

Accreditation Period

Units 1 and 2

2016–2022

Units 3 and 4

2017–2023

Victorian Certificate of Education

CHEMISTRY

STUDY DESIGN



www.vcaa.vic.edu.au

Amendments to study design history

Version	Status	Release Date	Comments
1.1	Current	February 2021	The accreditation period for Units 1 and 2 expired 31 December 2022. The accreditation period for Units 3 and 4 has been extended and expires 31 December 2023.
1	Superseded	December 2014	

Authorised and published by the Victorian Curriculum and Assessment Authority
Level 1, 2 Lonsdale Street, Melbourne VIC 3000

Accredited by the Victorian Registration and Qualifications Authority
Level 4, 2 Lonsdale Street, Melbourne VIC 3000

ISBN: 978-1-922082-78-7

© Victorian Curriculum and Assessment Authority 2015

No part of this publication may be reproduced except as specified under the *Copyright Act 1968* or by permission from the VCAA. For more information go to:
www.vcaa.vic.edu.au/Footer/Pages/Copyright.aspx.

The VCAA provides the only official, up-to-date versions of VCAA publications. Details of updates can be found on the VCAA website: www.vcaa.vic.edu.au.

This publication may contain copyright material belonging to a third party. Every effort has been made to contact all copyright owners. If you believe that material in this publication is an infringement of your copyright, please email the Copyright Officer:
vcaa.copyright@edumail.vic.gov.au.

Copyright in materials appearing at any sites linked to this document rests with the copyright owner/s of those materials, subject to the *Copyright Act*. The VCAA recommends you refer to copyright statements at linked sites before using such materials.

The VCAA logo is a registered trademark of the Victorian Curriculum and Assessment Authority.

Contents

Important information	5
Introduction	6
Scope of study	6
Rationale	6
Aims	7
Structure	7
Entry	7
Duration	7
Changes to the study design	8
Monitoring for quality	8
Safety and wellbeing	8
Employability skills	8
Legislative compliance	8
Assessment and reporting	9
Satisfactory completion	9
Levels of achievement	9
Authentication	9
Cross-study specifications	10
Units 1–4: Key science skills	10
Scientific investigation	11
Unit 1: How can the diversity of materials be explained?	12
Area of Study 1	12
Area of Study 2	14
Area of Study 3	15
Assessment	19
Unit 2: What makes water such a unique chemical?	20
Area of Study 1	20
Area of Study 2	21
Area of Study 3	23
Assessment	23
Unit 3: How can chemical processes be designed to optimise efficiency?	25
Area of Study 1	25
Area of Study 2	27
School-based assessment	28
External assessment	29

Unit 4: How are organic compounds categorised, analysed and used?	30
Area of Study 1	30
Area of Study 2	32
Area of Study 3	33
School-based assessment	34
External assessment	36

Important information

Accreditation period

Units 1 and 2: 1 January 2016 – 31 December 2022

Units 3 and 4: 1 January 2017 – 31 December 2023

Implementation for Units 1 and 2 of this study commences in January 2016.

Implementation for Units 3 and 4 of this study commences in January 2017.

Sources of information

The [VCAA Bulletin](#) is the only official source of changes to regulations and accredited studies. The *VCAA Bulletin* also regularly includes advice on VCE studies. It is the responsibility of each VCE teacher to refer to each issue of the *VCAA Bulletin*. The *VCAA Bulletin* is available as an e-newsletter via free subscription on the VCAA's website at: www.vcaa.vic.edu.au.

To assist teachers in developing courses, the VCAA publishes online the *Advice for teachers*, which includes teaching and learning activities for Units 1–4, and advice on assessment tasks and performance level descriptors for School-assessed Coursework in Units 3 and 4.

The current [VCE and VCAL Administrative Handbook](#) contains essential information on assessment processes and other procedures.

VCE providers

Throughout this study design the term 'school' is intended to include both schools and other VCE providers.

Copyright

VCE schools may reproduce parts of this study design for use by teachers. The full VCAA Copyright Policy is available at: www.vcaa.vic.edu.au/Footer/Pages/Copyright.aspx.

Introduction

Scope of study

Chemistry explores and explains the composition and behaviour of matter and the chemical processes that occur on Earth and beyond. Chemical models and theories are used to describe and explain known chemical reactions and processes. Chemistry underpins the production and development of energy, the maintenance of clean air and water, the production of food, medicines and new materials, and the treatment of wastes.

VCE Chemistry enables students to explore key processes related to matter and its behaviour. Students consider the relationship between materials and energy through four themes: the design and composition of useful materials, the reactions and analysis of chemicals in water, the efficient production and use of energy and materials, and the investigation of carbon-based compounds as important components of body tissues and materials used in society. Students examine classical and contemporary research, models and theories to understand how knowledge in chemistry has evolved and continues to evolve in response to new evidence and discoveries. An understanding of the complexities and diversity of chemistry leads students to appreciate the interconnectedness of the content areas both within chemistry, and across chemistry and the other sciences.

An important feature of undertaking a VCE science study is the opportunity for students to engage in a range of inquiry tasks that may be self-designed, develop key science skills and interrogate the links between theory, knowledge and practice. In VCE Chemistry inquiry methodologies can include laboratory experimentation, modelling, site tours, fieldwork, local and remote data-logging, simulations, animations, literature reviews and the use of global databases. Students work collaboratively as well as independently on a range of tasks. They pose questions, formulate hypotheses and collect, analyse and critically interpret qualitative and quantitative data. Students analyse the limitations of data, evaluate methodologies and results, justify conclusions, make recommendations and communicate their findings. They investigate and evaluate issues, changes and alternative proposals by considering both shorter and longer term consequences for the individual, environment and society. Knowledge of the safety considerations, including use of safety data sheets, and ethical standards associated with chemical investigations is integral to the study of VCE Chemistry.

As well as an increased understanding of scientific processes, students develop capacities that enable them to critically assess the strengths and limitations of science, respect evidence-based conclusions and gain an awareness of the ethical, social and political contexts of scientific endeavours.

Rationale

VCE Chemistry enables students to examine a range of chemical, biochemical and geophysical phenomena through the exploration of the nature of chemicals and chemical processes. In undertaking this study, students apply chemical principles to explain and quantify the behaviour of matter, as well as undertake practical activities that involve the analysis and synthesis of a variety of materials.

In VCE Chemistry students develop a range of inquiry skills involving practical experimentation and research specific to the knowledge of the discipline, analytical skills including critical and creative thinking, and communication skills. Students use scientific and cognitive skills and understanding to analyse contemporary chemistry-related issues, and communicate their views from an informed position.

VCE Chemistry provides for continuing study pathways within the discipline and leads to a range of careers. Branches of chemistry include organic chemistry, inorganic chemistry, analytical chemistry, physical chemistry and biochemistry. In addition, chemistry is applied in many fields of endeavour including agriculture, bushfire research, dentistry, dietetics, education, engineering, environmental sciences, forensic science, forestry, horticulture, medicine, metallurgy, meteorology, pharmacy, sports science, toxicology, veterinary science and viticulture.

Aims

This study enables students to:

- apply models, theories and concepts to describe, explain, analyse and make predictions about chemical phenomena, systems, structures and properties, and the factors that can affect them
- understand and use the language and methodologies of chemistry to solve qualitative and quantitative problems in familiar and unfamiliar contexts

and more broadly to:

- understand the cooperative, cumulative, evolutionary and interdisciplinary nature of science as a human endeavour, including its possibilities, limitations and political and sociocultural influences
- develop a range of individual and collaborative science investigation skills through experimental and inquiry tasks in the field and in the laboratory
- develop an informed perspective on contemporary science-based issues of local and global significance
- apply their scientific understanding to familiar and unfamiliar situations including personal, social, environmental and technological contexts
- develop attitudes that include curiosity, open-mindedness, creativity, flexibility, integrity, attention to detail and respect for evidence-based conclusions
- understand and apply the research, ethical and safety principles that govern the study and practice of the discipline in the collection, analysis, critical evaluation and reporting of data
- communicate clearly and accurately an understanding of the discipline using appropriate terminology, conventions and formats.

Structure

The study is made up of four units:

Unit 1: How can the diversity of materials be explained?

Unit 2: What makes water such a unique chemical?

Unit 3: How can chemical processes be designed to optimise efficiency?

Unit 4: How are organic compounds categorised, analysed and used?

Each unit deals with specific content contained in areas of study and is designed to enable students to achieve a set of outcomes for that unit. Each outcome is described with reference to key knowledge and is complemented by a set of key science skills.

The study is structured under a set of curriculum framing questions that reflect the inquiry nature of the discipline.

Entry

There are no prerequisites for entry to Units 1, 2 and 3. Students must undertake Unit 3 prior to undertaking Unit 4. Students entering Unit 3 without Units 1 and/or 2 may be required to undertake additional preparation as prescribed by their teacher. Units 1 to 4 are designed to a standard equivalent to the final two years of secondary education. All VCE studies are benchmarked against comparable national and international curriculum.

Duration

Each unit involves at least 50 hours of scheduled classroom instruction over the duration of a semester.

Changes to the study design

During its period of accreditation minor changes to the study will be announced in the [VCAA Bulletin](#). The *VCAA Bulletin* is the only source of changes to regulations and accredited studies. It is the responsibility of each VCE teacher to monitor changes and advice about VCE studies published in the *VCAA Bulletin*.

Monitoring for quality

As part of ongoing monitoring and quality assurance, the VCAA will periodically undertake an audit of VCE Chemistry to ensure the study is being taught and assessed as accredited. The details of the audit procedures and requirements are published annually in the [VCE and VCAL Administrative Handbook](#). Schools will be notified if they are required to submit material to be audited.

Safety and wellbeing

This study may involve the handling of potentially hazardous substances and the use of potentially hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students undertaking the study. Teachers and students should observe appropriate safety precautions when undertaking practical work. All laboratory work should be supervised by the teacher. It is the responsibility of schools to ensure that they comply with health and safety requirements.

Relevant acts and regulations include:

- *Occupational Health and Safety Act 2004*
- *Occupational Health and Safety Regulations 2007*
- *Occupational Health and Safety Management Systems (AS/NZ 4801)*
- *Dangerous Goods (Storage and Handling) Regulations 2012*
- *Dangerous Goods Storage and Handling Code of Practice 2000*
- *Hazardous Substances Code of Practice 2000*
- *Electrical Safety Act 1998*.

Employability skills

This study offers a number of opportunities for students to develop employability skills. The *Advice for teachers* companion document provides specific examples of how students can develop employability skills during learning activities and assessment tasks.

Legislative compliance

When collecting and using information, the provisions of privacy and copyright legislation, such as the Victorian *Privacy and Data Protection Act 2014* and *Health Records Act 2001*, and the federal *Privacy Act 1988* and *Copyright Act 1968*, must be met.

Assessment and reporting

Satisfactory completion

The award of satisfactory completion for a unit is based on the teacher's decision that the student has demonstrated achievement of the set of outcomes specified for the unit. Demonstration of achievement of outcomes and satisfactory completion of a unit are determined by evidence gained through the assessment of a range of learning activities and tasks.

Teachers must develop courses that provide appropriate opportunities for students to demonstrate satisfactory achievement of outcomes.

The decision about satisfactory completion of a unit is distinct from the assessment of levels of achievement. Schools will report a student's result for each unit to the VCAA as S (Satisfactory) or N (Not Satisfactory).

Levels of achievement

Units 1 and 2

Procedures for the assessment of levels of achievement in Units 1 and 2 are a matter for school decision. Assessment of levels of achievement for these units will not be reported to the VCAA. Schools may choose to report levels of achievement using grades, descriptive statements or other indicators.

Units 3 and 4

The VCAA specifies the assessment procedures for students undertaking scored assessment in Units 3 and 4. Designated assessment tasks are provided in the details for each unit in the VCE study designs.

The student's level of achievement in Units 3 and 4 will be determined by School-assessed Coursework (SACs) and/or School-assessed Tasks (SATs) as specified in the VCE study designs, and external assessment.

The VCAA will report the student's level of achievement on each assessment component as a grade from A+ to E or UG (ungraded). To receive a study score the student must achieve two or more graded assessments and receive S for both Units 3 and 4. The study score is reported on a scale of 0–50; it is a measure of how well the student performed in relation to all others who took the study. Teachers should refer to the current [VCE and VCAL Administrative Handbook](#) for details on graded assessment and calculation of the study score. Percentage contributions to the study score in VCE Chemistry are as follows:

- Unit 3 School-assessed Coursework: 16 per cent
- Unit 4 School-assessed Coursework: 24 per cent
- End-of-year examination: 60 per cent.

Details of the assessment program are described in the sections on Units 3 and 4 in this study design.

Authentication

Work related to the outcomes of each unit will be accepted only if the teacher can attest that, to the best of their knowledge, all unacknowledged work is the student's own. Teachers need to refer to the current [VCE and VCAL Administrative Handbook](#) for authentication procedures.

Cross-study specifications

Units 1–4: Key science skills

The development of a set of key science skills is a core component of the study of VCE Chemistry and applies across Units 1 to 4 in all areas of study. In designing teaching and learning programs and in assessing student learning for each unit, teachers should ensure that students are given the opportunity to develop, use and demonstrate these skills in a variety of contexts when undertaking their own investigations and when evaluating the research of others. As the complexity of key knowledge increases from Units 1 to 4 and as opportunities are provided to undertake investigations, students should aim to demonstrate the key science skills at a progressively higher level.

The key science skills are common to all VCE science studies and have been contextualised in the following table for VCE Chemistry.

Key science skill	VCE Chemistry Units 1–4
Develop aims and questions, formulate hypotheses and make predictions	<ul style="list-style-type: none"> determine aims, hypotheses, questions and predictions that can be tested identify independent, dependent and controlled variables
Plan and undertake investigations	<ul style="list-style-type: none"> determine appropriate type of investigation: experiments (including use of controls and calibration curves); solving a scientific or technological problem; simulations; access to secondary data, including data sourced through the internet that would otherwise be difficult to source as raw or primary data through a laboratory or a classroom select and use equipment, materials and procedures appropriate to the investigation, taking into account potential sources of error and uncertainty
Comply with safety and ethical guidelines	<ul style="list-style-type: none"> apply ethical principles when undertaking and reporting investigations apply relevant occupational health and safety guidelines while undertaking practical investigations, including following recommended protocols from safety data sheets
Conduct investigations to collect and record data	<ul style="list-style-type: none"> work independently and collaboratively as appropriate and within identified research constraints systematically generate, collect, record and summarise both qualitative and quantitative data
Analyse and evaluate data, methods and scientific models	<ul style="list-style-type: none"> process quantitative data using appropriate mathematical relationships, units and number of significant figures organise, present and interpret data using schematic diagrams and flow charts, balanced chemical equations, tables, graphs, percentages and calculations of mean take a qualitative approach when identifying and analysing experimental data with reference to accuracy, precision, reliability, validity, uncertainty and errors (random and systematic) explain the merit of replicating procedures and the effects of sample sizes in obtaining reliable data evaluate investigative procedures and possible sources of bias, and suggest improvements explain how models are used to organise and understand observed phenomena and concepts related to chemistry, identifying limitations of the models

Key science skill	VCE Chemistry Units 1–4
Draw evidence-based conclusions	<ul style="list-style-type: none"> determine to what extent evidence from an investigation supports the purpose of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation draw conclusions consistent with evidence and relevant to the question under investigation identify, describe and explain the limitations of conclusions, including identification of further evidence required critically evaluate various types of information related to chemistry from journal articles, mass media and opinions presented in the public domain discuss the implications of research findings and proposals
Communicate and explain scientific ideas	<ul style="list-style-type: none"> use appropriate chemical terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement discuss relevant chemical information, ideas, concepts, theories and models and the connections between them identify and explain formal chemical terminology about investigations and concepts use clear, coherent and concise expression acknowledge sources of information and use standard scientific referencing conventions

Scientific investigation

Students undertake scientific investigations across Units 1 to 4 of this study. Scientific investigations may be undertaken in groups, but all work for assessment must be completed individually. Students maintain a logbook of practical activities in each unit of this study for recording, authentication and assessment purposes.

Students communicate findings for the investigation in Outcome 3, Unit 4 of this study in a scientific poster. The poster may be produced electronically or in hard copy format and should not exceed 1000 words. Students must select information carefully so that they meet the word limit. The production quality of the poster will not form part of the assessment.

The following template is to be used by students in the development of the scientific poster for the investigation undertaken.

Section	Content and activities
Title	Question under investigation is the title
Introduction	Explanation or reason for undertaking the investigation, including a clear aim, a hypothesis and/or prediction, and relevant background chemical concepts
Methodology	<p>Summary that outlines the methodology used in the investigation and is authenticated by logbook entries</p> <p>Identification and management of relevant risks, including the relevant health, safety and ethical guidelines followed in the investigation</p>
Results	Presentation of collected data/evidence in appropriate format to illustrate trends, patterns and/or relationships
Discussion	<p>Analysis and evaluation of primary data</p> <p>Identification of outliers and their subsequent treatment</p> <p>Identification of limitations in data and methods, and suggested improvements</p> <p>Linking of results to relevant chemical concepts</p>
Conclusion	Conclusion that provides a response to the question
References and acknowledgments	Referencing and acknowledgment of all quotations and sourced content as they appear in the poster.

Unit 1: How can the diversity of materials be explained?

The development and use of materials for specific purposes is an important human endeavour. In this unit students investigate the chemical properties of a range of materials from metals and salts to polymers and nanomaterials. Using their knowledge of elements and atomic structure students explore and explain the relationships between properties, structure and bonding forces within and between particles that vary in size from the visible, through nanoparticles, to molecules and atoms.

Students examine the modification of metals, assess the factors that affect the formation of ionic crystals and investigate a range of non-metallic substances from molecules to polymers and giant lattices and relate their structures to specific applications.

Students are introduced to quantitative concepts in chemistry including the mole concept. They apply their knowledge to determine the relative masses of elements and the composition of substances. Throughout the unit students use chemistry terminology including symbols, formulas, chemical nomenclature and equations to represent and explain observations and data from experiments, and to discuss chemical phenomena.

A research investigation is undertaken in Area of Study 3 related to one of ten options that draw upon and extend the content from Area of Study 1 and/or Area of Study 2.

Area of Study 1

How can knowledge of elements explain the properties of matter?

In this area of study students focus on the nature of chemical elements, their atomic structure and their place in the periodic table. They review how the model of the atom has changed over time and consider how spectral evidence led to the Bohr model and subsequently to the Schrödinger model. Students examine the periodic table as a unifying framework into which elements are placed based upon similarities in their electronic configurations. In this context students explore patterns and trends of, and relationships between, elements with reference to properties of the elements including their chemical reactivity.

Students investigate the nature of metals and their properties, including metallic nanomaterials. They investigate how a metal is extracted from its ore and how the properties of metals may be modified for a particular use. Students apply their knowledge of the electronic structures of metallic elements and non-metallic elements to examine ionic compounds. They study how ionic compounds are formed, explore their crystalline structures and investigate how changing environmental conditions may change their properties.

Fundamental quantitative aspects of chemistry are introduced including the mole concept, relative atomic mass, percentage abundance and composition by mass and the empirical formula of an ionic compound.

Outcome 1

On completion of this unit the student should be able to relate the position of elements in the periodic table to their properties, investigate the structures and properties of metals and ionic compounds, and calculate mole quantities.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Elements and the periodic table

- the relative and absolute sizes of particles that are visible and invisible to the unaided eye: small and giant molecules and lattices; atoms and sub-atomic particles; nanoparticles and nanostructures
- the definition of an element with reference to atomic number; mass number; isotopic forms of an element using appropriate notation
- spectral evidence for the Bohr model and for its refinement as the Schrödinger model; electronic configurations of elements 1 to 36 using the Schrödinger model of the atom, including s, p, d and f notations (with copper and chromium exceptions)
- the periodic table as an organisational tool to identify patterns and trends in, and relationships between, the structures (including electronic configurations and atomic radii) and properties (including electronegativity, first ionisation energy, metallic/non-metallic character and reactivity) of elements.

Metals

- the common properties of metals (lustre, malleability, ductility, heat and electrical conductivity) with reference to the nature of metallic bonding and the structure of metallic crystals, including limitations of representations; general differences between properties of main group and transition group metals
- experimental determination of the relative reactivity of metals with water, acids and oxygen
- the extraction of a selected metal from its ore/s including relevant environmental, economic and social issues associated with its extraction and use
- experimental modification of a selected metal related to the use of coatings or heat treatment or alloy production
- properties and uses of metallic nanomaterials and their different nanoforms including comparison with the properties of their corresponding bulk materials.

Ionic compounds

- common properties of ionic compounds (brittleness, hardness, high melting point, difference in electrical conductivity in solid and liquid states) with reference to their formation, nature of ionic bonding and crystal structure including limitations of representations
- experimental determination of the factors affecting crystal formation of ionic compounds
- the uses of common ionic compounds.

Quantifying atoms and compounds

- the relative isotopic masses of elements and their representation on the relative mass scale using the carbon-12 isotope as the standard; reason for the selection of carbon-12 as the standard
- determination of the relative atomic mass of an element using mass spectrometry (details of instrument not required)
- the mole concept; Avogadro constant; determination of the number of moles of atoms in a sample of known mass; calculation of the molar mass of ionic compounds
- experimental determination of the empirical formula of an ionic compound.

Area of Study 2

How can the versatility of non-metals be explained?

In this area of study students explore a wide range of substances and materials made from non-metals including molecular substances, covalent lattices, carbon nanomaterials, organic compounds and polymers.

Students investigate the relationship between the electronic configurations of non-metallic atoms and the resultant structures and properties of a range of molecular substances and covalent lattices. They compare how the structures of these non-metallic substances are represented and analyse the limitations of these representations. Students study a variety of organic compounds and how they are grouped into distinct chemical families. They apply rules of systematic nomenclature to each of these chemical families. Students investigate useful materials that are made from non-metals, and relate their properties and uses to their structures. They explore the modification of polymers and the use of carbon-based nanoparticles for specific applications.

Students apply quantitative concepts to molecular compounds, including mole concept and percentage composition by mass, and determine the empirical and molecular formulas of given compounds.

Outcome 2

On completion of this unit the student should be able to investigate and explain the properties of carbon lattices and molecular substances with reference to their structures and bonding, use systematic nomenclature to name organic compounds, and explain how polymers can be designed for a purpose.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Materials from molecules

- representations of molecular substances (electron dot formulas, structural formulas, valence structures, ball-and-stick models, space-filling models) including limitations of representations
- shapes of molecules and an explanation of their polar or non-polar character with reference to the electronegativities of their atoms and electron-pair repulsion theory
- explanation of properties of molecular substances (including low melting point and boiling point, softness, and non-conduction of electricity) with reference to their structure, intramolecular bonding and intermolecular forces
- the relative strengths of bonds (covalent bonding, dispersion forces, dipole-dipole attraction and hydrogen bonding) and evidence and factors that determine bond strength including explanations for the floating of ice and expansion of water at higher temperatures.

Carbon lattices and carbon nanomaterials

- the structure and bonding of diamond and graphite that explain their properties (including heat and electrical conductivity and hardness) and their suitability for diverse applications
- the structures, properties and applications of carbon nanomaterials including graphene and fullerenes.

Organic compounds

- the origin of crude oil and its use as a source of hydrocarbon raw materials
- the grouping of hydrocarbon compounds into families (alkanes, alkenes, alkynes, alcohols, carboxylic acids and non-branched esters) based upon similarities in their physical and chemical properties including general formulas, their representations (structural formulas, condensed formulas, Lewis structures), naming according to IUPAC systematic nomenclature (limited to non-cyclic compounds up to C₁₀, and structural isomers up to C₇) and uses based upon properties
- determination of empirical and molecular formulas of organic compounds from percentage composition by mass and molar mass.

Polymers

- the formation of polymers from monomers including addition polymerisation of alkenes
- the distinction between linear (thermoplastic) and cross-linked (thermosetting) polymers with reference to structure, bonding and properties including capacity to be recycled
- the features of linear polymers designed for a particular purpose including the selection of a suitable monomer (structure and properties), chain length, degree of branching, percentage crystalline areas and addition of plasticisers
- the advantages and disadvantages of the use of polymer materials.

Area of Study 3

Research investigation

Knowledge of the origin, structure and properties of matter has built up over time through scientific and technological research, including medical research, space research and research into alternative energy resources. As a result, patterns and relationships in structures and properties of substances have been identified, applied and modified, and a vast range of useful materials and chemicals has been produced. This research and development is ongoing and new discoveries are being made at an accelerating rate.

In this area of study students apply and extend their knowledge and skills developed in Area of Study 1 and/or Area of Study 2 to investigate a selected question related to materials. They apply critical and creative thinking skills, science inquiry skills and communication skills to conduct and present the findings of an independent investigation into one aspect of the discoveries and research that have underpinned the development, use and modification of useful materials or chemicals.

Students undertake a research investigation relevant to one of the following ten options. A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

Option 1: The origin of the elements

Questions that may be explored in this investigation include:

- How are atoms 'seen'?
- Are there more elements to be discovered?
- What are electrons, protons and neutrons made of?
- How do we know what elements are in the Universe?
- What is the evidence that living things are made of stardust?
- Why are the ten most abundant elements in the Universe not the same as the ten most abundant elements on Earth?
- How does the abundance of elements on Earth compare with the abundance of elements in humans?
- Would there be life if elements did not form compounds?
- Why are the nuclei of some elements unstable?

Option 2: The development of the periodic table

Questions that may be explored in this investigation include:

- Is alchemy chemistry?
- How can lead be transformed into gold?
- On what basis are alternative forms of the periodic table constructed?
- Where would an element with an atomic number of 130 be placed in the modern periodic table, what properties would it have and how likely is it to be discovered?

- Why is the periodic table still a ‘work in progress’?
- Why is it difficult to place hydrogen in the modern periodic table?
- Is it worthwhile finding any more new elements?
- Why aren't all the metals placed together in the periodic table?
- What makes some elements magnetic?
- Why do transition metals have multiple oxidation states?
- Is it an advantage or a disadvantage for elements to be unreactive?

Option 3: The lanthanoids and actinoids

Questions that may be explored in this investigation include:

- Why are some lanthanoids and actinoids so highly sought after?
- Can we live without lanthanoids and actinoids?
- Based on their usefulness for society, how would you compare the value of lanthanoids and actinoids with the value of other metal groups in the periodic table?
- Is it worth sending people to the Moon to mine for lanthanoids and actinoids?
- How are the lanthanoids and actinoids extracted from their ores?
- Do the lanthanoids and actinoids rust or corrode?
- Where are the lanthanoids and actinoids located in the periodic table and why have they been placed there?

Option 4: Using light to solve chemical puzzles

Questions that may be explored in this investigation include:

- What is a crystal, and why do crystals have regular faces?
- What makes synchrotron light useful?
- What can a synchrotron tell us about the differences between salt and sugar crystals?
- How does the composition of a crystal relate to the bonding within and the ratios of the elements present?
- Given that crystals are not alive or functioning, how is it that crystal structures are used to understand biological functions?
- What significant discoveries contributed to the development of X-ray crystallography as an analytical technique?
- How does cryoprotection preserve protein samples for analysis in a synchrotron?
- How has the use of a synchrotron enabled Nobel Prize winning research to occur?
- Why use synchrotron light to determine crystal structure when other sources of X-rays can be used?
- How does the IR beamline in the Australian Synchrotron enable the study of organic molecules and covalent bonding patterns?

Option 5: Glass

Questions that may be explored in this investigation include:

- What would life be like without glass? What might have to be used instead?
- How are the special properties achieved in particular forms of glass such as transition lenses, bullet-proof glass, safety glass, bendable glass, heat-proof glass, glass that can be switched on or off to become transparent or opaque, coloured glass and fibreglass?
- How are glass ornaments, glass jewellery and specialised laboratory glassware created?
- How does lightning make glass?
- Is glass safer to use than other forms of storage vessels?
- How useful is the type of glass that is produced as a by-product when iron is extracted from its ore in a blast furnace?

Option 6: Crude oil

Questions that may be explored in this investigation include:

- Do we need crude oil?
- Why does the composition of crude oil vary between different oil wells?
- How do different crude oil extraction methods compare with reference to ease of extraction and environmental impacts?
- What might we do if crude oil supplies run out?
- How does the time taken to produce crude oil compare with the time taken to use it?
- What fuels and other chemicals are derived from crude oil? How is crude oil processed to obtain them?
- Why are tar balls found on beaches after an oil spill?
- What are some of the issues surrounding society's demand for and use of crude oil? What strategies are being used to address some of these issues?

Option 7: Surfactants

Questions that may be explored in this investigation include:

- How do surfactants help clean up oil spills?
- Why is it so difficult to remove oil from bird feathers? Why can water birds drown if they still have detergent on their feathers?
- How are surfactants used in cooking, cosmetics and personal hygiene?
- How do hair shampoos differ from conditioners?
- How are soaps different from detergents?
- Why are different detergents made for cleaning different surfaces? How does their composition differ?
- How are surfactants designed for biodegradability?
- Does surfactant biodegradability affect performance?
- How can surfactants protect dams from drying out?
- What is the role of natural surfactants in the human body in breathing and digestion?

Option 8: Polymers and composite materials

Questions that may be explored in this investigation include:

- Are the biomaterials that replace body parts as effective as the original materials with reference to their properties and function?
- How can biomimicry help in developing new materials?
- How do new materials improve sporting performance?
- What are some of the new generation composite materials that have been designed to meet the emerging demands posed by space programs, and medical and technological developments?
- Should cars be made from shape memory metals?
- What makes some materials 'smart'?
- How do different types of radiation affect the structure and properties of polymer films?
- What applications for conductive polymers could be possible?
- What properties might a new 'super material' have, what might it be made from and what difference could it make to people's lives?
- Why would it be an advantage for polymers not to be biodegradable?
- How are new polymer and composite materials tested for safety?

Option 9: Nanomaterials

Questions that may be explored in this investigation include:

- What useful materials have resulted from nanomaterial research and what could be produced in future?
- How are nanochemists able to ‘see’ nanoparticles and manipulate atoms to build particular nanomaterials?
- Why do nanomaterials have different properties to their related macromaterials?
- Are nanomaterials safe?
- What difference can nanomaterials make to society and the environment?
- What can nanobots do?
- How are nanomaterials used in medicine and research?

Option 10: The life cycle of a selected material or chemical

Questions that may be explored in this investigation include:

- What is the story behind the discovery of a selected material or chemical and why is it important?
- What is the relationship between the properties, structure and the nature and strength of the chemical bonding within the structure of a selected material or chemical?
- What are the main features of the life cycle of a selected material or chemical and how can these features be represented (they may include the extraction and processing of the raw materials; the manufacturing processes used, its packaging, distribution and use; any recycling and reuse; and its disposal at the end of its useful life)?
- What health and safety and environmental issues are involved in the manufacture, use and disposal of a selected material or chemical and how are these managed?
- What happens to a selected material or chemical at the end of its life?

Outcome 3

On completion of this unit the student should be able to investigate a question related to the development, use and/or modification of a selected material or chemical and communicate a substantiated response to the question.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

- the characteristics of effective science communication: accuracy of chemical information; clarity of explanation of chemical concepts, ideas and models; contextual clarity with reference to importance and implications of findings; conciseness and coherence
- the chemical concepts specific to the investigation: definitions of key terms; use of appropriate chemical terminology, conventions, units and representations
- the use of data representations, models and theories in organising and explaining observed phenomena and chemical concepts, and their limitations
- the nature of evidence and information: distinction between weak and strong evidence, and scientific and non-scientific ideas; and validity, reliability and authority of data including sources of possible errors or bias
- the influence of social, economic, environmental and ethical factors relevant to the selected chemical investigation.

Assessment

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study, including the key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessment at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate achievement of three outcomes. As a set these outcomes encompass all areas of study.

Suitable tasks for assessment may be selected from the following:

For Outcomes 1 and 2

- annotations of a practical work folio of activities or investigations
- a report of a practical activity or investigation
- a modelling activity
- media response
- problem-solving involving chemical concepts, skills and/or issues
- a reflective learning journal/blog related to selected activities or in response to an issue
- data analysis
- a test comprising multiple choice and/or short answer and/or extended response.

For Outcome 3

- a report of an independent investigation of a topic selected from Area of Study 1 and/or Area of Study 2, using an appropriate format, for example digital presentation, oral communication or written report.

Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. For Area of Study 3, between 4 and 6 hours of class time should be devoted to undertaking the investigation and communicating findings.

Unit 2: What makes water such a unique chemical?

Water is the most widely used solvent on Earth. In this unit students explore the physical and chemical properties of water, the reactions that occur in water and various methods of water analysis.

Students examine the polar nature of a water molecule and the intermolecular forces between water molecules. They explore the relationship between these bonding forces and the physical and chemical properties of water. In this context students investigate solubility, concentration, pH and reactions in water including precipitation, acid-base and redox. Students are introduced to stoichiometry and to analytical techniques and instrumental procedures, and apply these to determine concentrations of different species in water samples, including chemical contaminants. They use chemistry terminology including symbols, units, formulas and equations to represent and explain observations and data from experiments, and to discuss chemical phenomena. Students explore the solvent properties of water in a variety of contexts and analyse selected issues associated with substances dissolved in water.

A practical investigation into an aspect of water quality is undertaken in Area of Study 3. The investigation draws on content from Area of Study 1 and/or Area of Study 2.

Area of Study 1

How do substances interact with water?

In this area of study students focus on the properties of water and the reactions that take place in water including acid-base and redox reactions. Students relate the properties of water to the water molecule's structure, polarity and bonding. They also explore the significance of water's high specific heat capacity and latent heat of vaporisation for living systems and water supplies.

Students investigate issues associated with the solubility of substances in water. Precipitation, acid-base and redox reactions that occur in water are explored and represented by the writing of balanced equations. Students compare acids with bases and learn to distinguish between acid strength and acid concentration. The pH scale is examined and students calculate the expected pH of strong acids and strong bases of known concentration.

Outcome 1

On completion of this unit the student should be able to relate the properties of water to its structure and bonding, and explain the importance of the properties and reactions of water in selected contexts.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Properties of water

- trends in the melting and boiling points of Group 16 hydrides, with reference to the nature and relative strengths of their intermolecular forces and to account for the exceptional values for water
- specific heat capacity and latent heat including units and symbols, with reference to hydrogen bonding to account for the relatively high specific heat capacity of liquid water, and significance for organisms and water supplies of the relatively high latent heat of vaporisation of water.

Water as a solvent

- the comparison of solution processes in water for molecular substances and ionic compounds
- precipitation reactions represented by balanced full and ionic equations, including states
- the importance of the solvent properties of water in selected biological, domestic or industrial contexts.

Acid-base (proton transfer) reactions in water

- the Brønsted-Lowry theory of acids and bases including polyprotic acids and amphiprotic species, and writing of balanced ionic equations for their reactions with water including states
- the ionic product of water, the pH scale and the use of pH in the measurement and calculations of strengths of acids and bases and dilutions of solutions (calculations involving acidity constants are not required)
- the distinction between strong and weak acids and bases, and between concentrated and dilute acids and bases, including common examples
- the reactions of acids with metals, carbonates and hydroxides including balanced full and ionic equations, with states indicated
- the causes and effects of a selected issue related to acid-base chemistry.

Redox (electron transfer) reactions in water

- oxidising and reducing agents, conjugate redox pairs and redox reactions including writing of balanced half and overall redox equations with states indicated
- the reactivity series of metals and metal displacement reactions including balanced redox equations with states indicated
- the causes and effects of a selected issue related to redox chemistry.

Area of Study 2

How are substances in water measured and analysed?

In this area of study students focus on the use of analytical techniques, both in the laboratory and in the field, to measure the solubility and concentrations of solutes in water, and to analyse water samples for various solutes including chemical contaminants.

Students examine the origin and chemical nature of substances that may be present in a water supply, including contaminants, and outline sampling techniques used to assess water quality. They measure the solubility of substances in water, explore the relationship between solubility and temperature using solubility curves and learn to predict when a solute will dissolve or crystallise out of solution.

The concept of molarity is introduced and students measure concentrations of solutions using a variety of commonly used units. Students apply the principles of stoichiometry to gravimetric and volumetric analyses of aqueous solutions and water samples. Instrumental techniques include the use of colorimetry and/or UV-visible spectroscopy to estimate the concentrations of coloured species in solution, atomic absorption spectroscopy data to determine the concentration of metal ions in solution and high performance liquid chromatography data to calculate the concentration of organic compounds in solution.

Outcome 2

On completion of this unit the student should be able to measure amounts of dissolved substances in water and analyse water samples for salts, organic compounds and acids and bases.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Water sample analysis

- existence of water in all three states at Earth's surface including the distribution and proportion of available drinking water
- sampling protocols including equipment and sterile techniques for the analysis of water quality at various depths and locations
- the definition of a chemical contaminant and an example relevant to a selected water supply.

Measurement of solubility and concentration

- the use of solubility tables and experimental measurement of solubility in gram per 100 g of water
- the quantitative relationship between temperature and solubility of a given solid, liquid or gas in water
- the use of solubility curves as a quantitative and predictive tool in selected biological, domestic or industrial contexts
- the concept of solution concentration measured with reference to moles (mol L^{-1}) or with reference to mass or volume (g L^{-1} , mg L^{-1} , $\%(m/m)$, $\%(m/v)$, $\%(v/v)$, ppm, ppb) in selected domestic, environmental, commercial or industrial applications, including unit conversions.

Analysis for salts in water

- sources of salts found in water (may include minerals, heavy metals, organo-metallic substances) and the use of electrical conductivity to determine the salinity of water samples
- the application of mass-mass stoichiometry to gravimetric analysis to determine the mass of a salt in a water sample
- the application of colorimetry and/or UV-visible spectroscopy, including the use of a calibration curve, to determine the concentration of coloured species (ions or complexes) in a water sample
- the application of atomic absorption spectroscopy (AAS), including the use a calibration curve, to determine the concentration of metals or metal ions in a water sample (excluding details of instrument).

Analysis for organic compounds in water

- sources of organic contaminants found in water (may include dioxins, insecticides, pesticides, oil spills)
- the application of high performance liquid chromatography (HPLC) including the use of a calibration curve and retention time to determine the concentration of a soluble organic compound in a water sample (excluding details of instrument).

Analysis for acids and bases in water

- sources of acids and bases found in water (may include dissolved carbon dioxide, mining activity and industrial wastes)
- volume-volume stoichiometry (solutions only) and application of volumetric analysis including the use of indicators, calculations related to preparation of standard solutions, dilution of solutions and use of acid-base titrations to determine the concentration of an acid or a base in a water sample.

Area of Study 3

Practical investigation

Substances that are dissolved in water supplies may be beneficial or harmful, and sometimes toxic, to humans and other living organisms. They may also form coatings on, or corrode, water pipes. In this area of study students design and conduct a practical investigation into an aspect of water quality. The investigation relates to knowledge and skills developed in Area of Study 1 and/or Area of Study 2 and is conducted by the student through laboratory work and/or fieldwork.

The investigation requires the student to develop a question, plan a course of action that attempts to answer the question, undertake an investigation to collect the appropriate primary qualitative and/or quantitative data (which may include collecting water samples), organise and interpret the data and reach a conclusion in response to the question.

Outcome 3

On completion of this unit the student should be able to design and undertake a quantitative laboratory investigation related to water quality, and draw conclusions based on evidence from collected data.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 10 and 11](#) of the study design.

Key knowledge

- the chemical concepts specific to the investigation and their significance, including definitions of key terms, and chemical representations
- the characteristics of laboratory techniques of primary qualitative and quantitative data collection relevant to the investigation: sampling protocols; gravimetric analysis, acid-base titrations and/or pH measurement; precision, accuracy, reliability and validity of data; and minimisation of experimental bias
- ethics of and concerns with research including identification and application of relevant health and safety guidelines
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including identification of sources of error and uncertainty, and of limitations of data and methodologies
- observations and experiments that are consistent with, or challenge, current chemical models or theories
- the nature of evidence that supports or refutes a hypothesis, model or theory
- options, strategies or solutions to issues related to water quality
- the key findings of the selected investigation and their relationship to solubility, concentration, acid/base and/or redox concepts
- the conventions of scientific report writing including chemical terminology and representations, symbols, chemical equations, formulas, units of measurement, significant figures and standard abbreviations.

Assessment

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study, including the key knowledge and key skills listed for the outcomes, should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessment at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate achievement of three outcomes. As a set these outcomes encompass all areas of study.

Suitable tasks for assessment may be selected from the following:

For Outcomes 1 and 2

- annotations of a practical work folio of activities or investigations
- a report of a practical activity or investigation
- a modelling activity
- media response
- problem solving involving chemical concepts, skills and/or issues
- a reflective learning journal/blog related to selected activities or in response to an issue
- data analysis
- a test comprising multiple choice and/or short answer and/or extended response.

For Outcome 3

- a report of a student-designed quantitative laboratory investigation using an appropriate format, for example digital presentation, oral communication, scientific poster or written report.

Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. For Area of Study 3, between 4 and 6 hours of class time should be devoted to undertaking the investigation and communicating findings.

Unit 3: How can chemical processes be designed to optimise efficiency?

The global demand for energy and materials is increasing with world population growth. In this unit students explore energy options and the chemical production of materials with reference to efficiencies, renewability and the minimisation of their impact on the environment.

Students compare and evaluate different chemical energy resources, including fossil fuels, biofuels, galvanic cells and fuel cells. They investigate the combustion of fuels, including the energy transformations involved, the use of stoichiometry to calculate the amounts of reactants and products involved in the reactions, and calculations of the amounts of energy released and their representations. Students consider the purpose, design and operating principles of galvanic cells, fuel cells and electrolytic cells. In this context they use the electrochemical series to predict and write half and overall redox equations, and apply Faraday's laws to calculate quantities in electrolytic reactions.

Students analyse manufacturing processes with reference to factors that influence their reaction rates and extent. They investigate and apply the equilibrium law and Le Chatelier's principle to different reaction systems, including to predict and explain the conditions that will improve the efficiency and percentage yield of chemical processes. They use the language and conventions of chemistry including symbols, units, chemical formulas and equations to represent and explain observations and data collected from experiments, and to discuss chemical phenomena.

A student practical investigation related to energy and/or food is undertaken either in Unit 3 or Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The findings of the investigation are presented in a scientific poster format as outlined in the template on [page 11](#).

Area of Study 1

What are the options for energy production?

In this area of study students focus on analysing and comparing a range of energy resources and technologies, including fossil fuels, biofuels, galvanic cells and fuel cells, with reference to the energy transformations and chemical reactions involved, energy efficiencies, environmental impacts and potential applications. Students use the specific heat capacity of water and thermochemical equations to determine the enthalpy changes and quantities of reactants and products involved in the combustion reactions of a range of renewable and non-renewable fuels.

Students conduct practical investigations involving redox reactions, including the design, construction and testing of galvanic cells, and account for differences between experimental findings and predictions made by using the electrochemical series. They compare the design features, operating principles and uses of galvanic cells and fuel cells, and summarise cell processes by writing balanced equations for half and overall cell processes.

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.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Obtaining energy from fuels

- 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 (ΔH) 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
- 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.

Fuel choices

- 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.

Galvanic cells as a source of energy

- 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 a source 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.

Area of Study 2

How can the yield of a chemical product be optimised?

In this area of study students explore the factors that increase the efficiency and percentage yield of a chemical manufacturing process while reducing the energy demand and associated costs.

Students investigate how the rate of a reaction can be controlled so that it occurs at the optimum rate while avoiding unwanted side reactions and by-products. They explain reactions with reference to the collision theory including reference to Maxwell-Boltzmann distribution curves. The progression of exothermic and endothermic reactions, including the use of a catalyst, is represented using energy profile diagrams.

Students explore homogeneous equilibrium systems and apply the equilibrium law to calculate equilibrium constants and concentrations of reactants and products. They investigate Le Chatelier's principle and the effect of different changes on an equilibrium system and make predictions about the optimum conditions for the production of chemicals, taking into account rate and yield considerations. Students represent the establishment of equilibrium and the effect of changes to an equilibrium system using concentration-time graphs.

Students investigate a range of electrolytic cells with reference to their basic design features and purpose, their operating principles and the energy transformations that occur. They examine the discharging and recharging processes in rechargeable cells, and apply Faraday's laws to calculate quantities in electrochemistry and to determine cell efficiencies.

Outcome 2

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.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Rate of chemical reactions

- 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

- 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 (K_c 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 by electrolysis

- 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).

School-based assessment

Satisfactory completion

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

Assessment of levels of achievement

The student's level of achievement in Unit 3 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement.

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement. The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 3 will contribute 16 per cent to the study score.

Outcomes	Marks allocated*	Assessment tasks
Outcome 1 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.	50	Analysis and evaluation of stimulus material. OR A report on a laboratory investigation. OR A comparison of two electricity-generating cells. OR A reflective learning journal/blog related to selected activities or in response to an issue. (approximately 50 minutes or not exceeding 1000 words)
Outcome 2 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.	50	At least one task selected from: <ul style="list-style-type: none">• annotations of at least two practical activities from a practical logbook• a report of a student investigation• an evaluation of research• analysis of data including generalisations and conclusions• media analysis/response• a graphic organiser illustrating a chemical process• an analysis of an unfamiliar chemical manufacturing process or electrolytic cell• a response to a set of structured questions. (approximately 50 minutes or not exceeding 1000 words for each task)
Total marks	100	

*School-assessed Coursework for Unit 3 contributes 16 per cent.

Practical work and assessment

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2.

External assessment

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination, which will contribute 60 per cent.

Unit 4: How are organic compounds categorised, analysed and used?

The carbon atom has unique characteristics that explain the diversity and number of organic compounds that not only constitute living tissues but are also found in the fuels, foods, medicines and many of the materials we use in everyday life. In this unit students investigate the structural features, bonding, typical reactions and uses of the major families of organic compounds including those found in food.

Students study the ways in which organic structures are represented and named. They process data from instrumental analyses of organic compounds to confirm or deduce organic structures, and perform volumetric analyses to determine the concentrations of organic chemicals in mixtures. Students consider the nature of the reactions involved to predict the products of reaction pathways and to design pathways to produce particular compounds from given starting materials.

Students investigate key food molecules through an exploration of their chemical structures, the hydrolytic reactions in which they are broken down and the condensation reactions in which they are rebuilt to form new molecules. In this context the role of enzymes and coenzymes in facilitating chemical reactions is explored. Students use calorimetry as an investigative tool to determine the energy released in the combustion of foods.

A student practical investigation related to energy and/or food is undertaken in either Unit 3 or in Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The findings of the investigation are presented in a scientific poster format as outlined in the template on [page 11](#).

Area of Study 1

How can the diversity of carbon compounds be explained and categorised?

In this area of study students explore why such a vast range of carbon compounds is possible. They examine the structural features of members of several homologous series of compounds, including some of the simpler structural isomers, and learn how they are represented and named.

Students investigate trends in the physical and chemical properties of various organic families of compounds. They study typical reactions of organic families and some of their reaction pathways, and write balanced chemical equations for organic syntheses.

Students learn to deduce or confirm the structure and identity of organic compounds by interpreting data from mass spectrometry, infrared spectroscopy and proton and carbon-13 nuclear magnetic resonance spectroscopy.

Outcome 1

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.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Structure and nomenclature of organic compounds

- 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.

Categories, properties and reactions of organic compounds

- 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).

Area of Study 2

What is the chemistry of food?

Food contains various organic compounds that are the source of both the energy and the raw materials that the human body needs for growth and repair. In this area of study students explore the importance of food from a chemical perspective.

Students study the major components of food with reference to their structures, properties and functions. They examine the hydrolysis reactions in which foods are broken down, the condensation reactions in which new biomolecules are formed and the role of enzymes, assisted by coenzymes, in the metabolism of food.

Students study the role of glucose in cellular respiration and investigate the principles of calorimetry and its application in determining enthalpy changes for reactions in solution. They explore applications of food chemistry by considering the differences in structures of natural and artificial sweeteners, the chemical significance of the glycaemic index of foods, the rancidity of fats and oils, and the use of the term 'essential' to describe some amino acids and fatty acids in the diet.

Outcome 2

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.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

Key food molecules

- 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 non-essential 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.

Metabolism of food in the human body

- 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).

Energy content of food

- 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.

Area of Study 3

Practical investigation

A student-designed or adapted practical investigation related to energy and/or food is undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4. The investigation relates to knowledge and skills developed across Unit 3 and/or Unit 4.

The investigation requires the student to identify an aim, develop a question, formulate a hypothesis and plan a course of action to answer the question and that complies with safety and ethical requirements. The student then undertakes an experiment that involves the collection of primary qualitative and/or quantitative data, analyses and evaluates the data, identifies limitations of data and methods, links experimental results to science ideas, reaches a conclusion in response to the question and suggests further investigations which may be undertaken. Findings are communicated in a scientific poster format according to the template on [page 11](#). A practical logbook must be maintained by the student for record, authentication and assessment purposes.

Outcome 3

On the completion of this unit the student should be able to design and undertake a practical investigation related to energy and/or food, and present methodologies, findings and conclusions in a scientific poster.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key skills on [pages 10 and 11](#) of the study design.

Key knowledge

- independent, dependent and controlled variables
- chemical concepts specific to the investigation and their significance, including definitions of key terms, and chemical representations
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation: volumetric analysis, instrumental analysis, calorimetry and/or construction of electrochemical cells; precision, accuracy, reliability and validity of data; and minimisation of experimental bias
- ethics of and concerns with research including identification and application of relevant health and safety guidelines
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and uncertainty, and limitations of data and methodologies
- models and theories and their use in organising and understanding observed phenomena and chemical concepts including their limitations
- the nature of evidence that supports or refutes a hypothesis, model or theory
- the key findings of the selected investigation and their relationship to thermochemical, equilibrium and/or organic structure and bonding concepts
- the conventions of scientific report writing and scientific poster presentation including chemical terminology and representations, symbols, chemical equations, formulas, units of measurement, significant figures, standard abbreviations and acknowledgment of references.

School-based assessment

Satisfactory completion

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

Assessment of levels of achievement

The student's level of achievement in Unit 4 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement.

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement. The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 4 will contribute 24 per cent of the study score.

Outcomes	Marks allocated*	Assessment tasks
<p>Outcome 1</p> <p>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.</p>	30	<p>At least one task selected from:</p> <ul style="list-style-type: none"> • annotations of at least two practical activities from a practical logbook • a report of a student investigation • analysis of data including generalisations and conclusions • media analysis/response • a response to a set of structured questions • a reflective learning journal/blog related to comparison of organic structures or pathways. (approximately 50 minutes or not exceeding 1000 words for each task)
<p>Outcome 2</p> <p>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.</p>	30	<p>Response to stimulus material. OR A report of a laboratory investigation. OR A comparison of food molecules OR A reflective learning journal/blog related to selected activities or in response to an issue. (approximately 50 minutes or not exceeding 1000 words)</p>
<p>Outcome 3</p> <p>Design and undertake a practical investigation related to energy and/or food, and present methodologies, findings and conclusions in a scientific poster.</p>	30	<p>A structured scientific poster according to the VCAA standard template. (not exceeding 1000 words)</p>
Total marks	90	

*School-assessed Coursework for Unit 4 contributes 24 per cent.

Practical work and assessment

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. For Area of Study 3, between 7 and 10 hours of class time should be devoted to the investigation related to energy and/or food, to be undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4, including writing of the sections of the scientific poster.

External assessment

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination.

Contribution to final assessment

The examination will contribute 60 per cent.

End-of-year examination

Description

The examination will be set by a panel appointed by the VCAA. All the key knowledge that underpins the outcomes in Units 3 and 4 and the cross-study key science skills are examinable.

Conditions

The examination will be completed under the following conditions:

- Duration: 2.5 hours.
- Date: end-of-year, on a date to be published annually by the VCAA.
- VCAA examination rules will apply. Details of these rules are published annually in the [VCE and VCAL Administrative Handbook](#).
- The examination will be marked by assessors appointed by the VCAA.

Further advice

The VCAA publishes specifications for all VCE examinations on the VCAA website. Examination specifications include details about the sections of the examination, their weighting, the question format/s and any other essential information. The specifications are published in the first year of implementation of the revised Units 3 and 4 sequence together with any sample material.