Unit 27: Chemistry for Biology Technicians

Unit code: K/502/5557

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to provide learners with an understanding of the principles of chemistry for biology technicians and how these can be put into practice. This unit is primarily aimed at learners within a centre-based setting looking to progress into the sector or to further education and training.

Unit introduction

Biology technicians perform an enormous range of tasks including caring for a variety of animals, plants and other organisms, and preparing tissue slides in anatomy departments or pathology laboratories. They carry out microbiological tests on water or pathology specimens, make vaccines, grow cell cultures, work in infection control, investigate blood smears, carry out biochemical tests and analysis of DNA.

Biological knowledge continues to increase exponentially. In the 1970s, many textbooks would simply describe processes, explaining that underlying mechanisms were not fully understood. This has changed dramatically in recent years.

Biological processes work because of the underlying chemical processes. An understanding of chemistry is needed for any scientific role. If learners understand units of concentration, they will feel more confident in making up or diluting a solution. If they understand the nature of chemical bonding, they will know why certain solvents are used in processing tissue samples. Knowledge of chemical formulae is needed to ensure that correct chemicals are used. Learners need to understand rates of reaction and equilibrium to see why standard laboratory protocols may have timed steps.

These biological processes are complex and require a good understanding of chemistry. This unit covers some of the basic chemical concepts so learners can begin to understand and explain biological processes.

Learning outcomes

On completion of this unit a learner should:

1 Be able to relate enthalpy changes to the bonding in a range of substances

2 Be able to show how rates of reaction are affected by varying the reaction conditions

3 Be able to interpret key features of equilibrium processes

4 Be able to demonstrate the structure and properties of simple organic molecules.

Unit content

1 Be able to relate enthalpy changes to the bonding in a range of substances

Bonding: ionic; covalent; hydrophilic and hydrophobic interactions, electronegativity; dipoles; hydrogen bonds; van der Waals forces; intermolecular and intramolecular forces

Substances: salts; salt solutions; water; organic molecules; solids; liquids; gases; emulsions

Physical properties: solubility; melting and boiling point

Enthalpy and enthalpy change: system and surroundings; units of enthalpy change; standard conditions; exothermic and endothermic reactions; reaction profiles; activation energy; Hess's law; Henderson-Hasselbalch equation

2 Be able to show how rates of reaction are affected by varying the reaction conditions

Reaction rates: units (mol $dm^{-3}s^{-1}$); orders of reaction; rate constant, reaction mechanisms, rate determining steps; reaction profiles, activation energy

Factors influencing rates: collision theory; effects of changing concentration, particle size, surface area, temperature, addition of a catalyst (including enzymes)

Quantitative chemistry: calculations based on mass, mass of one mole and number of moles; calculations based on number of moles, volume and concentration; dilution; units (mol, dm^3, cm^3, mol dm^{-3}, g, g mol^{-1})

Practical work: reaction rates under varying reaction conditions eg enzyme kinetics/magnesium and hydrochloric acid/zinc and sulphuric acid

3 Be able to interpret key features of equilibrium processes

Chemical equilibrium: principles of equilibrium; equilibrium constants

Proton concentrations: pH eg Kw; strength of acids and bases; Ka, pKa; calculations of pH from Ka, and Ka from pH; conjugate acid and base; effect of pH on amino acids; action, mechanism and biological importance of buffer solutions

Concentrations either side of a membrane: diffusion and osmosis in terms of water potential (ψ); membrane potential; diffusion of gases

Redox processes: oxidation and oxidation states; reduction eg displacement reaction of metals; construction of half equations and redox equations for simple redox reactions; salt bridges; standard electrode potentials, $E^{\ominus}$; standard conditions; sign convention

4 Be able to demonstrate the structure and properties of simple organic molecules

Functional groups: nomenclature and classes of compounds: alkanes, alkenes, alcohols, alkyl halides, carboxylic acids, aldehydes, ketones, esters, amines, amides; tests for and recognition of functional groups in complex molecules

Structure: tetrahedral carbon; carbon-carbon double bonds; isomerism (structural, eg chain, positional, functional group), geometric, optical (chiral carbon, importance in natural systems); IUPAC nomenclature; monosaccharide and disaccharide structure

Properties: solubility of alkanes, alcohols and sugars; simple reactions of organic compounds (addition reactions for alkenes, oxidation of alcohols to aldehydes and ketones, oxidation of aldehydes to acids, carboxylic acids as acids, esterification, amines as bases, formation of amides)

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 experiments to illustrate the relative magnitude of the enthalpy changes associated with the formation and breakage of chemical bonds [IE, TW, SM]	**M1** explain physical properties of pure substances and solutions in terms of bonding and intermolecular forces	**D1** analyse the influence of electronegativity and size on the bonding and intermolecular forces in pure substances and solutions
P2 carry out experiments to show the effect on the rates of reactions of changes in concentration, particle size, and temperature, and of the presence of a catalyst [IE, SM]	**M2** account for the effects on rates of reactions due to changes in concentration, surface area, temperature and the presence of a catalyst	**D2** determine reaction rate equations for three reactions, the rate constants and orders of reaction
P3 carry out an experiment on osmosis to demonstrate the drive towards establishment of equilibrium [IE, SM]	**M3** describe the contribution of osmosis to physiological systems	**D3** research and explain an example of the dependence of enzyme activity on pH
P4 construct half equations and redox equations for simple redox reactions [IE]		
P5 outline how the acid dissociation constant, Ka, provides information about the extent to which acids and bases dissociate in aqueous solution [IE, 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:**	
P6	construct structural formulae for named examples of simple organic compounds, identifying structural, geometric and optical isomers where appropriate [IE]	**M4**	relate the reactions of organic molecules to the properties of their functional groups.	**D4**	carry out investigations into the solubility of compounds.
P7	list typical properties of simple organic compounds. [IE]				

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 is likely to be a mixture of classroom teaching and practical laboratory sessions. Assessment is likely to be via a portfolio of relevant evidence.

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 for themselves. This would give tutors an appreciation of the differences between industrial and centre-based laboratories and enable them to deliver this unit more effectively. Differences include the clear demarcation of 'clean' and 'contaminated' areas, 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 laboratory work and problem solving. The practical activities in this unit will develop learners' technical skills and help them to understand science, common scientific instruments, and the use of these instruments in a vocationally relevant context.

Before any practical work, 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 any practical activity starts.

Learners should be encouraged to use a standard scientific practical report format (introduction, aims/ hypothesis, materials, methods, results, discussion, conclusion, and references).

The unit content should be contextualised for all vocational routes. This could be reinforced by visits to relevant industrial organisations to enable learners to relate scientific theory to applications in relevant industrial sectors. Wherever possible, scientific theories should be applied to activity 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.

Studying blood and other bodily substances is not a banned activity (unless an employer has provided written instructions restricting the activity). A risk assessment **must** be carried out.

For learning outcome 1, learners should familiarise themselves with the theories of bonding, and develop an understanding of the behaviour of water and solutes.

The concept of polarity is central to understanding solubility. Enthalpy changes should be discussed in terms of bonds made and broken, and in terms of the energy required to overcome physical attractive forces or the energy released when physical attraction takes place. Learners do not need to carry out detailed calculations based on Hess's law, although this may be appropriate for some learners.

For learning outcome 2, learners must carry out experimental investigations on the factors affecting rate of reaction. They should also be able to make and test predictions based on changes in concentration, particle size, temperature and the use of a catalyst. Learners need to understand that enzymes are biological catalysts and should be able to describe details of a range of reactions catalysed by enzymes.

Biological technicians frequently have to make up solutions and perform dilutions. It is important for learners to understand how concentration is calculated. Learners must be able to calculate the mass of substance needed to make a given volume at a given concentration of solution. This should be linked as much as possible to practical work.

For learning outcome 3, the concept of strength of acids and bases should be investigated practically, as should the behaviour of buffer solutions. Practical work on diffusion may be carried out to develop a clearer understanding of the drive towards equilibrium.

The concept of electron transfer is easily investigated through observing the reactions of metals and metal ion solutions. Redox systems involving ions, such as manganate (VII) MnO-4 which is reduced to another water soluble ion, Mn^{2+}, should be explored. This can then be extended to biological species which may be in solution, as appropriate to learner needs.

Learners need to understand that the size of E^{θ} and its sign is related to the size of the equilibrium constant. Positive means the equilibrium constant is greater than 1 (effectively more products than reactants at equilibrium) and negative means equilibrium constant is less than 1 (effectively more reactants than products at equilibrium). High positive value means reaction effectively goes to completion.

For learning outcome 4, learners need to know that there are many classes of organic compound, and understand the concept of a functional group. They should be aware of those listed in the unit content. It is important that learners are made aware that more than one functional group may be present in a molecule of biological significance. Since certain aspects of biological activity depend on isomerism, it is important that learners recognise different types of isomers.

Physical properties such as solubility should be explored. Learners should practically investigate the oxidation of alcohols, aldehydes and esterification. The biological significance of reactions should be explained (for example oxidation of reducing sugars, fats as examples of esters, formation of amide linkages in proteins).

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 unit.
Review of periodic table and atomic structure.
Different types of bonding, physical properties of substances.
Enthalpy and enthalpy changes .
Personal study.
Assignment 1:Enthalpy (P1) Tutor introduces assignment brief
Practical investigations: endothermic and exothermic reactions, risk assessments.
Quantitative chemistry and calculations, including practical work based on preparation of solutions.
Reaction rates.
Practical investigation and discussion: rates of reaction.
Personal study.
Assignment 2: Rates of Reaction (P2, M2) Tutor introduces assignment brief
Individual support.
Personal study.

Topic and suggested assignments/activities and/assessment
Assignment 3: Reaction Rate Calculations (D2) Tutor introduces assignment brief
Principals of equilibrium, equilibrium constants, diffusion and osmosis.
Personal study.
Assignment 4: Osmosis (P3, M3) Tutor introduces assignment brief
Practical work needs to be spread over two days.
pH calculations, effect of pH on amino acids and enzymes.
Individual support.
Assignment 5: Enzymes and pH (P5, D3) Tutor introduces assignment brief
Personal study.
Redox processes, salt bridges, construction of half equations and redox equations.
Assignment 6: Redox (P4) Tutor introduces assignment brief
Practical work – displacement reactions of metals.
Personal study.
Assignment 7: Bonding, Intermolecular Forces and Functional Groups (P6, P7, M1, M4, D1) (Ongoing completion of a booklet) Tutor introduces assignment brief
Nomenclature and classes of compounds.
Structure of simple organic molecules – molecular models, internet research.
Personal study.
Properties of simple organic molecules.
Assignment 8: Solubility (D4) Tutor introduces assignment brief
Practical work: testing for functional groups, solubility of compounds.
Personal study.
Individual support.
Unit review.

Assessment

For P1, learners must carry out experiments to investigate the enthalpy change associated with a reaction chosen by the tutor. Learners need to follow a protocol. They do not have to plan the experiment themselves but they must compare the observed enthalpy change with an accepted value for that reaction and make relevant comments on any discrepancy. Suitable evidence for this is an observation record completed by the tutor and learner, along with associated calculations and comparisons.

For P2, learners need to obtain suitable results from practical experiments on the effect of changes of concentration, particle size, temperature, and the presence of a catalyst, on rates of reaction. This could be assessed at the same time as M2. Suitable evidence would be observation sheets from the practical

investigation.

P3 involves investigating the process of osmosis. Learners could place pieces of vegetable into solutions of varying concentrations of sucrose and monitor the change in mass due to the uptake or loss of water in each case, plotting the results on a suitable graph. They then need to apply their knowledge of the processes of diffusion and osmosis to explain their observations. Suitable evidence would be the write-up of the investigation (in standard scientific format).

P4 requires learners to construct half equations and redox equations for simple redox reactions. At least three biologically-relevant redox reactions must be covered. Suitable evidence would be an illustrated factsheet describing redox reactions.

For P5, learners need to explain the link between Ka and the dissociation of acids and bases. Learners must calculate the pH of two acids and two bases from experimental data or from data provided by the tutor. This could form part of a practical write-up or stand-alone essay.

P6 requires learners to construct structural formulae for named examples of simple organic compounds, identifying structural, geometric and optical isomers where appropriate. At least five examples should be named by the tutor. This could be conducted as a short-answer test or as part of an essay, where P7 may also be covered.

For P7, learners must list the typical properties of at least five simple organic compounds named by the tutor. This could be conducted as a short-answer test or as part of an essay, where P6 may also be covered.

For M1, learners should be given data on the physical properties of at least five pure substances and solutions. They should then use this data to write a report explaining these properties in terms of the bonding and intermolecular forces present.

M2 should be carried out at the same time as P2 as it involves a more in-depth explanation of the observed data. As part of M2 there must be discussion of activation energy, reaction profiles, orders of reaction, reaction mechanisms and rate determining steps. Evidence may also be presented as a stand-alone essay.

For M3, learners must fully describe the process of osmosis, including at least two examples of osmotic action in physiological systems. A discussion of the calculation of water potential, with examples, is also required. Evidence for M3 may be an extension of P3 (as part of the write-up), an essay or presentation with notes.

M4 requires learners to relate the reactions of organic molecules to the properties of their functional groups. This may follow on from laboratory practical work investigating tests for functional groups, where learners explain their results, or may follow on from assessment of P6 and/or P7, in which case suitable evidence would be in the same format. At least five reactions and functional groups must be described.

For D1, learners must interpret secondary data to analyse the influence of electronegativity and size on the bonding and intermolecular forces in pure substances and solutions. At least eight pure substances and solutions, which should be chosen by the tutor, must be fully covered. This may be in the form of a short-answer question paper, which could be assessed with P6, P7 and M4. Other suitable evidence would be an annotated poster or illustrated essay.

D2 requires learners to determine reaction rate equations for three reactions, the rate constants and orders of reaction. This should be determined experimentally by learners who then present their results in a meaningful context, comparing them to published data and explaining their significance.

For D3, learners must understand the mode of action of a particular enzyme in terms of substrate and binding site. They must explain how pH affects the chemical nature of the enzyme and describe the importance of maintaining a particular pH during enzyme-catalysed reactions both in vivo and during scientific investigations (in vitro).

D4 requires learners to investigate the solubility of compounds. At least two different solvents must be used and a minimum of eight compounds investigated. Evidence for this criterion would be the plan and write-up of the investigation in standard scientific format.

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	Enthalpy	Follow a protocol in order to measure the temperature change (over a length of time) associated with the displacement reaction $Zn(s) + Cu2+(aq) \rightarrow Zn\ 2+(aq) + Cu(s)$ then calculate the enthalpy change and compare it to the accepted value (-217kJ mol-1). Comment on any difference between the observed and accepted value.	Practical.
P2, M2	Rates of Reaction	Follow a protocol in order to investigate the effect of changes in concentration, surface area and temperature of a reaction, such as that between magnesium and hydrochloric acid. Then follow an additional protocol to observe the effects of a copper catalyst on the reaction between zinc and sulphuric acid. Carry out research and use this to account for the observed effects each variable has on the rate of reaction. The following must be covered within the discussion: activation energy, reaction profiles, orders of reaction, reaction mechanisms and rate determining steps.	Practical. Written.
D2	Reaction Rate Calculations	Follow a protocol to determine the reaction rate equations, rate constants and orders of reaction for three different chemical reactions.	Practical. Written.
P3, M3	Osmosis	Follow a protocol to investigate mass gained and/or lost when discs of potato (of equal initial mass) are placed into varying concentrations of sugar solution. Make the solutions from a stock concentration. Create a graph of your data and comment on your observations in terms of the processes of diffusion and osmosis. For M3, the write-up must be detailed and include reference to the importance of osmosis in at least two different physiological situations. The discussion must also include an explanation of water potential and an example of how it is calculated.	Practical. Written.
P4	Redox	Describe the processes of reduction and oxidation, illustrating the biological importance of redox processes using at least three biologically relevant redox reactions. Half equations and redox equations must be included for each.	Written.

Criteria covered	Assignment title	Scenario	Assessment method
P5, D3	Enzymes and pH	Follow a protocol to make standard pH solutions, carrying out tests to determine the accuracy of your preparations. Then outline how the acid dissociation constant, Ka, provides information about the extent to which acids and bases dissociate in aqueous solutions and thus the meaning of the pH scale. This must include example calculations of the pH of two acids and two bases from given experimental data. For D3, you need to discuss how pH affects both the substrate and the chemical nature of the enzyme in terms of binding site. You also need to describe the importance of maintaining pH during enzyme-catalysed reactions both in vivo and during scientific investigations.	Written.
P6, P7, M1, M4, D1	Bonding, Inter-molecular Forces and Functional Groups	Complete a short-answer booklet involving the construction of at least five structural formulae, and identification of structural, geometric and optical isomers. You also need to list typical properties of at least five simple organic compounds. For P6 and P7, you need to have at least five correct answers (for example five structural formulae plus five correctly identified isomers and so on). For M4, you also need to explain the relationship between the reactions of organic compounds and the functional groups they contain. This involves an explanation of the positive results for testing for at least five functional groups, at least six of which must be correct to achieve M4. You will be given data on at least eight pure substances and solutions, which you must interpret to analyse the influence of electronegativity and size on the bonding and intermolecular forces on those molecules. At least eight of these must be correct in order to achieve D1.	Written.
D4	Solubility	Follow a protocol to investigate the solubility of eight different compounds in two different solvents. Write up your investigation in standard scientific format.	Practical. Written.

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 Chemistry for Biological and Medical Science
Fundamentals of Science

Essential resources

Learners need access to standard laboratory facilities, including glassware and suitable chemical resources to carry out their investigations. Access to the internet and to a library with good quality scientific textbooks is also essential.

Employer engagement and vocational contexts

Placements in chemical, biological or biochemical laboratories will enhance the content and relevance of this unit. Centres are encouraged to make links with suitable organisations to facilitate these placements.

Indicative reading for learners

Textbooks

Chapman C – *Basic Chemistry for Biology* (McGraw-Hill Education, 1998) ISBN 9780697360878

Clark J – *Calculations in AS/A Level Chemistry* (Longman, 2000) ISBN 9780582411272

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

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

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

Sackheim G – *An Introduction to Chemistry for Biology Students 9th Edition* (Pearson Education, 2007) ISBN 9780805395716

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

Journals

Analytical Chemistry

Biological Sciences Review

Journal of Biological Chemistry

New Scientist

Websites

www.alevelchemistry.co.uk	A-Level chemistry notes
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.chembuddy.com	ChemBuddy chemical calculators
www.chemguide.co.uk	Chemguide
www.cleapss.org.uk	CLEAPSS
www.practicalchemistry.org	Practical Chemistry
www.rsc.org	Royal Society of Chemistry
www.scientificjournals.org	Scientific Journals International
www.wellcome.ac.uk/	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 experiments into enthalpy changes, rates of reactions and osmosis investigating the acid dissociation constant identifying isomers and typical properties of organic compounds
Team workers	carrying out experiments into enthalpy changes, rates of reactions and osmosis
Self-managers	carrying out experiments into enthalpy changes, rates of reactions and osmosis researching the extent to which acids and bases dissociate in aqueous solutions.

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	planning and carrying out research into enzyme activity
Creative thinkers	relating collision theory to observed rates of chemical reactions
Reflective learners	producing scientific reports and presentations based on scientific theory and their own investigations
Team workers	carrying out practical investigations
Self-managers	carrying out practical investigations carrying out research into electronegativity and solubility.

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 the properties of simple organic compounds
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	using online libraries to source relevant scientific literature
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	analysing results of investigations and presenting results in written reports producing poster presentations and other presentations
Bring together information to suit content and purpose	producing word processed scientific reports
Present information in ways that are fit for purpose and audience	producing posters, presentations and illustrated essays for assignments
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	relating the changes in enthalpy to the type of bonding present a range of substances studying quantitative chemistry and chemical equilibrium
Identify the situation or problem and the mathematical methods needed to tackle it	designing scientific investigations
Select and apply a range of skills to find solutions	analysing results of practical investigations
Use appropriate checking procedures and evaluate their effectiveness at each stage	
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	analysing results of practical investigations
Draw conclusions and provide mathematical justifications	discussing results of practical investigations

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	discussing isomerism in simple organic compounds
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	using books and journals to research background information on scientific theories
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing written assignments.