Unit title: Chemistry for Applied Biologists

Unit code: **K/601/0292**

QCF level: **5**

Credit value: **15**

Aim

This unit covers bonding, thermodynamics, reaction rates, equilibrium, oxidation and reduction and organic chemistry that are necessary to facilitate understanding of aspects of the biological sciences.

Unit abstract

Biological subjects such as biochemistry, genetics, pharmacology and physiology require an understanding of chemical concepts. Learners who have studied chemistry to Level 3 are likely to have sufficient background knowledge to gain a full understanding of the chemical aspects of these subjects.

This unit will help learners who may not have studied chemistry at Level 3 or learners who have not applied chemical knowledge for some time. On completion of this unit, learners should be more familiar with topics such as reactions of organic functional groups, intermolecular interactions, equilibrium, membrane potential, biochemical pathways involving oxidation and reduction, enzyme catalysis, pH and ionisation of amino acids.

The unit involves use of illustrative practical work and analysis of data and information to explain the chemical and physical behaviour of substances.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand how chemical bonding affects chemical and physical properties of molecules

2 Be able to relate feasibility of reactions to thermodynamic quantities

3 Understand the features of equilibrium processes

4 Understand the chemical behaviour of the main classes of organic compounds.

Unit content

1 **Understand how chemical bonding affects chemical and physical properties of molecules**

Chemical bonding: ionic; covalent; polar covalent; metallic; electrostatic interactions; intermolecular forces; Van der Waals forces; dipole-dipole interactions; hydrogen bonding

Physical properties: melting point; boiling point; electrical conductivity; surface tension; solubility

Enthalpy changes: reaction profile; activation energy; endothermic; exothermic; sign of ΔH; standard conditions; ΔH^{θ}; Hess's Law; enthalpy of combustion; enthalpy of formation; other types of enthalpy eg enthalpy of dissociation, mean bond enthalpy, enthalpy of solution, lattice enthalpy, enthalpy of hydration; enthalpy associated with breaking and making bonds; thermodynamic tables

Factors affecting rate of chemical reactions: concentration; particle size; temperature; presence of a catalyst

Effect of factors on rate: number of collisions per second; surface area; reaction profile; activation energy; distribution curve of particle energy at a given temperature; change in shape of distribution curve with temperature; number of particles with sufficient energy to react; lower activation energy in presence of a catalyst; enzymes as catalysts; examples of reactions

2 **Be able to relate feasibility of reactions to thermodynamic quantities**

Thermodynamic quantities: enthalpy; entropy; Gibb's energy; standard enthalpy change, ΔH^{θ}; standard entropy change ΔS^{θ}; standard change in Gibb's energy ΔG^{θ}; $\Delta G = 0$ as the condition for equilibrium; ΔG being negative for a reaction where products predominate; ΔG being positive for a reaction where reactants predominate; feasibility; sign of ΔG^{θ}; exergonic; endergonic

Oxidation and reduction: oxidation as loss of electrons; reduction as gain of electrons; half equations; overall redox equation; requirement to balance overall reaction in terms of the number of electrons; oxidation numbers

Standard reduction potentials: simple metal ion/metal half cells; half cells with a redox couple in solution and a platinum electrode; biological examples of redox half cells eg NAD^+/NADH; E^{θ}_{cell}; sign and magnitude of E^{θ}_{cell}; feasibility of reactions

3 **Understand the features of equilibrium processes**

Features: rates of forward and reverse reactions; sign of ΔH for forward and reverse reactions; dynamic equilibrium; concentration of reactants and products at equilibrium; examples eg osmosis, partition, dissociation of weak acids, Fe^{3+}/SCN^-

Calculated equilibrium constants: calculation of K_c from concentrations of reactants and products at equilibrium; meaning of magnitude of equilibrium constant

Effect of changes in conditions on equilibrium: concentration; pressure; pressure changes affecting reactions which involve gases; dependence on effect of pressure of the change in stoichiometric number for the reaction; temperature; dependence on effect of temperature of the sign of the enthalpy change; catalyst; Le Chatelier's Principle

pH and acid dissociation constant: Bronsted-Lowry theory; pH = - log $[H^+]$, ionic product for water $K_w = [H^+][OH^-] = 1 \times 10^{-14}$; pH of acidic solutions, neutral and alkaline solution; strong and weak acids; K_a; pKa; calculation of the pH of a weak acid solutions; Henderson Hasselbach equation; buffer solutions; ionisation of amino acids in solutions of different pH

4 **Understand the chemical behaviour of the main classes of organic compounds**

Bonding: spd notation; concept of sp^3, sp^2 and sp hybridisation of carbon, σ and π bonds, delocalisation; bond lengths; examples of compounds eg ethane, ethene, benzene; lone pairs of electrons in compounds containing nitrogen, oxygen and halogens

Classes of organic compounds: alkanes; alkenes; alcohols; haloalkanes; aldehydes; ketones; carboxylic acids; esters; amines; amides

Names and structural formulae: International Union of Pure and Applied Chemistry (IUPAC) system; full structural formulae; shortened structural formulae; other representations eg three dimensional, Fisher projection; functional groups

Main reactions of organic compounds: alkanes eg combustion and free radical substitution; alkenes addition eg Br_2, HBr, H_2, H_2O; alcohols eg oxidation of primary, secondary and tertiary, esterification; haloalkanes eg substitution; carboxylic acids eg reaction with base, esterification; esters eg hydrolysis to alcohol and acid; amines eg as bases

Isomerism: structural (chain, positional, functional group); stereoisomerism (geometric); optical; biological examples

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 Understand how chemical bonding affects chemical and physical properties of molecules	1.1 explain the physical properties of substances in terms of their chemical bonding 1.2 explain enthalpy changes in terms of bonding and interactions 1.3 explain the effect of various factors on rates of chemical reactions
LO2 Be able to relate feasibility of reactions to thermodynamic quantities	2.1 use values of thermodynamic state functions to assess the feasibility of reactions 2.2 write oxidation and reduction half equations for given reactions 2.3 categorise reactions as oxidation/reduction (redox) on the basis of oxidation numbers 2.4 justify the feasibility of redox reactions in terms of standard reduction potentials
LO3 Understand the features of equilibrium processes	3.1 explain the features of equilibrium processes 3.2 interpret the values of calculated equilibrium constants 3.3 explain the effects of changes in conditions on the position of chemical equilibrium 3.4 explain the relationship between acid dissociation constant and pH
LO4 Understand the chemical behaviour of the main classes of organic compounds	4.1 explain how bonding in organic molecules relates to shape 4.2 relate classes of organic compounds to the presence of functional groups 4.3 relate names of compounds to their structural formulae 4.4 write equations for the main reactions of organic compounds 4.5 relate types of isomerism in organic compounds to shapes.

Guidance

Links

This unit has particular links with the following units within this qualification:

- *Unit reference number L/601/0219: Laboratory Techniques for Applied Biology*
- *Unit reference number F/601/0217: Biochemistry of Macromolecules and Metabolic Path*
- *Unit reference number D/601/0225: Molecular Biology and Genetics.*

Essential requirements

Delivery

Where possible, the unit content must be contextualised in terms of biological systems. Learners are likely to have a wide range of prior chemistry knowledge. It may be necessary to revise basic concepts before starting the unit. This is likely to include Atomic Number, Mass Number, electronic arrangement, chemical formulae, writing simple formulae, writing and balancing equations and performing calculations involving molar mass, mass, number of moles, volume and concentration.

For learning outcome 1, it is essential to explore the effects of intermolecular forces, for example hydrogen bonding, on physical properties.

Learners must become familiar with reaction profiles for exothermic and endothermic processes. Tables of values of enthalpy of formation and mean bond enthalpy can be used in calculations based on Hess's Law. Learners must understand that there are enthalpy changes associated with physical processes such as melting and condensation.

Learners must be able to explain the effect of changes in concentration, particle size, temperature and presence of a catalyst in terms of collision theory, reaction profile and the distribution curve for the energy of molecules at a particular temperature.

Negative enthalpy change and positive entropy change may be introduced as contributing to the feasibility of a reaction. Learners can be taught to calculate ΔH^{θ} and ΔS^{θ} from thermodynamic tables and hence ΔG^{θ} from $\Delta H^{\theta} - T\Delta S^{\theta}$. They can work out whether reactants or products are likely to predominate under standard conditions from the sign of ΔG^{θ} and whether the reaction is likely to go virtually to completion or not to take place at all under standard conditions from the magnitude of ΔG^{θ}.

Since many reactions of biochemical significance involve oxidation and reduction (redox), for learning outcome 2, learners must become familiar with the terminology and features of redox before introducing standard reduction potentials as a method of assessing feasibility of redox reactions. Biological examples must be used where possible.

For learning outcome 3, learners must carry out practical exercises involving equilibrium processes, in order to appreciate that equilibrium may be reached from different initial concentrations.

Learners must be introduced to the Bronsted-Lowry theory of acids as proton donors and bases as proton acceptors. After introducing the concept of weak acids and acid dissociation constant, learners should be able to draw conclusions about the strength of acids, given values of acid dissociation constants and values of pK_a from tables.

Learners must be introduced to spd notation for the electronic arrangement of atoms. Learners must be familiar with the shapes of atomic orbitals before hybridisation is introduced. They must understand the nature of the overlap needed to produce sigma bonds and pi bonds. Learners must be familiar with different representations of organic molecules and also the different biochemical properties of isomers. Molecular model kits can be used to help learners understand the three dimensional qualities of molecules.

Assessment

For learning outcome 1, learners must be given the opportunity to calculate enthalpy changes and to explain the size and sign of the results in terms of the associated bonding and interaction. This may include physical processes.

For learning outcome 2, feasibility is likely to only relate to standard conditions. Learners may calculate values of ΔS^θ from tables of standard molar entropy of substances and values of ΔH^θ from tables of standard enthalpy changes for formation. The resulting values of ΔG^θ may be used to predict whether reactions are feasible under standard conditions. The sign and magnitude of the cell voltage should be used to justify whether, under standard conditions, a reaction is likely to go to completion, be an equilibrium process or hardly take place at all.

For learning outcome 3, learners could carry out measurements to determine equilibrium constants, or be given values for concentrations to calculate equilibrium constants. Assessment should involve straightforward substitution of values into equations. In explaining the relationship between acid dissociation constant and pH, learners must demonstrate the ability to calculate the pH of a weak acid solution and a buffer solution.

The emphasis in learning outcome 4 is on breadth, rather than depth. Assessment of knowledge of bonding could be based on specific straightforward molecules, involving sp^3 and sp^2 orbitals which form sigma bonds and p orbitals which form pi bonds or which are lone pairs of non-bonding electrons. It is expected that learners will name molecules whose structure is given and provide representations of the structures, given the names.

Resources

Learners will need access to appropriate laboratory, library and IT facilities.

Employer engagement and vocational contexts

Where possible, learners should have the opportunity to listen to speakers from industry. Visits would also be useful, for example to a pathology laboratory of a local hospital.

