000) ISBN 9780486234717

Jones A, Reed R, and Weyers J – *Practical Skills in Biology* (Benjamin Cummings, 2007) ISBN 9780131755093

Kent M – *Advanced Biology* (Oxford University Press, 2000) ISBN 9780199141951

Lobban C and Scheffer M – *Successful Lab Reports: A Manual for Science Students* (Cambridge University Press, 1992) ISBN 9780521407410

Lowe T and Rounce J – *Calculations for A-level Physics* (Nelson Thornes, 2002) ISBN 9780748767489

Muncaster R – *A-Level Physics, Fourth Edition* (Nelson Thornes, 1993) ISBN 9780748715848

Parsons R – *Head Start to AS Level Chemistry* (Coordination Group Publications, 2008) ISBN 9781847621160

Scerri E – *The Periodic Table: Its Story and Significance* (Oxford University Press USA, 2006) ISBN 9780195305739

Toole G And Toole S – *New Understanding Biology for Advanced Level* (Nelson Thornes, 1999) ISBN 9780748739578

Van Emden J – *Effective Communication for Science and Technology* (Palgrave Macmillan, 2001) ISBN 9780333775462

Winter M – *Chemical Bonding* (Oxford University Press, 1994) ISBN 9780198556947

Journals

Analytical Chemistry

Biological Sciences Review

Journal of Biological Chemistry

Journal of Physics

New Journal of Physics

New Scientist

Websites

www.creative-chemistry.org.uk	Creative Chemistry activities and resources
www.bbc.co.uk/schools/websites/16/site/science.shtml	BBC Schools, science, 16+
www.cellsalive.com	Cells alive!
www.chembuddy.com	ChemBuddy chemical calculators
www.cleapss.org.uk	CLEAPSS
www.iop.org	Institute of Physics
www.nasw.org/resource/teaching/	National Association of Science Writers (resources)
www.revisionworld.co.uk/level-revision/physics	Revision World physics resources
www.practicalchemistry.org	Practical Chemistry
www.rsc.org/	Royal Society of Chemistry
www.scientificjournals.org/	Scientific Journals International
www.s-cool.co.uk/alevel/physics.html	S-Cool Physics
www.wellcome.ac.uk/education-resources/index.htm	The Wellcome Trust (education resources)

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies the PLTS opportunities that have been included within the assessment criteria of this unit:

Skill	When learners are ...
Independent enquirers	carrying out scientific investigations
Creative thinkers	asking questions about scientific communication
Reflective learners	interpreting electron micrographs of cellular structures
Team workers	working in groups to carry out scientific investigations
Self-managers	organising time and resources to prepare chemical solutions anticipating, taking and managing risks throughout practical work.

Although PLTS opportunities 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	selecting information to support discussions of uses and actions of buffer solutions investigating different types of microscope researching the structure of tissues that serve a similar function
Creative thinkers	researching different methods of scientific communication and the impact of the media on controversial scientific issues
Team workers	organising practical tasks
Self-managers	organising time and resources for planning and carrying out scientific investigations.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	using the internet to research background information
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	using electronic databases to identify the pKa of acids
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.	producing word processed assignments
Bring together information to suit content and purpose	producing word processed assignments
Present information in ways that are fit for purpose and audience	producing word processed assignments
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	calculating acid dissociation constants, gravitational potential energy and kinetic energy transfers
Select and apply a range of skills to find solutions	identifying unknown acids and calculating concentrations from titration curves
Use appropriate checking procedures and evaluate their effectiveness at each stage	using pH meters and indicators to assess the accuracy of preparation of pH solutions
Draw conclusions and provide mathematical justifications	investigating the theory of conservation of energy; investigating the calorific value of fuels
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	presenting information on scientific communication
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching background information using books and journals
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing written assignments.