**A comparison of the Chemistry Study Design Units 3 and 4 2024-2027 to the Chemistry Study Design which concludes in 2023.**

Prepared by Lanna Derry for CEA VCE Implementation workshops, October 2023 – Please note that some similarities between the two study designs have been taken ‘in spirit’ rather than highlighting small changes in terminology.

Key Knowledge points extracted from VCE Chemistry Study Designs © VCAA 2022 and 2016

Colour code – blue = new (or changed emphasis or newly explicit reference) in 2024, red = removed from 2017-2023 SD

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| **Key science skills (2024 Study design only shown here)** |
| Develop aims and questions, formulate hypotheses and make predictions:  • identify, research and construct aims and questions for investigation  • identify independent, dependent and controlled variables in controlled experiments  • formulate hypotheses to focus investigations  • predict possible outcomes of investigations |
| Plan and conduct investigations:  • determine appropriate investigation methodology: case study; classification and identification; controlled experiment; correlational study; fieldwork; literature review; modelling; product, process or system development; simulation  • design and conduct investigations; select and use methods appropriate to the selected investigation methodology, including consideration of sampling technique and size, equipment and procedures, taking into account potential sources of error and causes of uncertainty; determine the type and amount of qualitative and/or quantitative data to be generated or collated  • work independently and collaboratively as appropriate and within identified research constraints, adapting or extending processes as required and recording such modifications |
| Comply with safety and ethical guidelines:  • demonstrate safe laboratory practices when planning and conducting investigations by using risk assessments that are informed by safety data sheets (SDS), and accounting for risks  • apply relevant occupational health and safety guidelines while undertaking practical investigations  • demonstrate ethical conduct when undertaking and reporting investigations |
| Generate, collate and record data:  • systematically generate and record primary data, and collate secondary data, appropriate to the investigation, including use of databases and reputable online data sources  • record and summarise both qualitative and quantitative data, including use of a logbook as an authentication of generated or collated data  • organise and present data in useful and meaningful ways, including schematic diagrams, flow charts, tables, bar charts and line graphs  • plot graphs involving two variables that show linear and non-linear relationships |
| Analyse and evaluate data and investigation methods:  • process quantitative data using appropriate mathematical relationships and units, including calculations of ratios, percentages, percentage change and mean  • use appropriate numbers of significant figures in calculations  • identify and analyse experimental data qualitatively, handling where appropriate concepts of: accuracy, precision, repeatability, reproducibility, resolution, and validity of measurements; errors (random and systematic); and uncertainty in data  • identify outliers, and contradictory, provisional or incomplete data  • repeat experiments to ensure findings are robust  • evaluate investigation methods and suggest ways to improve accuracy and precision, and to reduce the likelihood of errors |
| Construct evidence-based arguments and draw conclusions:  • distinguish between opinion, anecdote and evidence, and scientific and non-scientific ideas  • evaluate data to determine the degree to which the evidence supports the aim of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation  • evaluate data to determine the degree to which the evidence supports or refutes the initial prediction or hypothesis  • use reasoning to construct scientific arguments, and to draw and justify conclusions consistent with the evidence and relevant to the question under investigation  • identify, describe and explain the limitations of conclusions, including identification of further evidence required  • discuss the implications of research findings and proposals |
| Analyse, evaluate and communicate scientific ideas:  • use appropriate chemical terminology, representations and conventions, including standard abbreviations, graphing conventions, units of measurement and significant figures  • discuss relevant chemical information, ideas, concepts, theories and models and the connections between them  • analyse and explain how models and theories are used to organise and understand observed phenomena and concepts related to chemistry, identifying limitations of selected models/theories  • critically evaluate and interpret a range of scientific and media texts (including journal articles, mass media communications and opinions in the public domain), processes, claims and conclusions related to chemistry by considering the quality of available evidence  • apply sustainability concepts (green chemistry principles, development goals and the transition from a linear towards a circular  economy) to analyse and evaluate responses to chemistry-based scenarios, case studies, issues and challenges  • identify and explain when judgments or decisions associated with chemistry-related issues may be based on sociocultural, economic, political, legal and/or ethical factors and not solely on scientific evidence  • use clear, coherent and concise expression to communicate to specific audiences and for specific purposes in appropriate scientific genres, including scientific reports and posters  • acknowledge sources of information and assistance, and use standard scientific referencing conventions |

**Unit 3: How can design and innovation contribute to optimising chemical processes?**

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| **2024 – 2027 Study design** | **OLD COURSE: 2017-2023 Study design** |
| **Area of study 1: What are the options for producing chemical energy?**  **Outcome 1:** On completion of this unit the student should be able to compare fuels quantitatively with reference to combustion products and energy outputs, apply knowledge of the electrochemical series to design, construct and test primary cells and fuel cells, and evaluate the sustainability of electrochemical cells in producing energy for society. | **Area of study 1: What are the options for energy production?**  **Outcome 1:** On completion of this unit the student should be able to compare fuels quantitatively with reference to combustion products and energy outputs, apply knowledge of the electrochemical series to design, construct and test galvanic cells, and evaluate energy resources based on energy efficiency, renewability and environmental impact. |
| **Key knowledge** | |
| **Carbon-based fuels** | Obtaining energy from fuels |
| * the definition of a fuel, including the distinction between fossil fuels (coal, natural gas, petrol) and biofuels (biogas, bioethanol, biodiesel) with reference to their renewability (ability of a resource to be replaced by natural processes within a relatively short period of time) * fuel sources for the body measured in kJ g-1: carbohydrates, proteins and lipids (fats and oils) * photosynthesis as the process that converts light energy into chemical energy and as a source of glucose and oxygen for respiration in living things: 6CO2(g) + 6H2O(l) → C6H12O6(aq)+ 6O2(g) * oxidation of glucose as the primary carbohydrate energy source, including the balanced equation for cellular respiration: C6H12O6(aq) + 6O2(g) ⭢ 6CO2(g) + 6H2O(l) * production of bioethanol by the fermentation of glucose and subsequent distillation to produce a more sustainable transport fuel: C6H12O6(aq) → 2C2H5OH(aq) + 2CO2(g) * comparison of exothermic and endothermic reactions, with reference to bond making and bond breaking, including enthalpy changes (∆*H*) measured in kJ, molar enthalpy changes measured in kJ mol-1 and enthalpy changes for mixtures measured in kJ g-1, and their representations in energy profile diagrams * determination of limiting reactants or reagents in chemical reactions * combustion (complete and incomplete) reactions of fuels as exothermic reactions: the writing of balanced thermochemical equations, including states, for the complete and incomplete combustion of organic molecules using experimental data and data tables | • the definition of a fuel, including the distinction between fossil fuels and biofuels with reference to origin and renewability (ability of a resource to be replaced by natural processes within a relatively short period of time)  • combustion of fuels as exothermic reactions with reference to the use of the joule as the SI unit of energy, energy transformations and their efficiencies and measurement of enthalpy change including symbol (Δ*H*) and common units (kJ mol-1, kJ g-1, MJ/tonne)  • the writing of balanced thermochemical equations, including states, for the complete and incomplete combustion of hydrocarbons, methanol and ethanol, using experimental data and data tables  • the definition of gas pressure including units, the universal gas equation and standard laboratory conditions (SLC) at 25 °C and 100 kPa *[moved to U2 AoS2]*  • calculations related to the combustion of fuels including use of mass-mass, mass-volume and volume-volume stoichiometry in calculations of enthalpy change (excluding solution stoichiometry) to determine heat energy released, reactant and product amounts and net volume of greenhouse gases at a given temperature and pressure (or net mass) released per MJ of energy obtained  • the use of specific heat capacity of water to determine the approximate amount of heat energy released in the combustion of a fuel. |
| **Measuring changes in chemical reactions** | **Fuel choices** |
| * calculations related to the application of stoichiometry to reactions involving the combustion of fuels, including mass-mass, mass-volume and volume-volume stoichiometry, to determine heat energy released, reactant and product amounts and net volume or mass of major greenhouse gases  (CO2, CH4 and H2O), limited to standard laboratory conditions (SLC) at 25 °C and 100 kPa * the use of specific heat capacity of water to approximate the quantity of heat energy released during the combustion of a known mass of fuel and food * the principles of solution calorimetry, including determination of calibration factor and consideration of the effects of heat loss; analysis of temperature-time graphs obtained from solution calorimetry * energy from fuels and food: * calculation of energy transformation efficiency during combustion as a percentage of chemical energy converted to useful energy * comparison and calculations of energy values of foods containing carbohydrates, proteins and fats and oils | • the comparison of fossil fuels (coal, crude oil, petroleum gas, coal seam gas) and biofuels (biogas, bioethanol, biodiesel) with reference to energy content, renewability and environmental impacts related to sourcing and combustion  • the comparison of the suitability of petrodiesel and biodiesel as transport fuels with reference to sources, chemical structures, combustion products, flow along fuel lines (implications of hygroscopic properties and impact of outside temperature on viscosity) and the environmental impacts associated with their extraction and production. |
| **Primary galvanic cells and fuel cells as sources of energy** | **Galvanic cells as a source of energy** |
| * redox reactions as simultaneous oxidation and reduction processes, and the use of oxidation numbers to identify the reducing agent, oxidising agent and conjugate redox pairs * the writing of balanced half-equations (including states) for oxidation and reduction reactions, and the overall redox cell reaction in both acidic and basic conditions * the common design features and general operating principles of non-rechargeable (primary) galvanic cells converting chemical energy into electrical energy, including electrode polarities and the role of the electrodes (inert and reactive) and electrolyte solutions (details of specific cells not required) * the use and limitations of the electrochemical series in designing galvanic cells and as a tool for predicting the products of redox reactions, for deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions * the common design features and general operating principles of fuel cells, including the use of porous electrodes for gaseous reactants to increase cell efficiency (details of specific cells not required) * the application of Faraday’s Laws and stoichiometry to determine the quantity of galvanic or fuel cell reactant and product, and the current or time required to either use a particular quantity of reactant or produce a particular quantity of product * contemporary responses to challenges and the role of innovation in the design of fuel cells to meet society’s energy needs, with reference to green chemistry principles: design for energy efficiency, and use of renewable feedstocks | • redox reactions with reference to electron transfer, reduction and oxidation reactions, reducing and oxidising agents, and use of oxidation numbers to identify conjugate reducing and oxidising agents  • the writing of balanced half-equations for oxidation and reduction reactions and balanced ionic equations, including states, for overall redox reactions  • galvanic cells as primary cells and as portable or fixed chemical energy storage devices that can produce electricity (details of specific cells not required) including common design features (anode, cathode, electrolytes, salt bridge and separation of half-cells) and chemical processes (electron and ion flows, half-equations and overall equations)  • the comparison of the energy transformations occurring in spontaneous exothermic redox reactions involving direct contact between reactants (transformation of chemical energy to heat energy) compared with those occurring when the reactants are separated in galvanic cells (transformation of chemical energy to electrical energy)  • the use of the electrochemical series in designing and constructing galvanic cells and as a tool for predicting the products of redox reactions, deducing overall equations from redox half-equations and determining maximum cell voltage under standard conditions. |
| **Fuel cells as sources of energy** |
| * the common design features of fuel cells including use of porous electrodes for gaseous reactants to increase cell efficiency (details of specific cells not required)   • the comparison of the use of fuel cells and combustion of fuels to supply energy with reference to their energy efficiencies (qualitative), safety, fuel supply (including the storage of hydrogen), production of greenhouse gases and applications  • the comparison of fuel cells and galvanic cells with reference to their definitions, functions, design features, energy transformations, energy efficiencies (qualitative) and applications. |

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| **Area of study 2: How can the rate and yield of chemical reactions be optimised?**  **Outcome 2:** On completion of this unit the student should be able to experimentally analyse chemical systems to predict how the rate and extent of chemical reactions can be optimised, explain how electrolysis is involved in the production of chemicals, and evaluate the sustainability of electrolytic processes in producing useful materials for society. | | **Area of study 2: How can the yield of chemical reactions be optimised?**  On completion of this unit the student should be able to apply rate and equilibrium principles to predict how the rate and extent of reactions can be optimised, and explain how electrolysis is involved in the production of chemicals and in the recharging of batteries. |
| **Key knowledge** | | |
| **Rates of chemical reactions** | **Rate of chemical reactions** | |
| * factors affecting the frequency and success of reactant particle collisions and the rate of a chemical reaction in open and closed systems, including temperature, surface area, concentration, gas pressures, presence of a catalyst, activation energy and orientation * the role of catalysts in increasing the rate of specific reactions, with reference to alternative reaction pathways of lower activation energies and represented using energy profile diagrams | | • chemical reactions with reference to collision theory, including qualitative interpretation of Maxwell-Boltzmann distribution curves  • the comparison of exothermic and endothermic reactions including their enthalpy changes and representations in energy profile diagrams  • factors affecting the rate of a chemical reaction including temperature, surface area concentration of solutions, gas pressures and presence of a catalyst  • the role of catalysts in changing the rate of chemical reactions with reference to alternative reaction pathways and their representation in energy profile diagrams. |
| **Extent of chemical reactions** | | **Extent of chemical reactions** |
| * the distinction between reversible and irreversible reactions, and between rate and extent of a reaction * the dynamic nature of homogenous equilibria involving aqueous solutions or gases, and their representation by balanced chemical or thermochemical equations (including states) and by concentration-time graphs * the change in position of equilibrium that can occur when changes in temperature or species or volume (concentration or pressure) are applied to a system at equilibrium, and the representation of these changes using concentration-time graphs * the application of Le Chatelier’s principle to identify factors that favour the yield of a chemical reaction * calculations involving equilibrium expressions (including units) for a closed homogeneous equilibrium system and the dependence of the equilibrium constant (*K*) value on the system temperature and the equation used to represent the reaction * the reaction quotient (*Q*) as a quantitative measure of the extent of a chemical reaction: that is, the relative amounts of products and reactants present during a reaction at a given point in time * responses to the conflict between optimal rate and temperature considerations in producing equilibrium reaction products, with reference to the green chemistry principles of catalysis and designing for energy efficiency | | the distinction between reversible and irreversible reactions, and between rate and extent of a reaction  • homogenous equilibria involving aqueous solutions or gases with reference to collision theory and representation by balanced chemical or thermochemical equations (including states) and by concentration-time graphs  • calculations involving equilibrium expressions and equilibrium constants (*Kc* only) for a closed homogeneous equilibrium system including dependence of value of equilibrium constant, and its units, on the equation used to represent the reaction and on the temperature  • Le Chatelier’s principle: identification of factors that favour the yield of a chemical reaction, representation of equilibrium system changes using concentration-time graphs and applications, including competing equilibria  involved in the occurrence and treatment of carbon monoxide poisoning resulting from incomplete combustion of fuels. |
| **Production of chemicals using electrolysis** | | **Production of chemicals by electrolysis** |
| * the use and limitations of the electrochemical series to explain or predict the products of the electrolysis of particular chemicals, given their state (molten liquid or in aqueous solution) and the electrode materials used, including the writing of balanced equations (with states) for the reactions occurring at the anode and cathode and the overall redox reaction for the cell * the common design features and general operating principles of commercial electrolytic cells (including, where practicable, the removal of products as they form), and the selection of suitable electrode materials, the electrolyte (including its state) and any chemical additives that result in a desired electrolysis product (details of specific cells not required) * the common design features and general operating principles of rechargeable (secondary) cells, with reference to discharging as a galvanic cell and recharging as an electrolytic cell, including the conditions required for the cell reactions to be reversed and the electrode polarities in each mode (details of specific cells not required) * the role of innovation in designing cells to meet society’s energy needs in terms of producing ‘green’ hydrogen (including equations in acidic conditions) using the following methods: * polymer electrolyte membrane electrolysis powered by either photovoltaic (solar) or wind energy * artificial photosynthesis using a water oxidation and proton reduction catalyst system * the application of Faraday’s Laws and stoichiometry to determine the quantity of electrolytic reactant and product, and the current or time required to either use a particular quantity of reactant or produce  a particular quantity of product | | * electrolysis of molten liquids and aqueous solutions using different electrodes   • the general operating principles of commercial electrolytic cells, including basic structural features and selection of suitable electrolyte (molten or aqueous) and electrode (inert or reactive) materials to obtain desired products (no specific cell is required)  • the use of the electrochemical series to explain or predict the products of an electrolysis, including identification  of species that are preferentially discharged, balanced half-equations, a balanced ionic equation for the overall cell reaction, and states  • the comparison of an electrolytic cell with a galvanic cell with reference to the energy transformations involved  and basic structural features and processes  • the application of stoichiometry and Faraday’s Laws to determine amounts of product, current or time for a particular electrolytic process. |
| **Rechargeable batteries**  • the operation of rechargeable batteries (secondary cells) with reference to discharging as a galvanic cell and recharging as an electrolytic cell, including the redox principles (redox reactions and polarity of electrodes) and  the factors affecting battery life with reference to components and temperature (no specific battery is required). |

**Unit 4: Unit 4: How are carbon compounds designed for purpose?**

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| **2024 – 2027 Study design** | **OLD COURSE: 2017-2023 Study design** |
| **Area of study 1: How are organic compounds categorised and synthesised?**  **Outcome 1:** On completion of this unit the student should be able to analyse the general structures and reactions of the major organic families of compounds, design reaction pathways for organic synthesis, and evaluate the sustainability of the manufacture of organic compounds used in society. | **Area of study 1: how can the diversity of carbon compounds be explained and categorised?**  On completion of this unit the student should be able to compare the general structures and reactions of the major organic families of compounds, deduce structures of organic compounds using instrumental analysis data, and design reaction pathways for the synthesis of organic molecules. |
| **Structure, nomenclature and properties of organic compounds** | **Structure and nomenclature of organic compounds** |
| * characteristics of the carbon atom that contribute to the diversity of organic compounds formed, with reference to valence electron number, relative bond strength, relative stability of carbon bonds with other elements, degree of unsaturation, and the formation of structural isomers * molecular, structural and semi-structural (condensed) formulas and skeletal structures of alkanes (including cyclohexane), alkenes, benzene, haloalkanes, primary amines, primary amides, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters * the International Union of Pure and Applied Chemistry (IUPAC) systematic naming of organic compounds up to C8, with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters * trends in physical properties within homologous series (boiling point and melting point, viscosity), with reference to structure and bonding | • the carbon atom with reference to valence number, bond strength, stability of carbon bonds with other elements and the formation of isomers (structural and stereoisomers) to explain carbon compound diversity, including identification of chiral centres in optical isomers of simple organic compounds and distinction between cis- and trans- isomers in simple geometric isomers  • structures including molecular, structural and semi-structural formulas of alkanes (including cyclohexane), alkenes, alkynes, benzene, haloalkanes, primary amines, primary amides, alcohols (primary, secondary, tertiary), aldehydes, ketones, carboxylic acids and non-branched esters  • IUPAC systematic naming of organic compounds up to C8 with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary, tertiary), carboxylic acids and non-branched esters. |
| **Reactions of organic compounds** | **Categories, properties and reactions of organic compounds** |
| * organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required): * synthesis of primary haloalkanes and primary alcohols by substitution * addition reactions of alkenes * the esterification between an alcohol and a carboxylic acid * hydrolysis of esters * pathways for the synthesis of primary amines and carboxylic acids * transesterification of plant triglycerides using alcohols to produce biodiesel * hydrolytic reactions of proteins, carbohydrates and fats and oils to break down large biomolecules in food to produce smaller molecules * condensation reactions to synthesise large biologically important molecules for storage as proteins, starch, glycogen and lipids (fats and oils) * calculations of percentage yield and atom economy of single-step or overall reaction pathways, and the advantages for society and for industry of developing chemical processes with a high atom economy * the sustainability of the production of chemicals, with reference to the green chemistry principles of use of renewable feedstocks, catalysis and designing safer chemicals | • an explanation of trends in physical properties (boiling point, viscosity) and flashpoint with reference to structure and bonding  • organic reactions, including appropriate equations and reagents, for the oxidation of primary and secondary alcohols, substitution reactions of haloalkanes, addition reactions of alkenes, hydrolysis reactions of esters, the  condensation reaction between an amine and a carboxylic acid, and the esterification reaction between an alcohol and a carboxylic acid  • the pathways used to synthesise primary haloalkanes, primary alcohols, primary amines, carboxylic acids and esters, including calculations of atom economy and percentage yield of single-step or overall pathway reactions. |
| **Analysis of organic compounds** |
| the principles and applications of mass spectroscopy (excluding features of instrumentation and operation) and interpretation of qualitative and quantitative data, including identification of molecular ion peak, determination of molecular mass and identification of simple fragments  • the principles and applications of infrared spectroscopy (IR) (excluding features of instrumentation and operation) and interpretation of qualitative and quantitative data including use of characteristic absorption bands to identify bonds  • the principles (including spin energy levels) and applications of proton and carbon-13 nuclear magnetic resonance spectroscopy (NMR) (excluding features of instrumentation and operation); analysis of carbon-13 NMR spectra  and use of chemical shifts to determine number and nature of different carbon environments in a simple organic compound; and analysis of high resolution proton NMR spectra to determine the structure of a simple organic  compound using chemical shifts, areas under peak and peak splitting patterns (excluding coupling constants) and application of the n+1 rule  • determination of the structures of simple organic compounds using a combination of mass spectrometry (MS),  infrared spectroscopy (IR) and proton and carbon-13 nuclear magnetic resonance spectroscopy (NMR) (limited to data analysis)  • the principles of chromatography including use of high performance liquid chromatography (HPLC) and construction and use of a calibration curve to determine the concentration of an organic compound in a solution  • determination of the concentration of an organic compound by volumetric analysis, including the principles of direct acid-base and redox titrations (excluding back titrations). *[acid base titrations moves to U2 AoS2]* |

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| **Area of study 2: How are organic compounds analysed and used?**  **Outcome 2:** On completion of this unit the student should be able to apply qualitative and quantitative tests to analyse organic compounds and their structural characteristics, deduce structures of organic compounds using instrumental analysis data, explain how some medicines function, and experimentally analyse how some natural medicines can be extracted and purified. | **Area of study 2: What is the chemistry of food?**  On completion of this unit the student should be able to distinguish between the chemical structures of key food molecules, analyse the chemical reactions involved in the metabolism of the major components of food including the role of enzymes, and calculate the energy content of food using calorimetry. |
| **Key knowledge** | |
| **Laboratory analysis of organic compounds** | **Key food molecules** |
| * qualitative tests for the presence of carbon-carbon double bonds, hydroxyl and carboxyl functional groups * applications and principles of laboratory analysis techniques in verifying components and purity of consumer products, including melting point determination and distillation (simple and fractional) * measurement of the degree of unsaturation of compounds using iodine * volumetric analysis, including calculations of excess and limiting reactants using redox titrations (excluding back titrations) | proteins: formation of dipeptides and polypeptides as condensation polymers of 2-amino acids; primary (including peptide links), secondary, tertiary and quaternary structure and bonding; distinction between essential and non-essential amino acids as dietary components  • carbohydrates: formation of disaccharides from monosaccharides, and of complex carbohydrates (specifically starch and cellulose) as condensation polymers of monosaccharides; glycosidic links; storage of excess glucose in the body as glycogen; comparison of glucose, fructose, sucrose and the artificial sweetener aspartame with reference to their structures and energy content  • fats and oils (triglycerides): common structural features including ester links; distinction between fats and oils with reference to melting points; explanation of different melting points of triglycerides with reference to the structures of their fatty acid tails and the strength of intermolecular forces; chemical structures of saturated and unsaturated (monounsaturated and polyunsaturated) fatty acids; distinction between essential and nonessential  fatty acids; and structural differences between omega-3 fatty acids and omega 6 fatty acids  • vitamins: inability of humans to synthesise most vitamins (except Vitamin D) making them essential dietary requirements; comparison of structural features of Vitamin C (illustrative of a water-soluble vitamin) and Vitamin D  (illustrative of a fat-soluble vitamin) that determine their solubility in water or oil. |
| **Instrumental analysis of organic compounds** | **Metabolism of food in the human body** |
| * applications of mass spectrometry (excluding features of instrumentation and operation) and interpretation of qualitative and quantitative data, including identification of molecular ion peak, determination of molecular mass and identification of simple fragments * identification of bond types by qualitative infrared spectroscopy (IR) data analysis using characteristic absorption bands * structural determination of organic compounds by low resolution carbon-13 nuclear magnetic resonance (13C-NMR) spectral analysis, using chemical shift values to deduce the number and nature of different carbon environments * structural determination of organic compounds by low and high resolution proton nuclear magnetic resonance (1H-NMR) spectral analysis, using chemical shift values, integration curves (where the height is proportional to the area underneath a peak) and peak splitting patterns (excluding coupling constants), and application of the n+1 rule (where n is the number of neighbouring protons) to deduce the number and nature of different proton environments * the principles of chromatography, including high performance liquid chromatography (HPLC) and the use of retention times and the construction of a calibration curve to determine the concentration of an organic compound in a solution (excluding features of instrumentation and operation) * deduction of the structures of simple organic compounds using a combination of mass spectrometry (MS), infrared spectroscopy (IR), proton nuclear magnetic resonance (1H-NMR) and carbon-13 nuclear magnetic resonance (13C-NMR) (limited to data analysis) * the roles and applications of laboratory and instrumental analysis, with reference to product purity and the identification of organic compounds or functional groups in isolation or within a mixture | • metabolism of food as a source of energy and raw materials: general principles of metabolism of food involving enzyme-catalysed chemical reactions with reference to the breakdown of large biomolecules in food by hydrolytic reactions to produce smaller molecules, and the subsequent synthesis of large biologically important  molecules by condensation reactions of smaller molecules  • enzymes as protein catalysts: active site; modelling of process by which enzymes control specific biochemical  reactions (lock-and-key and induced fit models); consequences of variation in enzyme-substrate interaction (lock-and-key mechanism) due to the behaviour of a particular optical isomer; explanation of effects of changes in pH (formation of zwitterions and denaturation), increased temperature (denaturation) and decreased temperature (reduction in activity) on enzyme activity with reference to structure and bonding; action of enzymes in narrow pH ranges; and use of reaction rates to measure enzyme activity  • the distinction between denaturation of a protein and hydrolysis of its primary structure  • hydrolysis of starch in the body: explanation of the ability of all humans to hydrolyse starch but not cellulose, and of differential ability in humans to hydrolyse lactose; glycaemic index (GI) of foods as a ranking of carbohydrates based on the hydrolysis of starches (varying proportions of amylose and amylopectin) to produce glucose in the body  • hydrolysis of fats and oils from foods to produce glycerol and fatty acids; oxidative rancidity with reference to chemical reactions and processes, and the role of antioxidants in slowing rate of oxidative rancidity  • the principles of the action of coenzymes (often derived from vitamins) as organic molecules that bind to the active site of an enzyme during catalysis, thereby changing the surface shape and hence the binding properties  of the active site to enable function as intermediate carriers of electrons and/or groups of atoms (no specific cases required). |
| **Medicinal chemistry** | **Energy content of food** |
| * extraction and purification of natural plant compounds as possible active ingredients for medicines, using solvent extraction and distillation * identification of the structure and functional groups of organic molecules that are medicines * significance of isomers and the identification of chiral centres (carbon atom surrounded by four different groups) in the effectiveness of medicines * enzymes as protein-based catalysts in living systems: primary, secondary, tertiary and quaternary structures and changes in enzyme function in terms of structure and bonding as a result of increased temperature (denaturation), decreased temperature (lowered activity), or changes in pH (formation of zwitterions and denaturation) * medicines that function as competitive enzyme inhibitors: organic molecules that bind through lock-and-key mechanism to an active site preventing binding of the actual substrate | • the comparison of energy values of carbohydrates, proteins and fats and oils  • glucose as the primary energy source, including a balanced thermochemical equation for cellular respiration  • the principles of calorimetry; solution and bomb calorimetry, including determination of calibration factor and consideration of the effects of heat loss; and analysis of temperature-time graphs obtained from solution calorimetry. |