OFFICIAL

South Australian Certificate of Education
LEARNING AT THE PACE OF CHANGE

Government of South Australia

Chemistry

2024 Subject Outline | Stage 1

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INTRODUCTION

SUBJECT DESCRIPTION

Chemistry is a 10-credit subject or a 20-credit subject at Stage 1 and a 20-credit subject at Stage 2.

In their study of Chemistry, students develop and extend their understanding of how the physical world is chemically constructed, the interaction between human activities and the environment, and the use that human beings make of the planet's resources. They explore examples of how scientific understanding is dynamic and develops with new evidence, which may involve the application of new technologies.

Students consider examples of benefits and risks of chemical knowledge to the wider community, along with the capacity of chemical knowledge to inform public debate on social and environmental issues. The study of Chemistry helps students to make informed decisions about interacting with and modifying nature, and explore options such as green or sustainable chemistry, which seeks to reduce the environmental impact of chemical products and processes.

Through the study of Chemistry, students develop the skills that enable them to be questioning, reflective, and critical thinkers; investigate and explain phenomena around them; and explore strategies and possible solutions to address major challenges now and in the future (for example, in energy use, global food supply, and sustainable food production).

Students integrate and apply a range of understanding, inquiry, and scientific thinking skills that encourage and inspire them to contribute their own solutions to current and future problems and challenges, and pursue future pathways, including in medical or pharmaceutical research, pharmacy, chemical engineering, and innovative product design.

CAPABILITIES

The capabilities connect student learning within and across subjects in a range of contexts. They include essential knowledge and skills that enable people to act in effective and successful ways.

The SACE identifies seven capabilities. They are:

- literacy
- numeracy
- information and communication technology (ICT) capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding.

Literacy

In this subject students extend and apply their literacy capability by, for example:

- interpreting the work of scientists across disciplines, using chemical knowledge
- critically analysing and evaluating primary and secondary data
- extracting chemical information presented in a variety of modes
- using a range of communication formats to express ideas logically and fluently, incorporating the terminology and conventions of chemistry
- synthesising evidence-based arguments
- communicating appropriately for specific purposes and audiences.

Numeracy

In this subject students extend and apply their numeracy capability by, for example:

- solving problems using calculation and critical thinking skills
- measuring with appropriate instruments
- recording, collating, representing, and analysing primary data
- accessing and interpreting secondary data
- identifying and interpreting trends and relationships
- calculating and predicting values by manipulating data, using appropriate scientific conventions.

Information and communication technology (ICT) capability

In this subject students extend and apply their ICT capability by, for example:

- locating and accessing information
- collecting, analysing, and representing data electronically
- modelling concepts and relationships
- using technologies to create new ways of thinking about science

- communicating chemical ideas, processes, and information
- understanding the impact of ICT on the development of chemistry and its application in society
- evaluating the application of ICT to advance understanding and innovations in chemistry.

Critical and creative thinking

In this subject students extend and apply critical and creative thinking by, for example:

- analysing and interpreting problems from different perspectives
- deconstructing a problem to determine the most appropriate method for investigation
- constructing, reviewing, and revising hypotheses to design investigations
- interpreting and evaluating data and procedures to develop logical conclusions
- analysing interpretations and claims, for validity and reliability
- devising imaginative solutions and making reasonable predictions
- envisaging consequences and speculating on possible outcomes
- recognising the significance of creative thinking on the development of chemical knowledge and applications.

Personal and social capability

In this subject students extend and apply their personal and social capability by, for example:

- understanding the importance of chemical knowledge on health and well-being, both personally and globally
- making decisions and taking initiative while working independently and collaboratively
- planning effectively, managing time, following procedures effectively, and working safely
- sharing and discussing ideas about chemical issues, developments and innovations, while respecting the perspectives of others
- recognising the role of their own beliefs and attitudes in gauging the impact of chemistry in society
- seeking, valuing, and acting on feedback.

Ethical understanding

In this subject students extend and apply their ethical understanding by, for example:

- considering the implications of their investigations on organisms and the environment
- making ethical decisions based on an understanding of chemical principles
- using data and reporting the outcomes of investigations accurately and fairly
- acknowledging the need to plan for the future and to protect and sustain the biosphere
- recognising the importance of their responsible participation in social, political, economic, and legal decision-making.

Intercultural understanding

In this subject students develop their intercultural understanding by, for example:

- recognising that science is a global endeavour with significant contributions from diverse cultures
- respecting and engaging with different cultural views and customs and exploring their interaction with scientific research and practices
- being open-minded and receptive to change in the light of scientific thinking based on new information
- understanding that the progress of chemistry influences and is influenced by cultural factors.

ABORIGINAL AND TORRES STRAIT ISLANDER KNOWLEDGE, CULTURES, AND PERSPECTIVES

In partnership with Aboriginal and Torres Strait Islander communities, and schools and school sectors, the SACE Board of South Australia supports the development of high-quality learning and assessment design that respects the diverse knowledge, cultures, and perspectives of Indigenous Australians.

The SACE Board encourages teachers to include Aboriginal and Torres Strait Islander knowledge and perspectives in the design, delivery, and assessment of teaching and learning programs by:

- providing opportunities in SACE subjects for students to learn about Aboriginal and Torres Strait Islander histories, cultures, and contemporary experiences
- recognising and respecting the significant contribution of Aboriginal and Torres Strait Islander peoples to Australian society
- drawing students' attention to the value of Aboriginal and Torres Strait Islander knowledge and perspectives from the past and the present
- promoting the use of culturally appropriate protocols when engaging with and learning from Aboriginal and Torres Strait Islander peoples and communities.

HEALTH AND SAFETY

The handling of a range of chemicals and equipment requires appropriate health, safety, and welfare procedures.

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 and that school practices meet the requirements of the *Work Health and Safety Act 2012*, in addition to relevant state, territory, or national health and safety guidelines. Information about these procedures is available from the school sectors.

The following safety practices must be observed by students in all laboratory work:

- Use equipment only under the direction and supervision of a teacher or other qualified person.
- Follow safety procedures when preparing or manipulating apparatus.
- Use appropriate safety gear when preparing or manipulating apparatus.

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 1 Chemistry.

In this subject, students are expected to:

1. apply science inquiry skills to deconstruct a problem and design and conduct chemistry investigations, using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, analyse, and interpret the results of chemistry investigations
3. evaluate procedures and results, and analyse evidence to formulate and justify conclusions
4. develop and apply knowledge and understanding of chemical concepts in new and familiar contexts
5. explore and understand science as a human endeavour
6. communicate knowledge and understanding of chemical concepts, using appropriate terms, conventions and representations.

CONTENT

Chemistry is a 10-credit or a 20-credit subject at Stage 1.

The topics in Stage 1 Chemistry provide the framework for developing integrated programs of learning through which students extend their skills, knowledge, and understanding of the three strands of science.

The three strands of science to be integrated throughout student learning are:

- science inquiry skills
- science as a human endeavour
- science understanding.

The topics for Stage 1 Chemistry are:

- Topic 1: Materials and their atoms
- Topic 2: Combinations of atoms
- Topic 3: Molecules
- Topic 4: Mixtures and solutions
- Topic 5: Acid and bases
- Topic 6: Redox reactions

For a 10-credit subject, students study a selection of concepts from at least three of these topics.

For a 20-credit subject, students study a selection of concepts from all six topics.

The topics selected can be sequenced and structured to suit individual groups of students. Topics can be studied in their entirety or in part, taking into account student interests and preparation for pathways into future study of chemistry.

Note that the topics are not necessarily designed to be of equivalent length — it is anticipated that teachers may allocate more time to some than others.

In designing a Stage 1 Chemistry program for students who intend to study Chemistry at Stage 2, the information in the following table should be considered. This table shows Stage 1 subtopics that introduce key ideas that are later used in particular Stage 2 subtopics.

Stage 1	Stage 2
1.1 Properties and uses of materials	4.4 Materials
1.2 Atomic structure	1.5 Atomic spectroscopy
1.3 Quantities of atoms	1.3 Volumetric analysis
2.1 Types of materials	4.4 Materials
2.2 Bonding between atoms	1.5 Atomic spectroscopy 3.1 Introduction (organic and biological chemistry) 4.3 Soil
2.3 Quantities of molecules and ions	1.3 Volumetric analysis 2.2 Equilibrium and yield
3.1 Molecule polarity	1.4 Chromatography 3.1 Introduction (organic and biological chemistry) 3.10 Proteins
3.2 Interactions between molecules	1.4 Chromatography 3.1 Introduction (organic and biological chemistry) 3.10 Proteins 4.4 Materials
3.3 Hydrocarbons	3.1 Introduction (organic and biological chemistry) 3.9 Triglycerides 4.1 Energy
3.4 Polymers	3.4 Carbohydrates 4.4 Materials
4.1 Miscibility and solutions	3.1 Introduction (organic and biological chemistry) 3.9 Triglycerides
4.2 Solutions of ionic substances	3.5 Carboxylic acids 3.6 Amines 3.10 Proteins 4.2 Water 4.3 Soil
4.3 Quantities in reactions	1.3 Volumetric analysis 2.2 Equilibrium and yield

Stage 1	Stage 2
4.4 Energy in reactions	2.1 Rates of reactions 2.2 Equilibrium and yield 4.1 Energy
5.1 Acid–base concepts	1.1 Global warming and climate change
5.2 Reactions of acids and bases	3.5 Carboxylic acids 3.6 Amines 4.4 Materials
5.3 The pH scale	4.2 Water
6.1 Concepts of oxidation and reduction	3.2 Alcohols 3.3 Aldehydes and ketones 4.4 Materials
6.2 Metal reactivity	4.4 Materials
6.3 Electrochemistry	4.1 Energy 4.4 Materials

The following pages describe in more detail:

- science inquiry skills
- science as a human endeavour
- the topics for science understanding.

The descriptions of the science inquiry skills and the topics are structured in two columns: the left-hand column sets out the science inquiry skills or science understanding and the right-hand column sets out possible contexts.

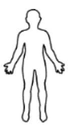
Together with science as a human endeavour, the science inquiry skills and science understanding form the basis of teaching, learning, and assessment in this subject.

The possible contexts are suggestions for potential inquiry approaches, and are neither comprehensive nor exclusive. Teachers may select from these and are encouraged to consider other approaches according to local needs and interests.

Within the topic descriptions, the following symbols are used in the possible contexts to show how a strand of science can be integrated:

indicates a possible teaching and learning strategy for science understanding

indicates a possible science inquiry activity



indicates a possible focus on science as a human endeavour.

Science Inquiry Skills

In Chemistry, investigation is an integral part of the learning and understanding of concepts, by using the scientific method to test ideas and develop new knowledge.

Practical investigations must involve a range of both individual and collaborative activities, during which students extend the science inquiry skills described in the table that follows.

Practical activities may take a range of forms, such as developing or using models and simulations that enable students to develop a better understanding of particular concepts. The activities include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements, or other information obtained during the investigation. Students represent and analyse the data they have collected; evaluate procedures, and describe the limitations of the data and procedures; consider explanations for their observations; and present and justify conclusions appropriate to the initial question or hypothesis.

For a 10-credit subject, it is recommended that a minimum of 8–10 hours of class time involves practical activities.

For a 20-credit subject, it is recommended that a minimum of 16–20 hours of class time involves practical activities.

Science inquiry skills are fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically consider the evidence they obtain so that they can present and justify a conclusion.

Science Inquiry Skills	Possible contexts
Scientific methods enable systematic investigation to obtain measurable evidence. • Deconstruct a problem to determine and justify the most appropriate method for investigation. • Design investigations, including: ◆ a hypothesis or inquiry question ◆ types of variables – dependent – independent – factors held constant (how and why they are controlled) – factors that may not be able to be controlled (and why not) ◆ materials required ◆ the method to be followed ◆ the type and amount of data to be collected ◆ identification of ethical and safety considerations.	Develop inquiry skills by, for example: • designing investigations that require investigable questions and imaginative solutions (with or without implementation) • critiquing proposed investigations • using the conclusion of one investigation to propose subsequent experiments • changing an independent variable in a given procedure and adapting the method • researching, developing, and trialling a method • improving an existing procedure • identifying options for measuring the dependent variable • researching hazards related to the use and disposal of chemicals and/or biological materials • developing safety audits • identifying relevant ethical and/or legal considerations in different contexts.
Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. • Conduct investigations, including: ◆ selection and safe use of appropriate materials, apparatus, and equipment ◆ collection of appropriate primary and/or secondary data (numerical, visual, descriptive) ◆ individual and collaborative work.	Develop inquiry skills by, for example: • identifying equipment, materials, or instruments fit for purpose • practising techniques and safe use of apparatus • comparing resolution of different measuring tools • distinguishing between, and using, primary and secondary data.
Results of investigations are represented in a well-organised way to allow them to be interpreted. • Represent results of investigations in appropriate ways, including: ◆ use of appropriate SI units, symbols ◆ construction of appropriately labelled tables ◆ drawing of graphs, including lines or curves of best fit as appropriate ◆ use of significant figures.	Develop inquiry skills by, for example: • practising constructing tables to tabulate data with column and row labels with units • identifying the appropriate representations to graph different data sets • selecting appropriate axes and scales to graph data • clarifying understanding of significant figures using, for example: www.astro.yale.edu/astro120/SigFig.pdf www.hccfl.edu/media/43516/sigfigs.pdf www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm • comparing data from different sources to describe as quantitative or qualitative.

Science Inquiry Skills	Possible contexts
Scientific information can be presented using different types of symbols and representations. • Select, use, and interpret appropriate representations, including: ◆ mathematical relationships, such as ratios ◆ diagrams ◆ writing equations to explain concepts, solve problems, and make predictions.	Develop inquiry skills by, for example: • writing chemical equations • drawing and labelling diagrams • recording images • constructing flow diagrams.
The analysis of the results of investigations allows them to be interpreted in a meaningful way. • Analyse data, including: ◆ identification and discussion of trends, patterns, and relationships ◆ interpolation or extrapolation where appropriate.	Develop inquiry skills by, for example: • analysing data sets to identify trends and patterns • determining relationships between independent and dependent variables • using graphs, e.g. from CSIRO or the Australian Bureau of Statistics (ABS), to predict values other than plotted points • calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and data can determine the meaningfulness of the results. • Identify sources of uncertainty, including: ◆ random and systematic errors ◆ uncontrolled factors. • Evaluate reliability, accuracy, and validity of results, by discussing factors including: ◆ sample size ◆ precision ◆ resolution of equipment ◆ random error ◆ systematic error ◆ factors that cannot be controlled.	Develop inquiry skills by, for example: • discussing how the repeating of an investigation with different materials/equipment may detect a systematic error • using an example of an investigation report to develop report-writing skills. Useful website: www.biologyjunction.com/sample%20ap%20lab%20reports.htm
Conclusions can be formulated that relate to the hypothesis or inquiry question. • Select and use evidence and scientific understanding to make and justify conclusions. • Recognise the limitations of conclusions. • Recognise that the results of some investigations may not lead to definitive conclusions.	Develop inquiry skills by, for example: • evaluating procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions • using data sets to discuss the limitations of the data in relation to the range of possible conclusions that could be made.

Science Inquiry Skills	Possible contexts
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: ◆ appropriate language ◆ terminology ◆ conventions.	Develop inquiry skills by, for example: • reviewing scientific articles or presentations to recognise conventions • developing skills in referencing and/or footnoting • distinguishing between reference lists and bibliographies • practising scientific communication in written, oral, and multimodal formats, e.g. presenting a podcast or a blog.

Science as a Human Endeavour

The science as a human endeavour strand highlights the development of science as a way of knowing and doing, and explores the purpose, use, and influence of science in society.

By exploring science as a human endeavour, students develop and apply their understanding of the complex ways in which science interacts with society, and investigate the dynamic nature of chemistry. They explore how chemists develop new understanding and insights, and produce innovative solutions to everyday and complex problems and challenges in local, national, and global contexts. In this way, students are encouraged to think scientifically and make connections between the work of others and their own learning. This enables them to explore their own solutions to current and future problems and challenges.

Students understand that the development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. They consider how and why science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as emerging technologies enable new avenues of investigation. They understand that scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice.

Students explore how scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. They investigate ways in which the application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. They understand how decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As critical thinkers, they appreciate science as an ever-evolving body of knowledge, that frequently informs public debate, but is not always able to provide definitive answers.

The key concepts of science as a human endeavour underpin the contexts, approaches, and activities in this subject, and must be integrated into all teaching and learning programs.

The key concepts of science as a human endeavour, with elaborations that are neither comprehensive nor exclusive, in the study of Chemistry are:

Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- Collaboration between scientists, governments, and other agencies is often required in scientific research and enterprise.

Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, cultural, and environmental impacts, offer valid explanations, and make reliable predictions.
- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk and provides opportunities for innovation.
- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Topic 1: Materials and their atoms

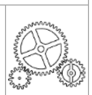
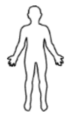
Chemistry is the study of the infinite variety of natural and synthetic materials in our world, all composed from a limited number of different atoms. Explanations of the structure of all materials are based on the concept of the atom. Evidence from diverse areas has contributed to contemporary understandings of atomic structure and chemical bonding. In this topic, students explore the development of the model of the atom over time, such as how spectral evidence has contributed to the current model, and how advances in one area of knowledge can lead to advances in another.

Students investigate the physical properties of a range of materials and how these properties relate to their uses; for example, how these properties are important in separating materials. They learn how the uses of diverse materials are also critically dependent on their properties.

Students explore and discuss how scientists attempted to represent and organise data about elements in meaningful and useful ways, leading to the development of the modern periodic table of elements as a means of identifying trends, patterns, and relationships.

Students extend their literacy skills through use of the terminology and conventions of chemistry. They study some of the most fundamental principles of chemistry: atomic structure, the periodic table, electronegativity, and the mole concept. Through practical activities, students extend their numeracy skills and apply their understanding of principles, concepts, and physical properties to investigate elemental spectra and their use in analysis.

Subtopic 1.1: Properties and uses of materials

Science Understanding	Possible contexts	
The uses of materials are related to their properties, including solubility, thermal and electrical conductivities, melting point, and boiling point. Nanomaterials are substances that contain particles in the size range 1–100 nm. • Suggest uses of materials, including nanomaterials, given their properties and vice versa.	View and discuss a video of the gallium spoon, e.g. at: www.sciencephoto.com/media/670443/view Very small particles have a high surface area to volume ratio. Explore how this may lead to unusual properties and to a diverse range of uses. Discuss examples of natural colloids (e.g. milk) and synthetic colloids (e.g. mayonnaise). Compare sizes of atoms with nanoparticles. View an animation of a nano-robot in the bloodstream at: www.sciencephoto.com/media/589889/view	
	Discuss the potential benefits and risks of using nano-robots in medicine. Explore links between macroscopic properties and uses of materials. Examples could include reference to the development and application of new materials such as aerogels or ferrofluid, e.g. at: www.aerogel.org/ www.youtube.com/watch?v=WXvar-4M6VA Investigate the influence of the scientific development of innovative new materials on society. Examples could include flexible plastics, steel production, or composite materials. Explore how scientists collaborate, e.g. Smalley (USA) and Kroto (UK) collaborated to produce C_{60} fullerenes. Examine how to evaluate scientific claims, e.g. using: http://www.exploratorium.edu/evidence/evidence.html?#/tester/	

Science Understanding	Possible contexts
Differences in the properties of substances in a mixture can be used to separate them. • Identify how the components of a mixture can be separated by methods including filtration, distillation, and evaporation.	Explore situations where the separation of components of mixtures is important in consumer products. Examples could include how: • filtration is used to separate insoluble contaminants from water during water treatment • chromatography can be used to separate components of a dye or amino acids from a hydrolysed protein • panning for gold and froth flotation depend on differences between components in mixtures • fractional distillation is used to separate the many components of petroleum and to separate alcohol from water • a variety of methods, including chromatography, can be used to identify, separate, and quantify contaminants, which must be removed from food, medicines, fuels, and cosmetics.
	Separate mixtures of substances on the basis of particle size, solubility, and boiling points. Separate components of dyes or chlorophyll using chromatography. Distil water from sea water and check the quality of the distillate.

Subtopic 1.2: Atomic structure

Science Understanding	Possible contexts
All materials consist of atoms. Atoms are commonly modelled as consisting of electrons orbiting a nucleus containing protons and neutrons. Emission and absorption spectra of elements provide evidence that electrons are arranged in distinct energy levels and can be used to identify some elements in matter.	Explore how spectra have been used to predict the existence of, and to identify, certain elements. Examples could include how: • elements in the sun were identified from absorption lines (Fraunhofer lines) in the sun's emission spectrum • Bunsen and Kirchoff predicted the existence of two unknown elements from spectral evidence and discovered caesium and rubidium.
	Explore how colours absorbed/emitted by some metals are used to give fireworks their colours. Perform flame tests to identify elements based on characteristic emission colours. Use spectroscopes to see individual spectral lines.
	Explore the contributions of different scientists to the current model of the atom, and how new evidence overcame the limitations of earlier models.
Atomic number and mass number provide information about the numbers of subatomic particles in an atom. Many elements consist of a number of different isotopes, which have different physical properties but the same chemical properties. • Represent isotopes of an element using appropriate notation.	Determine the numbers of protons, electrons, and neutrons in different isotopes, given the atomic and mass numbers. Investigate the use and supply of radioisotopes by the South Australian Health and Medical Research Institute (SAHMRI), e.g. at: www.sahmri.com/media-hub/latest-news
	Use mass spectra to determine the isotopic composition of an element.
	Explore the variety of uses of radioactive isotopes and discuss the risks involved with their use. Examples could include tracers used in medicine and agriculture, the potential uses of ^{3}He, or the use of the radioisotope ^{14}C by geologists and archaeologists.

Science Understanding	Possible contexts
The arrangement of electrons in atoms and monatomic ions can be described in terms of shells and subshells. • Write the electron configuration using subshell notation of an atom of any of the first 38 elements in the periodic table.	*Note that the electron configuration of monatomic ions is considered in subtopic 2.2.* Teachers may wish to introduce only elements 1–20 at first and return to the remaining elements later in the program. Teachers may wish to introduce subshell notation later in the program. Fill orbitals as an exercise on an interactive periodic table to visualise patterns and anomalies.

Subtopic 1.3: Quantities of atoms

Science Understanding	Possible contexts
The quantities of different substances can be conveniently compared using the mole unit. The relative atomic mass of an element is determined from all the isotopes of that element. The number of moles of atoms in a sample can be determined from the number of atoms present or from the mass of the atoms. • Undertake calculations using the relationship $n = \frac{m}{M}$ and its rearrangements.	*Note that the mole concept, concentrations of solutions, and stoichiometry, are developed in Stage 1 subtopics 2.3, 4.3, and 5.3, and in Stage 2 subtopic 1.3.* Undertake calculations to demonstrate the size of the Avogadro number, e.g. 1 mole of sheets of paper; how far would the pile extend into space? Display 1 mole of atoms of different elements. View the video, 'A Mole is a Unit!', at: www.youtube.com/watch?v=PvT51M0ek5c Discuss the relationship between the number of significant figures in numerical answers and the precision and resolution of the measurements.

Subtopic 1.4: The periodic table

Science Understanding	Possible contexts
In the modern periodic table, elements are arranged in order of increasing atomic number, and display periodic trends in their properties. • Identify trends in atomic radii, valencies, and electronegativities, across periods and down groups of the periodic table.	Plot graphs of the various properties of elements and use these graphs to explore patterns and make predictions relating to the behaviour and possible uses of the elements. Use the interactive periodic table at www.rsc.org/periodic-table to explore the arrangement of electrons in shells, subshells, and orbitals, and to visualise patterns and anomalies in the properties of the atoms and elements. Use the app, The Elements, by Theodore Gray.
	Investigate differences in physical and chemical properties of a group of elements and their compounds. Investigate the trends in properties of the oxides of period 3 elements.
	Explore the contributions made by scientists to the development of the periodic table proposed by Mendeleev.
The position of an element in the periodic table is related to its metallic or non-metallic character. • Identify the position of an atom in the periodic table given its electron configuration. • Identify the *s*, *p*, *d*, and *f* blocks of the periodic table.	Investigate the *f*-block elements: why are they important?
	Investigate the properties of samples of metals and non-metals.

Topic 2: Combining atoms

An important facet of human endeavour is the understanding that has developed over the last two centuries of the constituents of matter — the atoms that are considered in Topic 1: Materials and Their Atoms and the forces that hold them together. Although there are a limited number of different atoms, they can combine together in different ways to form enormous numbers of materials with a diverse range of properties.

In this topic students explore the different types of primary bonding — metallic, ionic, and covalent — as well as secondary interactions, and use models of bonding to develop and extend their understanding of the chemistry behind the macroscopic properties of materials. Their study of concepts of bonding also forms a key foundation for concepts introduced in other topics.

Students apply their science inquiry skills to investigate the physical properties of materials at the macroscopic scale, and relate these properties to the structures of the materials. They examine their own beliefs and attitudes in evaluating the impact of the use of various materials in society.

Subtopic 2.1: Types of materials

Science Understanding	Possible contexts
Materials can be classified according to their structure and bonding into four types of substances. Melting points can be used to classify materials into molecular and non-molecular lattices. Electrical conductivity of non-molecular materials provides evidence for three types of primary bonding: metallic, ionic, and covalent. • Classify materials as molecular, metallic, ionic, and covalent network, given relevant conductivity and melting point data.	Test physical properties (melting points, electrical conductivities) of a range of materials and use the results to classify the materials as metallic, ionic, covalent network, or molecular.

Subtopic 2.2: Bonding between atoms

Science Understanding	Possible contexts
The formation of bonds between atoms results in stable valence-shell configurations. Energy is released when bonds are formed. Energy is required to break bonds. Metallic, ionic, and covalent bonds are the strong forces of attraction (primary bonds) between particles.	*Note that this material draws on concepts introduced in subtopic 1.2.* Draw and annotate electron-dot diagrams to represent valence shells of atoms. Use electron-dot diagrams of atoms to predict their tendency to form chemical bonds. Model electron transfer and electron sharing using computer simulations.
	Explore the contribution of Linus Pauling to our understanding of the nature of chemical bonds and the influence of his later work, which laid the foundation for modern molecular biology.
Metallic Bonding Metallic bonding is the force of attraction between metal cations and their delocalised valence electrons. The physical properties of metallic elements can be explained using the model for metallic bonding. • Explain the melting and boiling points, and electrical conductivities of metallic elements.	Use a bubble-raft or ball bearings to model a metallic lattice. Explore how metals can be combined to produce alloys with a wide range of properties, and how these alloys can be tailored to suit particular uses.
	Investigate the costs, benefits, and unforeseen consequences and the need to assess risk in the mining of a metal, e.g. mining of platinum in South Africa, mining of gold in New Guinea.
Ionic Bonding Valence electrons are transferred from a metallic atom to a non-metallic atom to form ions. Ionic bonding is the force of attraction between the oppositely charged ions. • Predict the charge on the monatomic ion formed by an element, using its position in the periodic table. • Write the electron configuration, using subshell notation of the monatomic ion of any of the first 38 elements of the periodic table. Ionic compounds are continuous and are represented by empirical formulae. • Write formulae for ionic compounds given the charges on the ions.	Teachers may choose to introduce only the ions of elements 1–20 at first and return to the remaining ions later in the program. Consider the concept of electron transfer as redox half-equations. Determine ionic formulae, using cut-outs, including charges, of cations and anions. Play a game of 'Ion Bingo'.

Science Understanding	Possible contexts
The properties of ionic compounds can be explained using the model for ionic bonding. Explain the melting and boiling points, and electrical conductivities of ionic compounds.	
Covalent Bonding Non-metallic atoms share electrons to form covalent bonds. • Use electron-dot diagrams and structural formulae to show covalent bonds between non-metallic atoms. A covalent bond may be polar or non-polar. • Use electronegativity values, or the position of atoms in the periodic table, to predict and explain the polarity of a covalent bond. • Indicate the polarity of a covalent bond, using the appropriate convention.	*Note that the term 'Lewis structure', to refer to a structural formula, is used ambiguously in texts.* Use appropriate conventions to show covalent bonds and their polarities.
Covalent bonding is found in molecular and non-molecular (continuous) substances. A molecule can be represented by a molecular formula. A continuous covalent substance is represented by an empirical formula. The physical properties of continuous covalent substances can be explained using the model for covalent bonding. • Explain the melting point, hardness, and electrical conductivity of continuous covalent substances.	Investigate why carbon fibre has replaced metal in the construction of F1 cars: http://formula1.about.com/od/car1/a/carbon_fiber.htm Explore and explain the properties of graphite in 'lead' pencils. Investigate the occurrence, structures, physical properties, and uses of the allotropes of carbon. Silicon is more abundant in the Earth's crust than carbon. Discuss reasons why our biosphere is based on carbon and not on silicon. Write formulae for simple molecular substances given their systematic names.

Science Understanding	Possible contexts	
	Explore the potential economic, social, ethical, and environmental risks of using different fullerenes. Uses could include drug delivery in the body, lubricants, catalysts, and nanotubes for reinforcing materials. www.acs.org/content/dam/acsorg/education/whatischemistry/landmarks/lesson-plans/discovery-of-fullerenes.pdf Investigate the contribution of Rosalind Franklin to our understanding of the chemistry of coal using the technique of X-ray crystallography.	

Subtopic 2.3: Quantities of molecules and ions

Science Understanding	Possible contexts
The percentage composition of elements in compounds can be determined from the molar masses of the atoms. • Undertake calculations of percentage composition, by mass, of elements in compounds.	*Note that this material continues the work on quantitative chemistry introduced in subtopic 1.3.* Determine experimentally the percentage of magnesium in magnesium oxide or copper in copper sulfate and compare this value with the theoretical value.
The number of moles of particles (molecules, ions) in a sample can be determined from the mass of the sample and the molar masses of the particles. • Undertake calculations using the relationship $n = \frac{m}{M}$ and its rearrangements for molecules, and for ions and their compounds.	Teachers may choose to introduce stoichiometry (mass–mass) here. Determine the empirical formulae of compounds (oxides of tin, magnesium, and copper).

Topic 3: Molecules

Many chemicals important to human life are molecular. They range from small molecules such as water and gases to huge complex molecules found in proteins and other polymers.

In this topic, students explore the three-dimensional arrangement of simple molecules and the principles that explain these structures. They investigate properties of molecular substances and explain these properties in terms of the nature of the forces of attraction between molecules.

The variety and importance of compounds of carbon are so great that these molecules are assigned to their own branch of chemistry — organic chemistry. Students study the structures, properties, and uses of hydrocarbons and the nature and importance of their polymers. They become familiar with the international naming conventions for organic compounds and apply them to simple organic molecules. Students recognise the significance of creative thinking in the development of materials and their applications.

Subtopic 3.1: Molecule polarity

Science Understanding	Possible contexts
The shapes of molecules can be explained and predicted using three-dimensional representations of electrons as charge clouds, and using valence-shell electron-pair repulsion (VSEPR) theory. • Draw and annotate diagrams showing covalent bonds, non-bonding pairs, and shapes of molecules and ions in which there is only one central atom and up to eight valence electrons.	*Note that the expansion of the octet in molecules is considered in subtopic 5.2.* Use balloons ('charge clouds') to determine the shapes of molecules with two, three, or four electron clouds around a central atom. Model molecules with virtual molecular model kits and 3D-modelling software.
The polarity of a molecule results from the polar character of the bonds and their spatial arrangement. • Predict and explain whether or not a molecule is polar, given its spatial arrangement.	*Note that this develops the concept of polarity introduced in subtopic 2.2.* Explore the polarities of nitrogenous excretion products from animals in ocean ecosystems.
	Demonstrate molecular polarity by the deflection of liquids using a static electrical charge. For example, a charged rod will deflect a stream of water flowing from a burette.

Subtopic 3.2: Interactions between molecules

Science Understanding	Possible contexts
The physical properties of molecular substances can be explained by considering the nature and strength of the forces of attraction between the molecules. Secondary interactions between molecules are much weaker than primary metallic, ionic, and covalent bonds. The shape, polarity, and size of molecules can be used to explain and predict the nature and strength of secondary interactions. Dispersion forces exist between all molecules. Their strength depends on the size and shape of the molecules.	*Note that the ion–dipole interaction is introduced in subtopic 4.2.* Compare boiling points of the halogens and of the noble gases. Recognise that dispersion forces are often referred to as London dispersion forces in recognition of the work of Fritz London. View the animation of hydrogen bonding in water at: www.sciencephoto.com/media/609850/view Discuss how hydrogen bonding between base pairs in the DNA strands leads to the stability of the DNA double-helix structure.
Dipole–dipole interactions exist between polar molecules and their strength depends on the polarity and size of the molecules. • Predict the relative strengths of interactions between molecules, given relevant information. Hydrogen bonding is a particularly strong form of dipole–dipole interaction that exists between molecules. • Draw diagrams showing partial charges and hydrogen bonding between HF, H_2O, and NH_3 molecules. • Explain the boiling points of HF, H_2O, and NH_3 in terms of hydrogen bonding between the molecules.	Explore the effect of hydrogen bonding on the strength of interactions by plotting boiling points of the covalent hydrides of period 2 elements. Investigate the effect of the number of O-H bonds in a molecule on the strength of the hydrogen bonding, by comparing the rate at which a small ball sinks in test tubes containing propan-1-ol, propane-1,2-diol and propane-1,2,3-triol.

Subtopic 3.3: Hydrocarbons

Science Understanding	Possible contexts
Carbon forms hydrocarbon compounds, including alkanes and alkenes. The physical properties of hydrocarbons depend on the size of the molecules. • Compare the melting and boiling points of hydrocarbons, given relevant information.	Explore the influence of molecular size on the strength of secondary interactions, by plotting the boiling points of hydrocarbons. View the interactive animations of fractional distillation, such as: www.footprints-science.co.uk/flash/Fractional%20distillation.swf www.chem-ilp.net/labTechniques/FractionalDistillationIAnimation.htm
	Demonstrate the process of the distillation of petroleum and compare the physical properties of the fractions produced. Compare the volatility, viscosity, and solubility in water and ethanol, of petrol, kerosene, and car oil.
Hydrocarbons are used as fuels and as feedstock for the chemical industry. • Write equations for the complete combustion of hydrocarbons.	Explore the range of uses of materials derived from the extraction and processing of petroleum. Debate the claim that burning oil in a car is like burning dollar bills in a fireplace.
	Compare the sootiness of a flame of a small hydrocarbon (e.g. Bunsen-burner flame) and a long-chain hydrocarbon (e.g. candle flame).
	Investigate the contribution of the work of chemists such as Wöhler, Perkin, and Kekulé on the rapid development of organic chemistry and how this knowledge has influenced modern chemistry. Describe the effect that discoveries in organic chemistry have had on the development of drugs by the pharmaceutical industry.
The chemical reactions of hydrocarbons are determined by the functional groups present. • Predict the product of an addition reaction of an alkene.	Compare the behaviour of cyclohexane and cyclohexene with bromine or iodine solution.

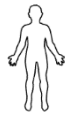
Science Understanding	Possible contexts

Hydrocarbons can be represented by empirical formulae, molecular formulae, and structural formulae, including extended, condensed, and skeletal representations.
 	
Hydrocarbons can exist as different structural isomers.
 	
Hydrocarbons are named systematically to provide unambiguous identification.
 	
The structural formula of a hydrocarbon can be deduced from its systematic name.
• Identify, name systematically, and draw structural formulae of hydrocarbons containing:
  ◆ up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms
  ◆ one or more alkene groups.
	Use information on the composition of a compound and molar mass to determine the empirical and molecular formulae of hydrocarbons.

	Model hydrocarbons and their isomers, using molecular model kits or software.
	Recognise that collaboration of international scientists resulted in the IUPAC nomenclature, which is an example of an international scientific protocol that facilitates clear communication globally.
Organic molecules have a hydrocarbon skeleton and can contain functional groups.	*Note that teachers may consider introducing some of the functional groups included in Stage 2.* Determine the boiling points of methanol, ethanol, and propanol with a closed capillary. Prepare a range of esters and compare their odours with the parent carboxylic acids.

Subtopic 3.4: Polymers

Science Understanding	Possible contexts
Polymers or macromolecules are very large molecules composed of small repeating structural units. • Identify the repeating unit of a polymer, given the structural formula of a section of a chain.	Explore the influence of molecular size on the strength of secondary interactions, by plotting the boiling points of hydrocarbons. View the interactive animations of fractional distillation, such as: www.footprints-science.co.uk/flash/ Fractional%20distillation.swf
Addition polymerisation occurs when monomer molecules link without the loss of atoms. Addition polymers can be synthesised from alkene monomers. • Draw the structural formula of an addition polymer that could be produced from monomers containing one carbon–carbon double bond, given the structural formula(e) of the monomer(s) or vice versa.	*Note that condensation polymers are considered in Stage 2 subtopics 3.7 and 3.8.*
Organic polymers have diverse properties and uses. The properties of organic polymers depend on the interactions between the polymer chains.	*Note that this subtopic builds on concepts of covalent bonding introduced in Topic 2, and secondary interactions introduced in Topic 3.* *Note that properties of polymers are also discussed in Stage 2, subtopic 4.4.* Explore the positive and negative aspects of the use of additives to improve the properties of polymers. Discuss how and why the vulcanisation of natural rubber improves its properties. Make PVA 'slime' or plastic from potatoes.
	Collect information about common plastics, including monomers, properties, uses, and recycling possibilities. Model polymer chains with paper clips, to compare tangling of chains of different lengths, and the ability of chains with and without cross-links between the chains to slip over each other. Distinguish between HDPE and LDPE, using a 50:50 solution of ethanol and water.

Science Understanding	Possible contexts	
	Explore the benefits and unintended consequences of innovative polymers such as hydrogels and smart materials. Discuss the economic, social, and environmental considerations for producing polymers from renewable materials.	

Topic 4: Mixtures and solutions

Many reactions that are important to humans occur in solution, including reactions in the cells of living organisms, the soil, the air, and the oceans.

In this topic, students investigate the properties of polar and non-polar liquids, their miscibility with other liquids, and their capacity to act as solvents. They investigate the solubility of substances in water, and compare and analyse a range of solutions.

Students use new chemical terminology and conventions to express ideas about solubility and extend their numeracy skills in calculations of concentrations and enthalpy changes.

Subtopic 4.1: Miscibility and solutions

<table>
<tr><th>Science Understanding</th><th>Possible contexts</th></tr>
<tr><td rowspan="2">Solvents can be considered as polar (e.g. water, methanol) or non-polar (e.g. hexane, turpentine, petrol).
• Identify water as a polar solvent and hydrocarbons as non-polar solvents.
Polar and non-polar solvents do not readily mix.
• Identify a solvent as polar or non-polar, based on its miscibility with water and hydrocarbons.</td><td>Explain the need to use appropriate solvents to clean paint brushes.</td></tr>
<tr><td>Mix different liquids and examine their properties in terms of their bonding.
Make a simple lava lamp and explain the effect, e.g. see: www.mcchesneychemistry.weebly.com/uploads/2/2/9/3/22938812/chemmattersapr1997.pdf</td></tr>
<tr><td rowspan="2">Highly polar molecular substances are more soluble in water than non-polar molecules of a similar size.
Molecular substances with small molecules are more soluble in water than larger molecules of similar polarity.
• Predict, given the structural formulae, which of two compounds would be more soluble in polar and non-polar solvents.</td><td>Compare the solubilities of methane, hydrogen fluoride, and ammonia in water.
Discuss why ethanol can be mixed with petrol (E10 fuel) but methanol will not mix with petrol.</td></tr>
<tr><td>Compare solubilities of glucose, sucrose, and starch.
Compare solubilities of alcohols in water and a non-polar solvent, e.g. hexane.</td></tr>
<tr><td rowspan="2">Compounds with non-polar and polar or ionic components facilitate the mixing of polar and non-polar substances.</td><td>Explore the use of:
• detergents in froth flotation of minerals
• lecithin in eggs to allow the mixing of oil and vinegar in mayonnaise
• emulsifiers to prevent immiscible components from separating in foods and cosmetics.</td></tr>
<tr><td>Make a sample of cold-cream cleanser.</td></tr>
</table>

Subtopic 4.2: Solutions of ionic substances

Science Understanding	Possible contexts
Many ionic substances are soluble in water. This is particularly so for ammonium and alkali metal salts. • Describe the formation of ion-dipole interactions when ionic substances dissolve in water. Equations can be written to represent the dissociation and hydration of ions that occurs when ionic substances dissolve in water. • Write equations for the dissolving of ionic substances in water.	*Note that this extends the concept of secondary interactions introduced in Topic 3.* Test solubility of different ionic substances in water and other liquids.
	Design an experiment to investigate the effect of particle size on the rate of dissolving.
Some ionic substances are not very soluble in water; such substances form as precipitates when solutions containing the relevant ions are mixed. • Write ionic equations for precipitation reactions. • Explain why soap forms a scum in water containing calcium ions.	Undertake problem-solving activities to identify unknown solutions Discuss the use of precipitation in chemical analysis. Discuss the impact of hard water on the effectiveness of soap.
	Prepare some substances by precipitation (e.g. barium sulfate, silver chloride, copper hydroxide, copper carbonate). Undertake simple analysis using precipitation. Prepare precipitates representing football club colours.
	Explore the development of detergents in response to biodegradability and reduction of precipitates during cleaning.

Subtopic 4.3: Quantities in reactions

Science Understanding	Possible contexts
Chemical equations can be written to describe a chemical change. • Write chemical equations when given the reactants and products of a reaction.	Refer to the Khan Academy series on balancing equations: www.khanacademy.org/science/chemistry/chemical-reactions-stoichiome/balancing-chemical-equations Note the contribution of Lavoisier in recognising that mass is conserved in chemical reactions.
The concentration of a solution can be described in terms of mass concentration (mass of solute per unit volume, ρ) or as molar concentration (moles of solute per unit volume, c). • Undertake calculations using the relationship $$\rho = \frac{m}{V}$$ and its rearrangements. • Undertake calculations using the relationship $$c = \frac{n}{V}$$ and its rearrangements. • Undertake conversions between mass concentrations and molar concentrations.	Given the equation for a reaction, the quantity of one reactant or product involved in a chemical reaction can be used to determine the quantity of another. Determine the concentration of a solution of sodium chloride by weighing the precipitate formed with silver nitrate solution.
Chemicals react in definite proportions. • Undertake stoichiometric calculations for precipitation reactions.	*Note that teachers may choose to introduce stoichiometry at some time other than when focusing on molarity;* *mass–mass stoichiometry could be introduced in subtopic 2.2.*

Subtopic 4.4: Energy in reactions

Science Understanding	Possible contexts
All chemical reactions involve the formation of a new substance and are accompanied by the gain of energy (endothermic reactions) or the loss of energy (exothermic reactions). The energy changes in endothermic and exothermic reactions can be explained in terms of the Law of Conservation of Energy and the breaking and forming of bonds. • Identify a reaction as exothermic or endothermic, given relevant information.	*Note that concepts of energy and energy change are developed in Stage 2 subtopic 4.1.* Discuss exothermic reactions used for cooking, heating, and electricity generation. View a video clip of the 'barking dog' reaction at: www.sciencephoto.com/media/612108/view
	Investigate the heat absorbed or evolved on mixing chemicals together: http://www.rsc.org/learn-chemistry/resource/res00000468/heats-of-reaction-exothermic-or-endothermic-reactions Plot a graph of temperature against time as water, lauric acid, or stearic acid freezes. Perform a range of chemical reactions and classify the reactions as exothermic or endothermic. Examples could include mixing acid and hydroxide solutions, adding magnesium to hydrochloric acid, and dissolving ammonium chloride or sodium thiosulfate in water Design and undertake a collaborative practical investigation: www.rsc.org/learn-chemistry/resource/res00001165/cooking-an-egg-by-a-chemical-reaction
When ionic substances dissolve in water, the dissociation of the ions requires energy and the hydration of the ions releases energy. • Explain the endothermic or exothermic nature of dissolving ionic substances in terms of the Law of Conservation of Energy, the energy required for dissociation of ions, and the energy released by hydration of the ions. • Write thermochemical equations for the dissolving of ionic substances in water.	Explore ideas for activities on hand warmers: www.rsc.org/learn-chemistry/content/filerepository/CMP/00/000/871/HAND_WARMERS_Teacher.pdf
	Investigate the reason why ammonium nitrate was commonly used in first-aid cold packs but is no longer used.

<table>
<tr><th>Science Understanding</th><th colspan="2">Possible contexts</th></tr>
<tr><td rowspan="2">Enthalpy changes for solution reactions can be determined experimentally.
• Explain the following relationships and undertake calculations involving their rearrangements:
$Q = mc\Delta T$
$\Delta H = \frac{Q}{n}$
• Experimentally determine enthalpies of solution.
• Identify a reaction as exothermic or endothermic, given a thermochemical equation or the value of its enthalpy change.</td><td>Use enthalpy calculations to discuss the appropriate number of significant figures to give in the answers.</td><td></td></tr>
<tr><td>Determine enthalpy of solution (e.g. for sodium thiosulfate, ammonium chloride, sodium ethanoate)
Investigate whether the use of ammonium chloride or urea is more effective in cold packs.</td><td></td></tr>
</table>

Topic 5: Acids and bases

Reactions between acids and bases occur everywhere: in homes, industry, oceans, and living organisms.

Students use contemporary models to investigate and explain the nature of acids and bases, and their properties and uses. Through investigations, they explore the reactions of acids with bases, the differing strengths of acids, and the pH of a variety of solutions. This is important for the safe handling of many materials used every day. Students develop their communication skills by learning new types of equations and calculations.

Students explore how human activities can lead to the formation of acid rain and how an understanding of the relevant science is used globally to develop strategies for its prevention.

Subtopic 5.1: Acid–base concepts

Science Understanding	Possible contexts
Acids are compounds or ions that donate protons, whereas bases are compounds or ions that accept protons, which are H^+ ions. The reactions between acids and bases can be represented using chemical equations that illustrate the transfer of protons. • Write equations showing proton transfer between an acid and a base. • Identify the conjugate acid–base pairs given the equation for a proton-transfer reaction.	*Note that conjugate acid–base pairs may be used as an introduction to reversible reactions.* Explore the evolution of our understanding of acids and bases, from the earliest classification of acids in terms of sour taste, and of early bases in terms of neutralising acids. View and discuss 'Acid-Base Reactions in Solution: Crash Course Chemistry #8': www.youtube.com/watch?v=ANi709MYnWg
	Explore the historical contribution of scientists to the development of modern acid–base theories.
Acid–base indicators are weak acids or bases where the acidic form is of a different colour from the basic form.	Discuss the origins of litmus and why the metaphor 'litmus test' has entered common, non-chemical usage. Observe the range of colours of universal indicator associated with changes in pH by adding dry ice to a large measuring cylinder containing water.
	Observe and record colours obtained in acidic and basic conditions for a range of common indicators and plant extracts.
Acids can be classified as monoprotic or polyprotic, depending on the number of protons available for donation. • Given the structural formula of an acid, classify it as monoprotic, diprotic, or triprotic.	Investigate a variety of monoprotic and polyprotic examples of acids.
	Explore reasons why the IUPAC naming system used for acids includes both systematic and non-systematic names.

Subtopic 5.2: Reactions of acids and bases

Science Understanding	Possible contexts
The oxides of non-metals are commonly acidic and generate oxyacids when dissolved in water. • Draw structural formulae for CO_2, SO_2 and SO_3, H_2SO_3, H_2SO_4, and H_3PO_4. • Write equations for the reactions with water of CO_2, SO_2, SO_3, and P_4O_{10}. Metal oxides are commonly basic. • Write equations for the reactions with water of Na_2O, K_2O, and CaO.	*Note that the expansion of the octet extends the concept of bonding introduced in subtopic 3.1.*
Similarities in the reactions of different acids with bases (metal oxides, hydroxides, and carbonates) allow products to be predicted from known reactants. Neutralisation is an exothermic reaction. • Identify the products obtained and write full and ionic equations for reactions between a given acid and a nominated metal oxide, hydroxide, carbonate, or hydrogencarbonate. • Undertake stoichiometric calculations for reactions between acids and bases.	Explore uses of acidic and basic chemicals in the home. Examples could include antacid preparations; phosphoric acid, oxalic acid, and vinegar for rust removal; and baking powder in cooking. Explore reactions of acids with metal oxides and carbonates. Observe solid metal oxides and carbonates forming solutions during reactions with acids. Demonstrate that there is a limit to how much base (e.g. copper carbonate, copper oxide, zinc oxide) will react with a given quantity of acid, to test the concept of excess reagent. Use an indicator to observe the process of neutralisation between an acid and a base. Explore energy changes in neutralisation reactions. Make copper sulfate crystals from copper oxide and sulfuric acid, or from copper carbonate and sulfuric acid. Undertake titrations to investigate acid content in beverages. Participate in the RACI Titration Competition. Make sherbet to explore an acid–base reaction. www.csiro.au/en/Education/DIY-science/Chemistry/Sherbet

Science Understanding	Possible contexts
The strength of acids is explained by the degree of ionisation in aqueous solution.	Complete an exercise about strength and concentration of acids: http://media.rsc.org/Misconceptions/Miscon%20acid%20strength.pdf Test the conductivity of aqueous solutions of ethanoic, ethanedioic, hydrochloric, nitric, and sulfuric acids, and compare with the conductivities of the pure substances.

Subtopic 5.3: The pH scale

Science Understanding	Possible contexts
The pH scale is a logarithmic scale that describes the concentration of hydrogen ions in aqueous solutions. Solutions with pH < 7 are acidic, solutions with pH > 7 are basic, and solutions with pH = 7 are neutral. • Undertake calculations using the relationship $pH = -\log [H^+]$ and its rearrangements. CO_2 dissolves in rainwater to form carbonic acid, which is a weak acid, giving rainwater a pH of about 5.6. • Write equations for the reaction of CO_2 with water to produce hydrogen ions. Oxides of sulfur and nitrogen in the atmosphere can produce rain with a pH below 5.6. • Write equations for the reactions of oxides of sulfur and nitrogen with water that lead to acid rain. • Examine the human activities that can cause acid rain to form and the strategies used to prevent this from happening.	*Note that teachers may choose to introduce the relationship* *$[H^+][OH^-] = 10^{-14}$ here.* *Note that because pH is a logarithmic scale, an increase in atmospheric carbon dioxide concentration has little effect on rainfall pH.* Investigate the formation of acid rain and its harmful environmental effects. 'Acid Rain — Why It is a Concern', EPA
	Collect and test the pH of a range of household substances to determine whether they are acidic, basic, or neutral. Explore the common acids and bases present in each. Plot change in pH as a base is added to an acid.
	Explore how the identification and treatment of acid rain in Europe is an example of international collaboration and non-experimental investigations. Discuss lessons from this example, and their possible application to solving future environmental challenges.

Topic 6: Redox reactions

Some of the most important processes in the world rely on redox reactions. The energy produced from carbon-based fuels and batteries emanates from redox reactions, while the processes of photosynthesis and respiration involve complex sequences of redox reactions.

In this topic, students examine redox reactions using a variety of approaches, and explore a range of redox reactions and differences in metal reactivity. They learn to write redox half-equations and consider the stoichiometry of redox reactions. Students have opportunities to design investigations that test hypotheses, interpret data, and devise creative solutions.

Students investigate production and storage of electricity using electrochemical cells and explore how the development of new electrochemical cells offers environmental, social, and economic advances.

Subtopic 6.1: Concepts of oxidation and reduction

Science Understanding	Possible contexts
A range of reactions, including reactions of metals, combustion, and electrochemical processes, can be considered as redox reactions.	Use gas jars to demonstrate burning iron (steel wool), magnesium, sulfur, and phosphorus in oxygen or chlorine. Demonstrate fireworks reactions using $KClO_3$ and sugar. Demonstrate the combustion of gun cotton.
	View 'Redox Reactions: Crash Course Chemistry #10': www.youtube.com/watch?v=lQ6FBA1HM3s Investigate rusting and metal corrosion as examples of oxidation.
Oxidation and reduction can be defined in terms of combination with oxygen, transfer of electrons, or change in oxidation number. • Identify oxidation and reduction in given equations. • Write oxidation and reduction half-equations, in neutral and acidic conditions, given reactant and product species. • Combine half-equations to write a chemical equation. • Determine the oxidation states of atoms in elements and monatomic ions, and in compounds and polyatomic ions.	Discuss the similarities of combining magnesium with oxygen and with chlorine to extend the definition of oxidation to losing electrons. Discuss the similarities of combining sulfur or phosphorus with oxygen or chlorine to introduce oxidation number. Consider why oxidation number is not used in organic chemistry, and why the concept of gain and loss of oxygen and hydrogen is more useful. Discuss the use of metal hydrides in batteries in hybrid vehicles.
	Use test reactions to observe changes to confirm species that have reacted, such as MnO_4^-, $Cr_2O_7^{2-}$, H_2O_2, and Fe^{2+}.
	Discuss the development of redox concepts as scientific evidence emerged, starting with oxidation as a process involving oxygen to the current understanding of redox reactions.

Subtopic 6.2: Metal reactivity

Science Understanding	Possible contexts
Metals differ in their tendency to lose electrons; more reactive metals lose electrons more easily. A more reactive metal is able to donate electrons to the ion of a less active metal in a displacement reaction. • Write equations and half-equations for reactions between a metal and the ion of a less active metal. Differences in metal reactivity can be represented as a metal activity series. • Determine whether a reaction will occur between a metal and a solution containing the ions of another metal, given a metal activity series containing both metals. The reactivity of a metal affects its ability to react with other chemicals. • Investigate the reactions of various metals with water and acidic solutions. • Compare the vigour of reactions of different metals with their position on the metal activity series. • Write equations and half-equations for reactions between a given acid and a nominated active metal.	Look at the formation of silver crystals on copper wire under a digital microscope or flexcam. Use the exothermic reaction of magnesium powder in copper sulfate solution to boil water. Make Christmas trees by placing a copper ‘tree’ in a solution of silver nitrate. Consider the use of magnesium and zinc in the protection of iron and steel from corrosion. Add calcium, potassium, and sodium to water, note observations, and test products. View ‘Braniac Alkali Metals’ at: www.youtube.com/watch?v=m55kgyApYrY Discuss why: • the metals known since ancient times are the less reactive metals such as copper, gold, and silver • aluminium and chromium are active metals but their surfaces remain shiny • active metals are more costly to produce than less active metals.
	Test a range of metals and metal salt solutions for evidence of displacement reaction. Test a range of metals in water and acidic solutions. Construct a metal activity series from experimental data.

Subtopic 6.3: Electrochemistry

Science Understanding	Possible contexts
Electrochemical reactions involve a flow of electrons during a chemical reaction. Galvanic cells produce electrical energy from spontaneous redox reactions. • Identify the anode and cathode and their charges, and the direction of ion and electron flow, in a galvanic cell, given sufficient information. • Draw a diagram of a galvanic cell, given sufficient information. • Write electrode half-equations for a galvanic cell, given sufficient information. Galvanic cells are commonly used as portable sources of electric current. • Compare the operation of different types of batteries.	View VEA, 'Wet Cells, Dry Cells, Fuel Cells': www.vea.com.au/secondary-school/wet-cells-dry-cells-fuel-cells.html Use the Horizon fuel cell car kit to design an investigation on energy production from a fuel cell. www.horizoneducational.com/juniorproducts/fuel-cell-car-science-kit/ Discuss uses of common rechargeable batteries, e.g. lead–acid batteries in cars, nicad cells. Compare galvanic cells with electrolytic cells.
	Construct a galvanic cell using magnesium, copper, and a lemon connected to an ammeter or voltmeter. Use various half-cells to construct galvanic cells. Design an investigation to test the effect of one factor on the operation of a galvanic cell.
	Investigate the environmental, social, economic, political, and/or ethical implications of the use and disposal of commercial batteries, e.g. fuel cells or cells containing lithium, mercury, or silver. Investigate the use of batteries for home electricity storage, and the environmental, social, and economic implications.

ASSESSMENT SCOPE AND REQUIREMENTS

Assessment at Stage 1 is school based.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 1 Chemistry:

- Assessment Type 1: Investigations Folio
- Assessment Type 2: Skills and Applications Tasks.

For a 10-credit subject, students provide evidence of their learning through four assessments. Each assessment type should have a weighting of at least 20%.

Students complete:

- at least one practical investigation
- one investigation with a focus on science as a human endeavour
- at least one skills and applications task.

For a 20-credit subject, students provide evidence of their learning through eight assessments. Each assessment type should have a weighting of at least 20%.

Students complete:

- at least two practical investigations
- two investigations with a focus on science as a human endeavour
- at least two skills and applications tasks.

For both the 10-credit and 20-credit subjects, at least one assessment should involve collaborative work.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by teachers to:

- clarify for the student what they need to learn
- design opportunities for the student to provide evidence of their learning at the highest level of achievement.

The assessment design criteria are comprised of the specific features that:

- students should demonstrate in their learning
- teachers look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:

- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described below.

The set of assessments, as a whole, must give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

IAE1 Deconstruction of a problem and design of a chemistry investigation.

IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats.

IAE3 Analysis and interpretation of data and other evidence to formulate and justify conclusions.

IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

KA1 Demonstration of knowledge and understanding of chemical concepts.

KA2 Application of chemical concepts in new and familiar contexts.

KA3 Exploration and understanding of the interaction between science and society.

KA4 Communication of knowledge and understanding of chemical concepts and information, using appropriate terms, conventions, and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio

For a 10-credit subject, students undertake at least one practical investigation and one investigation with a focus on science as a human endeavour. Students may undertake more than one practical investigation within the maximum number of assessments allowed.

For a 20-credit subject, students undertake at least two practical investigations and two investigations with a focus on science as a human endeavour. Students may undertake more than two practical investigations within the maximum number of assessments allowed.

Students inquire into aspects of chemistry through practical discovery and data analysis, and/or by selecting, analysing, and interpreting information.

Practical Investigations

As students design and safely carry out investigations, they demonstrate their science inquiry skills by:

- deconstructing a problem to determine the most appropriate method for investigation
- formulating investigable questions and hypotheses
- selecting and using appropriate equipment, apparatus, and techniques
- identifying variables
- collecting, representing, analysing, and interpreting data
- evaluating procedures and considering their impact on results
- drawing conclusions
- communicating knowledge and understanding of concepts.

As a set, practical investigations should enable students to:

- work both individually or collaboratively
- investigate a question or hypothesis for which the outcome is uncertain
- investigate a question or hypothesis linked to one of the topics in Stage 1 Chemistry
- individually deconstruct a problem to design their own method and justify their plan of action.

For each investigation, students present an individual report.

Evidence of deconstruction (where applicable) should outline the deconstruction process, the method designed as most appropriate, and a justification of the plan of action, to a maximum of 4 sides of an A4 page. This evidence must be attached to the practical report.

Suggested formats for this evidence include flow charts, concept maps, tables, or notes.

In order to manage the implementation of an investigation efficiently, students could individually design investigations and then conduct one of these as a group, or design hypothetical investigations at the end of a practical activity.

A practical report must include:

- introduction with relevant chemistry concepts, and either a hypothesis and variables, or an investigable question
- materials/apparatus
- the method that was implemented
- identification and management of safety and/or ethical risks
- results, including table(s) and/or graph(s)
- analysis of results, including identifying trends and linking results to concepts
- evaluation of procedures and their effect on data, and identifying sources of uncertainty
- conclusion, with justification.

The report should be a maximum of 1000 words if written, or a maximum of 6 minutes for an oral presentation, or the equivalent in multimodal form.

Only the following sections of the report are included in the word count:

- introduction
- analysis of results
- evaluation of procedures
- conclusion and justification.

Suggested formats for presentation of a practical investigation report include:

- a written report
- an oral presentation
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate a contemporary example of how science interacts with society. This may focus on one or more of the key concepts of science as a human endeavour described on pages 11 and 12 and may draw on a context suggested in the topics or relate to a new context.

Students could consider, for example, how:

- humans seek to improve their understanding and explanation of the natural world
- working scientifically is a way of obtaining knowledge that allows for testing scientific claims
- scientific theory can change in the light of new evidence
- technological advances change ways of working scientifically
- links between advances in science impact and influence society
- society influences scientific research
- emerging chemistry-related careers and pathways involve science.

Students access information from different sources, select relevant information, analyse their findings, and explain the connection to science as a human endeavour.

Possible starting points for the investigation could include, for example:

- the announcement of a discovery in the field of chemistry
- an expert's point of view on a controversial innovation
- a TED talk based on a chemical development
- an article from a scientific publication (e.g. *Cosmos*)
- public concern about an issue that has environmental, social, economic, or political implications.

Based on their investigation, students prepare a scientific communication, which must include the use of scientific terminology.

The communication should be a maximum of 1000 words if written, or a maximum of 6 minutes for an oral presentation, or the equivalent in multimodal form.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks

For a 10-credit subject, students undertake at least one skills and applications task. Students may undertake more than one skills and applications task within the maximum number of assessments allowed, but at least one should be under the direct supervision of the teacher. The supervised setting (e.g. classroom, laboratory, or field) should be appropriate to the task.

For a 20-credit subject, students undertake at least two skills and applications tasks. Students may undertake more than two skills and applications tasks within the maximum number of assessments allowed, but at least two should be under the direct supervision of the teacher. The supervised setting (e.g. classroom, laboratory, or field) should be appropriate to the task.

Skills and applications tasks allow students to provide evidence of their learning in tasks that may:

- be applied, analytical, and/or interpretative
- pose problems in new and familiar contexts
- involve individual or collaborative assessments, depending on task design.

A skills and applications task may involve, for example:

- solving problems
- designing an investigation to test a hypothesis or investigable question
- considering different scenarios in which to apply knowledge and understanding
- graphing, tabulating, and/or analysing data
- evaluating procedures and identifying their limitations
- formulating and justifying conclusions
- representing information diagrammatically or graphically
- using chemical terms, conventions, and notations.

As a set, skills and applications tasks should be designed to enable students to apply their science inquiry skills, demonstrate knowledge and understanding of key chemical concepts and learning, and explain connections with science as a human endeavour. Problems and scenarios should be set in a relevant context, which may be practical, social, or environmental.

Skills and applications tasks may include, for example:

- modelling or representing concepts
- developing simulations
- practical and/or graphical skills
- a multimodal product
- an oral presentation
- participation in a debate

- an extended response
- responses to short-answer questions
- a structured interview
- an excursion report
- a response to science in the media.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills and understanding that teachers refer to in deciding how well students have demonstrated their learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student’s completion of study of a subject, the teacher makes a decision about the quality of the student’s learning by:

- referring to the performance standards
- taking into account the weighting of each assessment type
- assigning a subject grade between A and E.

Performance Standards for Stage 1 Chemistry

	Investigation, Analysis, and Evaluation	Knowledge and Application
A	Critically deconstructs a problem and designs a logical, coherent, and detailed chemistry investigation. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and discusses their effect on data.	Demonstrates deep and broad knowledge and understanding of a range of chemical concepts. Applies chemical concepts highly effectively in new and familiar contexts. Critically explores and understands in depth the interaction between science and society. Communicates knowledge and understanding of chemistry coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Logically deconstructs a problem and designs a well-considered and clear chemistry investigation. Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effect on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of chemical concepts. Applies chemical concepts mostly effectively in new and familiar contexts. Logically explores and understands in some depth the interaction between science and society. Communicates knowledge and understanding of chemistry mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Deconstructs a problem and designs a considered and generally clear chemistry investigation. Obtains, records, and represents data, using generally appropriate conventions and formats, with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates procedures and some of their effect on data.	Demonstrates knowledge and understanding of a general range of chemical concepts. Applies chemical concepts generally effectively in new or familiar contexts. Explores and understands aspects of the interaction between science and society. Communicates knowledge and understanding of chemistry generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares a basic deconstruction of a problem and an outline of a chemistry investigation. Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and undertakes some basic interpretation to formulate a basic conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of chemical concepts. Applies some chemical concepts in familiar contexts. Partially explores and recognises aspects of the interaction between science and society. Communicates basic chemical information, using some appropriate terms, conventions, and/or representations.
E	Attempts a simple deconstruction of a problem and a procedure for a chemistry investigation. Attempts to record and represent some data, with limited accuracy or effectiveness. Attempts to describe results and/or interpret data to formulate a basic conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of chemical concepts. Attempts to apply chemical concepts in familiar contexts. Attempts to explore and identify an aspect of the interaction between science and society. Attempts to communicate information about chemistry.

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (www.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement in the school assessment are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 1 are available on the SACE website (www.sace.sa.edu.au).

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.edu.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website (www.sace.sa.edu.au).

South Australian Certificate of Education
LEARNING AT THE PACE OF CHANGE

Chemistry

2024 Subject Outline | Stage 2

- In Australian and SACE International schools from January 2024 to December 2024
- In SACE International schools only, from May/June 2024 to March 2025

Government of South Australia

For teaching

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CONTENTS

INTRODUCTION

SUBJECT DESCRIPTION

Chemistry is a 10-credit subject or a 20-credit subject at Stage 1 and a 20-credit subject at Stage 2.

In their study of Chemistry, students develop and extend their understanding of how the physical world is chemically constructed, the interaction between human activities and the environment, and the use that human beings make of the planet's resources. They explore examples of how scientific understanding is dynamic and develops with new evidence, which may involve the application of new technologies.

Students consider examples of benefits and risks of chemical knowledge to the wider community, along with the capacity of chemical knowledge to inform public debate on social and environmental issues. The study of Chemistry helps students to make informed decisions about interacting with and modifying nature, and explore options such as green or sustainable chemistry, which seeks to reduce the environmental impact of chemical products and processes.

Through the study of Chemistry, students develop the skills that enable them to be questioning, reflective, and critical thinkers; investigate and explain phenomena around them; and explore strategies and possible solutions to address major challenges now and in the future (for example, in energy use, global food supply, and sustainable food production).

Students integrate and apply a range of understanding, inquiry, and scientific thinking skills that encourage and inspire them to contribute their own solutions to current and future problems and challenges, and pursue future pathways, including in medical or pharmaceutical research, pharmacy, chemical engineering, and innovative product design.

CAPABILITIES

The capabilities connect student learning within and across subjects in a range of contexts. They include essential knowledge and skills that enable people to act in effective and successful ways.

The SACE identifies seven capabilities. They are:

- literacy
- numeracy
- information and communication technology (ICT) capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding.

Literacy

In this subject students extend and apply their literacy capability by, for example:

- interpreting the work of scientists across disciplines, using chemical knowledge
- critically analysing and evaluating primary and secondary data
- extracting chemical information presented in a variety of modes
- using a range of communication formats to express ideas logically and fluently, incorporating the terminology and conventions of chemistry
- synthesising evidence-based arguments
- communicating appropriately for specific purposes and audiences.

Numeracy

In this subject students extend and apply their numeracy capability by, for example:

- solving problems using calculation and critical thinking skills
- measuring with appropriate instruments
- recording, collating, representing, and analysing primary data
- accessing and interpreting secondary data
- identifying and interpreting trends and relationships
- calculating and predicting values by manipulating data, using appropriate scientific conventions.

Information and communication technology (ICT) capability

In this subject students extend and apply their ICT capability by, for example:

- locating and accessing information
- collecting, analysing, and representing data electronically
- modelling concepts and relationships
- using technologies to create new ways of thinking about science

- communicating chemical ideas, processes, and information
- understanding the impact of ICT on the development of chemistry and its application in society
- evaluating the application of ICT to advance understanding and innovations in chemistry.

Critical and creative thinking

In this subject students extend and apply critical and creative thinking by, for example:

- analysing and interpreting problems from different perspectives
- deconstructing a problem to determine the most appropriate method for investigation
- constructing, reviewing, and revising hypotheses to design investigations
- interpreting and evaluating data and procedures to develop logical conclusions
- analysing interpretations and claims, for validity and reliability
- devising imaginative solutions and making reasonable predictions
- envisaging consequences and speculating on possible outcomes
- recognising the significance of creative thinking on the development of chemical knowledge and applications.

Personal and social capability

In this subject students extend and apply their personal and social capability by, for example:

- understanding the importance of chemical knowledge on health and well-being, both personally and globally
- making decisions and taking initiative while working independently and collaboratively
- planning effectively, managing time, following procedures effectively, and working safely
- sharing and discussing ideas about chemical issues, developments and innovations, while respecting the perspectives of others
- recognising the role of their own beliefs and attitudes in gauging the impact of chemistry in society
- seeking, valuing, and acting on feedback.

Ethical understanding

In this subject students extend and apply their ethical understanding by, for example:

- considering the implications of their investigations on organisms and the environment
- making ethical decisions based on an understanding of chemical principles
- using data and reporting the outcomes of investigations accurately and fairly
- acknowledging the need to plan for the future and to protect and sustain the biosphere
- recognising the importance of their responsible participation in social, political, economic, and legal decision-making.

Intercultural understanding

In this subject students develop their intercultural understanding by, for example:

- recognising that science is a global endeavour with significant contributions from diverse cultures
- respecting and engaging with different cultural views and customs and exploring their interaction with scientific research and practices
- being open-minded and receptive to change in the light of scientific thinking based on new information
- understanding that the progress of chemistry influences and is influenced by cultural factors.

ABORIGINAL AND TORRES STRAIT ISLANDER KNOWLEDGE, CULTURES, AND PERSPECTIVES

In partnership with Aboriginal and Torres Strait Islander communities, and schools and school sectors, the SACE Board of South Australia supports the development of high-quality learning and assessment design that respects the diverse knowledge, cultures, and perspectives of Indigenous Australians.

The SACE Board encourages teachers to include Aboriginal and Torres Strait Islander knowledge and perspectives in the design, delivery, and assessment of teaching and learning programs by:

- providing opportunities in SACE subjects for students to learn about Aboriginal and Torres Strait Islander histories, cultures, and contemporary experiences
- recognising and respecting the significant contribution of Aboriginal and Torres Strait Islander peoples to Australian society
- drawing students' attention to the value of Aboriginal and Torres Strait Islander knowledge and perspectives from the past and the present
- promoting the use of culturally appropriate protocols when engaging with and learning from Aboriginal and Torres Strait Islander peoples and communities.

HEALTH AND SAFETY

The handling of a range of chemicals and equipment requires appropriate health, safety, and welfare procedures.

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 and that school practices meet the requirements of the *Work Health and Safety Act 2012*, in addition to relevant state, territory, or national health and safety guidelines. Information about these procedures is available from the school sectors.

The following safety practices must be observed by students in all laboratory work:

- Use equipment only under the direction and supervision of a teacher or other qualified person.
- Follow safety procedures when preparing or manipulating apparatus.
- Use appropriate safety gear when preparing or manipulating apparatus.

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 2 Chemistry.

In this subject, students are expected to:

1. apply science inquiry skills to deconstruct a problem and design and conduct chemistry investigations using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, analyse, and interpret the results of chemistry investigations
3. evaluate procedures and results, and analyse evidence to formulate and justify conclusions
4. develop and apply knowledge and understanding of chemical concepts in new and familiar contexts
5. explore and understand science as a human endeavour
6. communicate knowledge and understanding of chemical concepts, using appropriate terms, conventions, and representations.

CONTENT

Stage 2 Chemistry is a 20-credit subject.

The topics in Stage 2 Chemistry provide the framework for developing integrated programs of learning through which students extend their skills, knowledge, and understanding of the three strands of science.

The three strands of science to be integrated throughout student learning are:

- science inquiry skills
- science as a human endeavour
- science understanding.

The topics for Stage 2 Chemistry are:

- Topic 1: Monitoring the environment
- Topic 2: Managing chemical processes
- Topic 3: Organic and biological chemistry
- Topic 4: Managing resources.

Students study all four topics. The topics can be sequenced and structured to suit individual groups of students.

Many of the concepts studied in Stage 2 Chemistry build on concepts introduced in Stage 1 Chemistry. The table shown below, from the Stage 1 content section, shows the Stage 1subtopics containing concepts that link to concepts in Stage 2 subtopics.

Stage 1	Stage 2
1.1 Properties and uses of materials	4.4 Materials
1.2 Atomic structure	1.5 Atomic spectroscopy
1.3 Quantities of atoms	1.3 Volumetric analysis
2.1 Types of materials	4.4 Materials
2.2 Bonding between atoms	1.5 Atomic spectroscopy 3.1 Introduction (organic and biological chemistry) 4.3 Soil
2.3 Quantities of molecules and ions	1.3 Volumetric analysis 2.2 Equilibrium and yield
3.1 Molecule polarity	1.4 Chromatography 3.1 Introduction (organic and biological chemistry) 3.10 Proteins
3.2 Interactions between molecules	1.4 Chromatography 3.1 Introduction (organic and biological chemistry) 3.10 Proteins 4.4 Materials
3.3 Hydrocarbons	3.1 Introduction (organic and biological chemistry) 3.9 Triglycerides 4.1 Energy
3.4 Polymers	3.4 Carbohydrates 4.4 Materials
4.1 Miscibility and solutions	3.1 Introduction (organic and biological chemistry) 3.9 Triglycerides
4.2 Solutions of ionic substances	3.5 Carboxylic acids 3.6 Amines 3.10 Proteins 4.2 Water 4.3 Soil
4.3 Quantities in reactions	1.3 Volumetric analysis 2.2 Equilibrium and yield
4.4 Energy in reactions	2.1 Rates of reactions 2.2 Equilibrium and yield 4.1 Energy
5.1 Acid–base concepts	1.1 Global warming and climate change

Stage 1	Stage 2
5.2 Reactions of acids and bases	3.5 Carboxylic acids 3.6 Amines 4.4 Materials
5.3 The pH scale	4.2 Water
6.1 Concepts of oxidation and reduction	3.2 Alcohols 3.3 Aldehydes and ketones 4.4 Materials
6.2 Metal reactivity	4.4 Materials
6.3 Electrochemistry	4.1 Energy 4.4 Materials

The following pages describe in more detail:

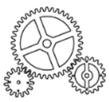
- science inquiry skills
- science as a human endeavour
- the topics for science understanding.

The descriptions of the science inquiry skills and the topics are structured in two columns: the left-hand column sets out the science inquiry skills or science understanding and the right-hand column sets out possible contexts.

Together with science as a human endeavour, the science inquiry skills and science understanding form the basis of teaching, learning, and assessment in this subject.

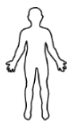
The possible contexts are suggestions for potential approaches, and are neither comprehensive nor exclusive. Teachers may select from these and are encouraged to consider other approaches according to local needs and interests.

Within the topic descriptions, the following symbols are used in the possible contexts to show how a strand of science can be integrated:



indicates a possible teaching and learning strategy for science understanding

indicates a possible science inquiry activity



indicates a possible focus on science as a human endeavour.

Science Inquiry Skills

In Chemistry, investigation is an integral part of the learning and understanding of concepts, by using scientific methods to test ideas and develop new knowledge.

Practical investigations must involve a range of both individual and collaborative activities, during which students extend the science inquiry skills described in the table that follows.

Practical activities may take a range of forms, such as developing or using models and simulations that enable students to develop a better understanding of particular concepts. The activities include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements, or other information obtained during the investigation. Students represent and analyse the data they have collected; evaluate procedures, and describe limitations of the data and procedures; consider explanations for their observations; and present and justify conclusions appropriate to the initial question or hypothesis.

For a 20-credit subject, it is recommended that a minimum of 16–20 hours of class time involves practical activities.

Science inquiry skills are also fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically consider the evidence they obtain so that they can present and justify a conclusion.

Science Inquiry Skills	Possible contexts
Scientific methods enable systematic investigation to obtain measurable evidence. • Deconstruct a problem to determine and justify the most appropriate method for investigation. • Design investigations, including: ◆ a hypothesis or inquiry question ◆ types of variables – dependent – independent – factors held constant (how and why they are controlled) – factors that may not be able to be controlled (and why not) ◆ materials required ◆ the method to be followed ◆ the type and amount of data to be collected ◆ identification of ethical and safety considerations.	Develop inquiry skills by, for example: • designing investigations that require investigable questions and imaginative solutions (with or without implementation) • critiquing proposed investigations • using the conclusion of one investigation to propose subsequent experiments • changing an independent variable in a given procedure and adapting the method • researching, developing, and trialling a method • improving an existing procedure • identifying options for measuring the dependent variable • researching hazards related to the use and disposal of chemicals and/or biological materials • developing safety audits • identifying relevant ethical and/or legal considerations in different contexts.

<table>
<tr><th>Science Inquiry Skills</th><th>Possible contexts</th></tr>
<tr><td>Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices.
• Conduct investigations, including:
◆ selection and safe use of appropriate materials, apparatus, and equipment
◆ collection of appropriate primary and/or secondary data (numerical, visual, descriptive)
◆ individual and collaborative work.</td><td>Develop inquiry skills by, for example:
• identifying equipment, materials, or instruments fit for purpose
• practising techniques and safe use of apparatus
• comparing resolution of different measuring tools
• distinguishing between, and using, primary and secondary data.</td></tr>
<tr><td>Results of investigations are represented in a well-organised way to allow them to be interpreted.
• Represent results of investigations in appropriate ways, including:
◆ use of appropriate SI units, symbols
◆ construction of appropriately labelled tables
◆ drawing of graphs, including lines or curves of best fit as appropriate
◆ use of significant figures.</td><td>Develop inquiry skills by, for example:
• practising constructing tables to tabulate data, including column and row labels with units
• identifying the appropriate representations to graph different data sets
• selecting appropriate axes and scales to graph data
• clarifying understanding of significant figures using, for example:
www.astro.yale.edu/astro120/SigFig.pdf
www.hccfl.edu/media/43516/sigfigs.pdf
www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm
• comparing data from different sources to describe as quantitative or qualitative.</td></tr>
<tr><td>Scientific information can be presented using different types of symbols and representations.
• Select, use, and interpret appropriate representations, including:
◆ mathematical relationships, such as ratios
◆ diagrams
◆ writing equations
to explain concepts, solve problems and make predictions.</td><td>Develop inquiry skills by, for example:
• writing chemical equations
• drawing and labelling diagrams
• recording images
• constructing flow diagrams.</td></tr>
</table>

<table>
<tr><th>Science Inquiry Skills</th><th>Possible contexts</th></tr>
<tr><td>Analysis of the results of investigations allows them to be interpreted in a meaningful way.
• Analyse data, including:
◆ identification and discussion of trends, patterns, and relationships
◆ interpolation or extrapolation where appropriate.</td><td>Develop inquiry skills by, for example:
• analysing data sets to identify trends and patterns
• determining relationships between independent and dependent variables
• using graphs from different sources (e.g. from CSIRO or the Australian Bureau of Statistics (ABS)) to predict values other than plotted points
• calculating mean values and rates of reaction, where appropriate.</td></tr>
<tr><td>Critical evaluation of procedures and data can determine the meaningfulness of the results.
• Identify sources of uncertainty, including:
◆ random and systematic errors
◆ uncontrolled factors.
• Evaluate reliability, accuracy, and validity of results, by discussing factors including:
◆ sample size
◆ precision
◆ resolution of equipment
◆ random error
◆ systematic error
◆ factors that cannot be controlled.</td><td>Develop inquiry skills by, for example:
• discussing how the repeating of an investigation with different materials/equipment may detect a systematic error
• using an example of an investigation report to develop report-writing skills.
Useful website:
www.biologyjunction.com/sample%20ap%20lab%20reports.htm</td></tr>
<tr><td>Conclusions can be formulated that relate to the hypothesis or inquiry question.
• Select and use evidence and scientific understanding to make and justify conclusions.
• Recognise the limitations of conclusions.
• Recognise that the results of some investigations may not lead to definitive conclusions.</td><td>Develop inquiry skills by, for example:
• evaluating procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions
• using data sets to discuss the limitations of the data in relation to the range of possible conclusions that could be made.</td></tr>
<tr><td>Effective scientific communication is clear and concise.
• Communicate to specific audiences and for specific purposes using:
◆ appropriate language
◆ terminology
◆ conventions.</td><td>Develop inquiry skills by, for example:
• reviewing scientific articles or presentations to recognise conventions
• developing skills in referencing and/or footnoting
• distinguishing between reference lists and bibliographies
• practising scientific communication in written, oral, and multimodal formats (e.g. presenting a podcast or a blog).</td></tr>
</table>

Science as a Human Endeavour

The science as a human endeavour strand highlights the development of science as a way of knowing and doing, and explores the purpose, use, and influence of science in society.

By exploring science as a human endeavour, students develop and apply their understanding of the complex ways in which science interacts with society, and investigate the dynamic nature of chemistry. They explore how chemists develop new understanding and insights, and produce innovative solutions to everyday and complex problems and challenges in local, national, and global contexts. In this way, students are encouraged to think scientifically and make connections between the work of others and their own learning. This enables them to explore their own solutions to current and future problems and challenges.

Students understand that the development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. They consider how and why science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as emerging technologies enable new avenues of investigation. They understand that scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice.

Students explore how scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. They investigate ways in which the application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. They understand how decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As critical thinkers, they appreciate science as an ever-evolving body of knowledge, that frequently informs public debate, but is not always able to provide definitive answers.

The key concepts of science as a human endeavour underpin the contexts, approaches, and activities in this subject, and must be integrated into all teaching and learning programs.

The key concepts of science as a human endeavour, with elaborations that are neither comprehensive nor exclusive, in the study of Chemistry are:

Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- Collaboration between scientists, governments, and other agencies is often required in scientific research and enterprise.

Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, cultural, and environmental impacts, offer valid explanations, and make reliable predictions.
- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk and provides opportunities for innovation.
- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Topic 1: Monitoring the environment

Population growth, industrialisation, and a globalised economy have led to increasing demands on natural resources and the generation of pollutants at levels not seen in the past. Many environmental issues have been directly attributed to anthropogenic change, an observation acknowledged by the scientific community. Chemists perform a key role in monitoring and giving expert advice on the environment and on the impact of environmental issues and changes. Innovations in technology enable chemists to collect data over longer periods of time and with greater resolution and to contribute more effectively to international collaboration on global problems.

In this topic, students undertake practical analytical activities, develop manipulative skills, and examine sources of experimental errors. They analyse the causes of environmental issues and explore possible solutions.

Students investigate the impact of fossil fuel use in examining the effect of combustion products on global warming, ocean acidity, and photochemical smog. They explore chromatography and atomic spectroscopy as analytical processes. In volumetric titrations, students extend the application of their understanding of stoichiometry.

Subtopic 1.1: Global warming and climate change

Science Understanding	Possible contexts
Some gases in the atmosphere, called 'greenhouse gases', keep the Earth's atmosphere warmer than it would be without these gases. This is known as the 'greenhouse effect'. • Describe the action of the common greenhouse gases, carbon dioxide and methane, to maintain a steady temperature in the Earth's atmosphere. Anthropogenic increases in greenhouse gases disrupt the thermal balance of the atmosphere. • Explain the warming associated with global climate change and its consequences for the environment.	Use the Keeling Curve to examine changes in carbon dioxide levels in the Earth's atmosphere since 1958. Use statistics from the Bureau of Meteorology to plot trends in global concentration of carbon dioxide, sea surface temperature, or air temperature. Explore sections of the documentary, *An Inconvenient Truth*, along with the accompanying interactive app, Our Choice. *An Inconvenient Sequel: Truth to Power* and the 2021 film https://www.thecarbonmovie.com provide further resource. Discuss the impact of thawing permafrost using an article such as: http://www.dailymail.co.uk/sciencetech/article-3284502/Loss-permafrost-unbelievable-Melting-ice-release-devastating-quantities-methane-accelerate-global-warming-warns-expert.html Discuss the strategies being suggested to reduce greenhouse gas emissions. Explore the effectiveness of international collaboration on using these strategies in reducing global greenhouse gas emissions.
Ocean acidification is caused by the ocean absorbing higher levels of carbon dioxide from the atmosphere. • Describe and write equations to show how carbon dioxide lowers the pH of the oceans. • Calculate the pH of solutions given the concentration of H^+ or OH^-, and vice versa. The exoskeletons and shells of many marine organisms are made of calcium carbonate and are vulnerable to dissolution at low pH.	*Note that this work builds upon acid base concepts introduced in Stage 1 subtopics 5.1, 5.2, and 5.3.* Consider connections to the development of the concept of equilibrium in subtopic 2.2 by examining how oceans contribute to the maintenance of steady concentrations of atmospheric carbon dioxide. Investigate how human activity since the beginning of the Industrial Revolution has led to increased ocean acidity and subsequent effects on marine life.

Science Understanding	Possible contexts	
• Explain, using equilibrium principles, the impact of altering ocean pH on the formation of carbonates. • Write equations for carbonates reacting in acidic conditions.	Undertake practical investigations to establish the reactions of carbonates with various acids, and discuss their effects. Design an investigation to test the effects of solutions of different pH on the mass of carbonate dissolved.	
	Research one or more recent strategies proposed to reduce ocean acidification.	

Subtopic 1.2: Photochemical smog

Science Understanding	Possible contexts	
Nitrogen oxides are formed in high-temperature engines and furnaces. • Write equations, and explain the conditions necessary, for the formation of nitrogen oxides NO and NO_2.	Compare live readings from around the globe, using software and apps such as the China Air Quality Index, for the monitoring of air pollution. Investigate factors contributing to one or more of the readings.	
Nitrogen oxides and ozone are pollutants in the troposphere that are associated with photochemical smog. • Describe and write equations showing the role of nitrogen oxides in the formation of ozone in the troposphere. • Describe the harmful effects of nitrogen oxides and ozone in the troposphere. • Describe and write equations showing how catalytic converters reduce the quantities of nitrogen oxides generated by motor vehicles.	Discuss how ozone is a pollutant in the troposphere but is beneficial in the stratosphere, absorbing solar ultraviolet radiation.	
	Discuss the potential benefits and risks associated with the use of nanoparticles in catalytic converters and how this technology has reduced demands on precious metals. Investigate the political and environmental influences that led to the adoption of catalytic converters in motor vehicles across the world.	

Subtopic 1.3: Volumetric analysis

Science Understanding	Possible contexts	
Concentrations can be described by using a number of standard conventions. • Calculate concentration and interconvert units, including: mol L^{-1}, g L^{-1}, %w/v, ppm, and ppb. • Apply SI prefix conventions to quantities. Knowledge of the mole ratios of reactants can be used in quantitative calculations. • Perform stoichiometric calculations when given the reaction equation and the necessary data. A titration can be used to determine the concentration of a solution of a reactant in a chemical reaction. • Describe and explain the procedure involved in carrying out a titration, particularly rinsing glassware and determining the end-point. • Determine the concentration of a solution of a reactant in a chemical reaction by using the results of a titration.	*Note that this work builds upon concepts introduced in Stage 1 subtopics 1.3, 2.3, and 4.3.* Introduce apparatus and discuss techniques, using sites such as the interactive lab primer at: http://www.rsc.org/learn-chemistry/resource/res00001064/the-interactive-lab-primer?cmpid=CMP00007674 Analyse the data obtained in titrations in terms of precision and accuracy. Explore the use of back titrations and indirect titrations in atmospheric and waste water analyses.	
	Undertake titrations to determine or compare concentrations of various solutes (e.g. acid content in beverages, calcium or magnesium concentration, waste vegetable oil in biodiesel production, and dissolved oxygen in water). Participate in the RACI Titration Competition. Use indirect titration in ozone detection and other examples of air pollution analysis.	
	Investigate how modern titration techniques improve the efficiency of quality control in industries producing wine, food, pharmaceuticals, cosmetics, or other chemicals.	

Subtopic 1.4: Chromatography

Science Understanding	Possible contexts	
Chromatography techniques, including thin layer chromatography (TLC), gas chromatography (GC), high-performance liquid chromatography (HPLC), and ion chromatography (IC), involve the use of a stationary phase and a mobile phase to separate the components of a mixture. The rate of movement of the components is caused by the differences between the strengths of the interactions between atoms, molecules, or ions in the mobile and stationary phases. • Predict the relative rates of movement of components along a stationary phase on the basis of their polarities and charge, given the structural formulae or relative polarities of the two phases. Data from chromatography techniques can be used to determine the composition and purity of substances. • Calculate and apply R_F values and retention times in the identification of components in a mixture.	*Note that this work builds upon concepts of polarity introduced in Stage 1 subtopics 3.1 and 3.2.* Explain the principles of separation through the rate of movement of components, using Learn Chemistry's interactive lab primers for TLC and column chromatography.	
	Undertake investigations using TLC, such as extraction and confirmation of caffeine from energy drinks, separation of individual indicators from universal indicator, or identification of analgesics using R_F. Use column chromatography to separate the pigments in chlorophyll from spinach leaves. Simulate HPLC for the separation of fluorescein in glow sticks, using column chromatography. Instructions available at: http://chemlab.truman.edu/CHEM131Labs/Chromatography.asp	
	Explore the legal and ethical aspects associated with applications of chromatography, such as forensic analysis, drug analysis in sports, blood alcohol analysis, industrial espionage, and analysis of residual insecticides and pesticides in the environment.	
Ion chromatography (also known as ion exchange chromatography) is used to remove either cations or anions from a mixture by replacing them with ions of another type. • Explain, using equilibrium principles, how ions attached to the surface of a resin can be exchanged with ions in aqueous solution.	Consider connections to the development of the concept of equilibrium in subtopic 2.2. *Note that ion exchange is developed in subtopics 4.2 and 4.3.* Watch a YouTube video on ion chromatography. Discuss factors affecting the elution time of proteins in an ion exchange column.	
	Explore how the development of the technique of ion chromatography allows analysis of a wide range of molecules in numerous applications and industries.	

Subtopic 1.5: Atomic spectroscopy

Science Understanding	Possible contexts
Flame tests and atomic absorption spectroscopy (AAS) are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels. • Write the electron configuration using subshell notation of an atom or monatomic ion of any of the first 38 elements in the periodic table. • Explain the effect of the absorption or emission of radiation on the electron configuration of electrons in atoms or ions. The wavelengths of radiation emitted and absorbed by an element are unique to that element and can be used to identify its presence in a sample. • Explain why some wavelengths of radiation emitted and absorbed by an element are unique to that element. Atomic absorption spectroscopy is used for quantitative analysis. • Explain the principles of atomic absorption spectroscopy in identifying elements in a sample. • Describe the construction and use of calibration graphs in determining the concentration of an element in a sample.	*Note the connection to atomic theory established in Stage 1 subtopics 1.2 and 2.2.* Discuss everyday examples of atomic emission, such as fireworks, sodium vapour streetlamps, or cooking with salted water over a flame. View a YouTube video on AAS, such as: https://www.youtube.com/watch?v=YDh4EjyDmjc Explore applications of AAS, such as analysis of arsenic in treated pine, water analysis for metal (or arsenic) content, or percentage of metals in ore samples. Perform flame tests and use spectroscopes to identify elements based on characteristic emission colours and spectra. Consider the contribution of the ideas of Sir Alan Walsh and colleagues to the development of atomic absorption spectroscopy. How has this scientific research impacted on the ability of chemists to identify elements in samples?

Topic 2: Managing chemical processes

The chemical industry produces a range of chemicals that allow naturally occurring materials to be modified or replaced, and previously unknown materials to be developed. In this topic, students investigate how chemicals are produced and how creative thinking has led to innovations in production. They explore aspects of green chemistry relating to improving efficiency of processes and reduction in energy use.

In this topic, students extend their understanding and skills developed through earlier investigations on reaction rate. They explore energy use and the factors that influence the reaction rates of chemical reactions, and how these can be applied to chemical processes and systems. They apply equilibrium law and Le Châtelier's principle to predict and explain the conditions that will optimise chemical processes.

Subtopic 2.1: Rates of reactions

Science Understanding	Possible contexts
The rates of a reaction at different times can be compared by considering the slope of a graph of quantity or concentration of reactant or product against time. • Draw and interpret graphs representing changes in quantities or concentration of reactants or products against time. Rates of reaction can be influenced by a number of factors, including the presence of inorganic and biological catalysts (enzymes). • Predict and explain, using collision theory, the effect on rates of reaction due to changes in: ◆ concentration ◆ temperature ◆ pressure (for reactions involving gases) ◆ surface area ◆ the presence of a catalyst. Energy profile diagrams can be used to represent the relative enthalpies of reactants and products, the activation energy, and the enthalpy change for a chemical reaction. • Draw and interpret energy profile diagrams.	*Note that section builds on concepts from Stage 1 subtopic 4.4.* Investigate the change in mass of the system over time when marble chips are added to hydrochloric acid, and tabulate and graph the results. Discuss the action of enzymes in living cells. Review factors affecting the rate of reaction at: http://ed.ted.com/lessons/how-to-speed-up-chemical-reactions-and-get-a-date
	Design an experiment to investigate: • the effect of initial reactant concentration, or particle size, on the rate of the reaction between calcium carbonate or magnesium, and hydrochloric acid • the effect of changing the temperature or pH on the rate of an enzyme-catalysed reaction.
	Explain how chemists have used nanoparticles to develop new catalysts to improve the efficiency of chemical processes. Consider how these new catalysts could lead to more sustainable practices in industry.

Subtopic 2.2: Equilibrium and yield

Science Understanding	Possible contexts
Chemical systems may be open or closed. Over time, reversible chemical reactions carried out in a closed system at fixed temperature eventually reach a state of chemical equilibrium. The changes in concentrations of reactants and products, as a system reaches equilibrium, can be represented graphically. • Draw and interpret graphs representing changes in concentrations of reactants and products. The position of equilibrium in a chemical system at a given temperature can be indicated by a constant, K_c, related to the concentrations of reactants and products. • Write K_c expressions that correspond to given reaction equations for homogeneous equilibrium systems. • Undertake calculations involving K_c and initial and/or equilibrium quantities of reactants and products for homogeneous equilibrium systems. The final equilibrium concentrations, and hence position of equilibrium, for a given reaction depend on various factors. • Predict and explain, using Le Châtelier's principle, the effect on the equilibrium position of a system of a change in the: ◆ concentration of a reactant or product ◆ overall pressure of a gaseous mixture ◆ temperature of an equilibrium mixture for which the ΔH value for the forward or back reaction is specified. • Predict the change that occurred in a system, or whether a reaction is exothermic or endothermic, given the effect of the change on the equilibrium position of the system.	*Note that this subtopic uses energy concepts from Stage 1 subtopics 2.3, 4.3, and 4.4.* Use reversible reactions with colour changes, such as $CrO_4^{2-} \leftrightarrow Cr_2O_7^{2-}$ and $CoCl_2 \leftrightarrow CoCl_2 \cdot 6H_2O$, to demonstrate factors that alter the position of equilibrium. Introduce the concepts of reversible reactions and dynamic equilibrium, using the ionisation of weak acids and bases (see subtopic 5.2). View and discuss the high-speed video of the effect of pressure change on the NO_2/N_2O_4 equilibrium: www.sciencephoto.com/media/627886/view View the high-speed video of the effect of concentration changes on equilibrium between Co^{2+} complexes in solution: www.sciencephoto.com/media/600219/view Simulate the effect of changes in concentration and temperature on $Fe(SCN)^{2+}$, see: www.mhhe.com/physsci/chemistry/essentialchemistry/flash/lechv17.swf *Note that this subtopic links to Stage 2 subtopics 1.1 (ocean acidification), 4.2 (water treatment), and 4.3 (availability of soil nutrients).* Apply the principles of equilibrium in relevant contexts such as O_2 exchange in the blood, the cause and treatment of CO poisoning, maintenance of acidity levels in the blood, CO_2 equilibrium in effervescent soft drinks, and equilibria between various forms of SO_2 in wine and the effect of wine acidity on these equilibria.
	Use colour comparison to study the effect of changes in concentration on the equilibrium concentration of $Fe(SCN)^{2+}$ in solution.

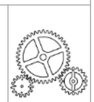
Subtopic 2.3: Optimising production

<table>
<tr><th>Science Understanding</th><th colspan="2">Possible contexts</th></tr>
<tr><td rowspan="2">Designing chemical-synthesis processes involves constructing reaction pathways that may include more than one chemical reaction.

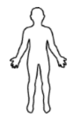
The steps in industrial chemical processes can be conveniently displayed in flow charts.
• Interpret flow charts and use them for such purposes as identifying raw materials, chemicals present at different steps in the process, waste products, and by-products.

Industrial processes are designed to maximise profit and to minimise impact on the environment.
• Explain how certain reaction conditions represent a compromise that will give maximum yield in a short time.
• Explain the impact of increases in temperature and pressure on manufacturing conditions and costs, and on the environment.
• Explain how use of a catalyst may benefit both the manufacturer and the environment.</td><td>Note that this subtopic integrates concepts from subtopics 2.1 and 2.2.

Explore the reasons why sulfuric acid tops the list of most-produced industrial chemicals in the world.

Illustrate the use of flow charts and of compromises involved in the selection of reaction conditions in the production of industrial chemicals such as ammonia, nitric acid, and sulfuric acid.</td><td></td></tr>
<tr><td>Use the green chemistry principle that the energy requirements of chemical processes should be minimised to explore the advantages and disadvantages of using catalysts in chemical processes.

Investigate the impact on society of the work of Fritz Haber in the development of the synthetic production of ammonia fertiliser.

Discuss the benefits of developing low-energy production methods for nitrogen and phosphorus fertilisers and how these processes are essential to the production of food for a growing world population.</td><td></td></tr>
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Topic 3: Organic and biological chemistry

Organic and biological chemistry is an important area of research; it includes medical technology, genetic engineering, and the development of pharmaceuticals. In this topic, students investigate the major groups of organic compounds, with a focus on those of biological significance.

Students investigate the reactions and preparations of a range of organic compounds and extend their laboratory skills by using specialised glassware. They increase their understanding of international protocols used by organic chemists for naming organic compounds and writing structural formulae.

Students examine the physical and chemical properties of a range of functional groups: alcohols, aldehydes and ketones, carboxylic acids, amines, esters, and amides. From this basis, they explore three biologically important classes of compounds: carbohydrates, triglycerides, and proteins.

Subtopic 3.1: Introduction

Science Understanding	Possible contexts
Organic compounds can be represented by molecular and structural formulae. • Determine the molecular formula of an organic compound given its extended, condensed, or skeletal structural formula. Organic compounds are named systematically to provide unambiguous identification. Condensation reactions occur when two organic molecules combine to form a larger molecule, also releasing another small molecule, such as water.	*Note that this continues the work on organic* chemistry introduced in Stage 1 subtopic 3.3. Students consider the IUPAC rules for systematic nomenclature using examples in the relevant subtopics. *Note that condensation reactions produce esters, amides, proteins, some carbohydrates, and some polymers.*
The physical properties of organic compounds are influenced by the molar masses of the molecules, and the number and polarity of functional groups. • Predict, explain, and compare the melting points, boiling points, and solubilities in water and in non-polar solvents of organic compounds, given their structural formulae.	*Note that discussion of physical properties throughout this topic draws on concepts introduced in Stage 1 subtopics 2.2, 3.2, and 4.1.* Relate the physical properties of compounds to their uses. Examples include: • small organic compounds are often used as solvents for non-polar molecules (e.g. propanone (acetone) and butanone in industry; iodine dissolves in ethanol but is not readily soluble in water) • ethanol is used in some cosmetics and external preparations because it evaporates quickly when applied to the skin • because of their odours, many aldehydes and ketones are used in perfumes (e.g. β-jasmone, β-ionone, α-ionone, civetone, carvones) and as flavouring agents (e.g. cinnamaldehyde, vanillin, benzaldehyde) • short-chain carboxylic acids have unpleasant odours (e.g. parmesan cheese, vomit, sweaty socks) • the volatility of small esters, and their sweet, fruity odours, make them suitable for use as perfumes, flavouring agents (e.g. in ice creams), and solvents (e.g. ethyl ethanoate can be used to extract caffeine from coffee and tea to produce the decaffeinated product)

Science Understanding	Possible contexts
	• the volatility of many organic solvents, including ketones and esters, causes their use to be hazardous; photocatalysis (UV light on nanoparticles of TiO_2 on surfaces) can be used to remove the solvent vapours from air • triglycerides have a higher boiling point than water and cooking foods in triglycerides at higher temperatures than boiling water produces quicker cooking and different flavours • cooking in triglycerides retains water-soluble nutrients that would be removed from the food if cooked in water (e.g. asparagus).

Subtopic 3.2: Alcohols

Science Understanding	Possible Contexts
Alcohols are classified as primary, secondary, or tertiary. • Identify, name systematically, and draw structural formulae of alcohols containing: ◆ up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms ◆ one or more hydroxyl groups. Primary, secondary, and tertiary alcohols behave differently with oxidising agents. • Describe how primary and secondary alcohols can be distinguished from tertiary alcohols by their reaction with acidified dichromate solution. • Predict the structural formula(e) of the product(s) of oxidation of a primary or secondary alcohol, given its structural formula.	*Note that this builds upon the concept of oxidation introduced in Stage 1 subtopic 6.1.* *Note that the production and use of ethanol as a fuel is considered in subtopic 4.1.* Classify a range of primary, secondary, and tertiary alcohols by testing with acidified $K_2Cr_2O_7$ solution. Consider the economic and environmental advantages and disadvantages of using ethanol to replace fossil fuels.

Subtopic 3.3: Aldehydes and ketones

Science Understanding	Possible contexts
Aldehydes and ketones are produced by the oxidation of the corresponding primary and secondary alcohols respectively. • Identify, name systematically, and draw structural formulae of aldehydes and ketones containing: ◆ up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms ◆ one or more aldehyde or ketone groups. Aldehydes can be readily oxidised; ketones cannot. • Draw the structural formula of the oxidation product of a given aldehyde in either acidic or alkaline conditions. • Describe how acidified dichromate solution and Tollens reagent (ammoniacal silver nitrate solution) can be used to distinguish between aldehydes and ketones.	*Note that this builds upon the concept of oxidation introduced in Stage 1 subtopic 6.1.* Consider aldehydes in relevant contexts. Examples could include: • oxygen diffuses into casks of whisky and oxidises the ethanol to aldehydes, which are the key flavour components in the whisky • in the liver, the ethanol in alcoholic beverages is oxidised to ethanal, which is toxic and can cause severe headaches and nausea.
	Prepare an aldehyde (e.g. propanal) from the appropriate primary alcohol, implementing the necessary reaction conditions. Use Tollens reagent to identify a sample of an aldehyde. Use the silver mirror reaction to line glass bottles with silver.

Subtopic 3.4: Carbohydrates

<table>
<tr><th>Science Understanding</th><th>Possible contexts</th></tr>
<tr><td rowspan="3">Carbohydrates are naturally occurring sugars and their polymers. They are defined as either polyhydroxy aldehydes or polyhydroxy ketones, or substances that form these compounds on hydrolysis.
• Given its structural formula, determine whether a molecule is a carbohydrate.

In aqueous solution, monosaccharides exist in an equilibrium between a ring and a chain form.

Disaccharides and polysaccharides are produced by the condensation of monosaccharide units linked in chains by covalent bonds.
• Write molecular formulae for glucose, and for disaccharides and polysaccharides, based on glucose monomers.
• Draw the structural formulae of the monosaccharide(s), given the structural formula of a disaccharide.
• Identify the repeating unit and draw the structural formula of the monomer, given the structural formula of a section of a polysaccharide.</td><td>Note that this builds upon the concept of repeating units introduced in Stage 1 subtopic 3.4.

Note that many, but not all, carbohydrates satisfy the general formula $C_xH_{2y}O_y$. Consider carbohydrates that do not satisfy this general formula (e.g. deoxyribose).

Discuss functions of carbohydrates in living systems. Examples could include:
• storage of chemical energy (glycogen in animals, starch in plants)
• structural support in plants (cellulose)
• essential components of nucleic acids (ribose and deoxyribose in both plants and animals).</td></tr>
<tr><td>Perform Tollens test on a solution of glucose and discuss the results in terms of the principles of equilibrium.</td></tr>
<tr><td>Investigate cellulose as an alternative source to petroleum for the production of petrochemicals.</td></tr>
</table>

Subtopic 3.5: Carboxylic acids

<table>
<tr><th>Science Understanding</th><th>Possible contexts</th><th></th></tr>
<tr><td rowspan="3">Carboxylic acids can be produced by the oxidation of aldehydes or primary alcohols.
• Identify, name systematically, and draw structural formulae of carboxylic acids containing:
◆ up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms
◆ one or two carboxyl groups.

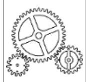
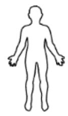
Carboxylic acids are weak acids and, to a small extent, ionise in water.
• Write equations for the reactions of carboxylic acids with bases, including hydroxides, carbonates, and hydrogencarbonates, to form carboxylate salts, and describe changes that accompany these reactions.
• Explain why sodium and potassium carboxylate salts are more soluble in water than their parent carboxylic acids.</td><td>Note that this builds upon the concepts introduced in Stage 1 subtopics 4.2 and 5.2.

Relate the oxidation of ethanol, to form ethanoic acid, to the odour of vinegar in wines exposed to air.</td><td></td></tr>
<tr><td>Discuss uses of vinegar in household cleaning products designed to remove insoluble carbonates on plumbing fixtures, and as a preservative in the food industry.

Observe the effervescence produced when carboxylic acids react with samples of carbonates.

Titrate commercial vinegars to determine their concentration of ethanoic acid. This enables students to:
• select and use correctly appropriate glassware
• collect data to an appropriate number of significant figures
• analyse results
• evaluate the procedure and results.</td><td></td></tr>
<tr><td>Discuss how knowledge of carboxylic acid chemistry has enabled chemists to design new, more effective drugs that have benefits to society (e.g. soluble aspirin).</td><td></td></tr>
</table>

Subtopic 3.6: Amines

<table>
<tr><th>Science Understanding</th><th>Possible contexts</th><th></th></tr>
<tr><td rowspan="2">Amines are classified as primary, secondary, or tertiary.
• Identify, name systematically, and draw structural formulae of primary amines containing:
◆ up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms
◆ one or more amino groups.
Amines act as bases.
• Draw the structural formula of the protonated form of an amine, given the structural formula of its molecular form, and vice versa.
• Explain why the protonated form of an amine is more soluble in water than its parent molecular amine.</td><td>Note that this builds upon the concepts introduced in Stage 1 subtopics 4.2 and 5.2.
Use examples of amines in hormones, anaesthetics, and addictive drugs to identify amino groups and draw structural formulae of amine salts.
Explore the role of amines in the function of the nervous system.
Discuss information about amines and their salts in drugs.</td><td></td></tr>
<tr><td>Discuss the benefits to consumers of the use of lignocaine as a numbing agent, or nicotine salts in nicotine patches, examples of drugs produced by converting an amine into its salt.</td><td></td></tr>
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Subtopic 3.7: Esters

Science Understanding	Possible contexts
Carboxylic acids undergo condensation reactions with alcohols to form esters. • Identify, name systematically, and draw structural formulae of methyl and ethyl esters of acids containing up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms. • Draw the structural formula of the ester that could be produced by the condensation reaction between a carboxylic acid and an alcohol, given their structural formulae or vice versa. • Draw the structural formula of a polyester, given the structural formula(e) of the monomer(s) or vice versa. Condensation reactions are slow at 25°C. • Explain the use of heating under reflux, and the use of a trace of concentrated sulfuric acid in the laboratory preparation of esters. Esters may be hydrolysed under acidic or alkaline conditions. • Identify the products of acidic or alkaline hydrolysis of an ester or polyester, given the appropriate structural formula.	View a solvent-based extraction of caffeine from coffee and discuss the procedure. www.youtube.com/watch?v=_CoxEgbyeK4 Demonstrate the extraction of caffeine from tea using an aqueous solution of Na_2CO_3 followed by sublimation of the caffeine. One method, *DIY: Taking the Caffeine Out of Tea*, can be found at: www.open.edu/openlearn/science-maths-technology/science/chemistry/diy-taking-the-caffeine-out-tea
	Consider why old perfume bottles frequently have an unpleasant odour. Prepare, or hydrolyse, an ester in the laboratory, implementing the necessary reaction conditions. These procedures provide an opportunity to use techniques of reflux, liquid–liquid extraction, and fractional distillation.
	Evaluate whether the description of terylene as a 'miracle fibre' is valid.

Subtopic 3.8: Amides

Science Understanding	Possible contexts
Carboxylic acids undergo condensation reactions with amines to form amides. • Draw the structural formula of the amide formed from a carboxylic acid and an amine, given their structural formulae or vice versa. • Draw the structural formula of a polyamide, given the structural formula(e) of the monomer(s) or vice versa. Amides may be hydrolysed under acidic or alkaline conditions. • Identify the products of acidic or alkaline hydrolysis of an amide or polyamide, given the appropriate structural formula.	Use paracetamol as an example to draw hydrolysis products of an amide. Discuss the behaviour of Kevlar in persistent warm and humid conditions.
	Conduct a competition in the laboratory to make the longest strand of nylon.
	Investigate current examples where natural fibres have been replaced by synthetic fibres and there have been unexpected consequences for society. Discuss potential economic and political impacts of new materials.

Subtopic 3.9: Triglycerides

Science Understanding	Possible contexts
Edible oils and fats are esters of propane-1,2,3-triol (glycerol) and various carboxylic acids. • Draw the structural formula of an edible oil or fat, given the structural formula(e) of the carboxylic acid(s) from which it is derived. Triglycerides can be hydrolysed to produce propane-1,2,3-triol and various carboxylic acids. • Identify and draw the structural formulae of the alcohol and acid(s) from which a triglyceride is derived, given its structural formula. Triglycerides may be saturated or unsaturated. • Describe and explain the use of a solution of bromine or iodine to determine the degree of unsaturation of a compound. Draw the structural formula of the reaction product. • Explain how the degree of unsaturation causes differences in the melting points of edible oils and fats. Liquid triglycerides can be converted into triglycerides of higher melting point. • Explain the role of pressure, temperature, and a catalyst in the hydrogenation of liquid triglycerides to form triglycerides of higher melting point. Alkaline hydrolysis of triglycerides produces carboxylate ions, which have both hydrophilic and hydrophobic regions. • Explain how the structure of these carboxylate ions allow them to form micelles in solutions. • Explain how micelles can dissolve and move non-polar substances through an aqueous medium or vice versa.	*Note that this builds upon concepts introduced in Stage 1 subtopics 3.3 and 4.1.* Note that the carboxylic acid components of triglycerides are unbranched and usually contain an even number of carbon atoms between 12 and 20. Edible oils and fats are distinguished on the basis of melting point. Explain why the structure of the oil or fat relates to its melting point. Discuss methods of production of margarine. Consider why hydrolysis of triglycerides (e.g. in butter) over time can lead to unpleasant odours. Investigate how soap anions remove grease from surfaces and how emulsifiers stabilise salad dressings, ice creams, cosmetics, and paints. Use bromine solution to test a range of saturated and unsaturated triglycerides. Consider contemporary uses of amphiphilic particles such as how nano-sized micelles of biocompatible polymers can be used to encapsulate, protect, and deliver hydrophobic drugs in the body. Evaluate the benefits and limitations of these types of innovations for individuals and society.

Subtopic 3.10: Proteins

Science Understanding	Possible contexts	
Proteins are polymers of amino acids. Amino acids contain a carboxyl group and an amino group. • Write the general formula of amino acids and recognise their structural formulae. Amino acids have both acidic and basic properties. • Draw the structural formula of the product formed when an amino acid self-ionises, given its structural formula. Amino acids can undergo condensation to form protein chains. The amide groups within proteins are also known as 'peptide links'. • Draw the structural formula of a section of a protein chain that could be formed from amino acids, given their structural formulae or vice versa. The unique spatial arrangement of a protein depends on secondary interactions between sections of the chain and, in aqueous environments, between the chain and water. • Identify where secondary interactions can occur, given the structural formula of a section of a protein chain. The biological function of a protein is a consequence of its spatial arrangement. • Explain why the biological function of a protein (e.g. an enzyme) may be affected by changes in pH and temperature.	*Note that this subtopic revisits concepts introduced in Stage 1 subtopics 3.1, 3.2, and 4.2, and in Stage 2 subtopics 3.5 and 3.6.* Recognise that in the biologically important amino acids that form proteins, the amino group is on the carbon atom adjacent to the carboxyl group. These are known as α-amino acids. Construct a model of an amino acid molecule and note how the orientation of the amino and carboxyl groups facilitates self-ionisation. Discuss why certain amino acids are referred to as 'essential' amino acids. Apply understanding of physical properties of protein chains to their function as major structural materials in animal tissue (e.g. hair, spider silk). Consider the importance of the sequence of amino acids in a protein. Discuss the importance of enzymes in the maintenance and regulation of life processes.	
	Explore how the work of scientists from various disciplines contributes to the development of the technique of amino acid sequencing and how this technique contributes to our knowledge of protein function.	

Topic 4: Managing resources

Recent centuries have seen great increases in human consumption of energy and other resources, linked to new understandings and new technologies. Although these developments can provide benefits, they also pose risks. Chemists are able to respond to social concerns and inform public debate, for example, on environmental issues, as well as explore and undertake development of strategies to address issues of concern.

Students examine issues that have arisen as a consequence of human exploitation of the Earth's resources, and how these issues might be addressed. Possible practical investigations include fermentation, biodiesel production, and the energy available from different fuels.

Students consider energy resources such as fossil and renewable fuels, and the use of electrical energy to facilitate greater use of intermittent sources such as sunlight. They examine material sources such as natural materials, water, and soil, as well as synthetic polymers. They also examine benefits and problems associated with recycling of materials.

Subtopic 4.1: Energy

Science Understanding	Possible contexts	
Photosynthesis and respiration are important processes in the cycling of carbon and oxygen on Earth. In photosynthesis the light energy absorbed by chlorophyll is stored as chemical energy in carbohydrates such as glucose. • Describe and write the equation for photosynthesis. The chemical energy present in carbohydrates can be accessed by respiration and combustion. • Describe and write the equation for the aerobic respiration of glucose.	*Note that the concepts of energy change in reactions, introduced in Stage 1 subtopic 4.4, can be applied in this subtopic.*	
Fossil fuels (coal, petroleum, and natural gas) have been formed over geological time scales by anaerobic decomposition of dead organisms. They are considered to be non-renewable because reserves are depleted more quickly than they are formed. Carbon-based fuels provide energy and are feedstock for the chemical industry. • Discuss the advantages and disadvantages of using carbon-based fuels as sources of heat energy, compared with their use as feedstock.	Compare the environmental, social, and/or economic impact of using carbon-based fuels in two or more different types of locations (e.g. urban and rural, different countries). Discuss how the rapid increase in the use of fuels has led to the need for the development of new technologies that enable more efficient energy production or for devices that use energy more efficiently and hence have less impact on the environment.	
Renewable energy is generated over time scales of years to decades, from sources that are replenished much more quickly than fossil fuels. • Identify biofuels, such as bioethanol and biodiesel, sunlight, and wind as renewable energy sources. • Compare the contributions of fossil fuels to global warming with those from renewable energy sources. Biofuels are produced by present-day biological processes. • Describe the production, from biological materials, of bioethanol and biodiesel, including the writing of chemical equations for the reactions involved. • Explain how fossil fuels contribute more than biofuels to global warming.	Investigate the issues associated with increasing the contribution of agriculture to the production of biofuels. Examine how the use of agriculture for fuel production might affect the food available for a growing world population. Discuss the principle of green chemistry that, where practicable, renewable raw materials should be used for chemical processes. Investigate the growing of algae as a source of biofuels such as ethanol, butanol, methane, and hydrogen. Explore the possibility of the development of microbes that are able to generate hydrogen from waste.	

Science Understanding	Possible contexts	
	Carry out fermentation and fractional distillation processes. Research the methods available to produce biodiesel and prepare a sample from a renewable resource.	
The complete combustion of fuels containing carbon and hydrogen produces carbon dioxide and water and energy. • Write thermochemical equations for the complete combustion of fuels in which the only products are carbon dioxide and water. Incomplete combustion, producing carbon (soot) and carbon monoxide, is more likely with longer-chain carbon-based fuels. • Explain why incomplete combustion is more likely with longer-chain carbon-based fuels than with shorter chains. • Discuss the undesirable consequences of incomplete combustion.	*Note that this extends the work on writing combustion equations introduced in Stage 1 subtopic 3.3.* Consider diesel and biodiesel as examples of longer-chain fuels, and methane, ethanol, and octane (petrol) as examples of shorter-chain fuels. View and discuss a high-speed video of incomplete combustion: www.sciencephoto.com/media/595178/view	
The energy released in combustion of fuels can be determined experimentally. • Use experimental data to determine the enthalpy of combustion of a fuel. • Undertake thermochemical calculations involving enthalpy changes and temperature changes of a specified mass of water given the necessary data. Fuels, including fossil fuels and biofuels, can be compared in terms of their energy output and the nature of products of combustion. • Calculate the quantities of heat evolved per mole, per gram, and per litre (for liquids) for the complete combustion of fuels. • Compare fuels given appropriate data.	*Note that this extends the work on enthalpy introduced in Stage 1 subtopic 4.4.* Evaluate the advantages and disadvantages of different fuels for various purposes and justify the use of a fuel for a particular purpose.	
	Experimentally determine the enthalpy of combustion of an alcohol using a spirit burner. Evaluate the practical procedure and consider the impact on the data of systematic and random errors.	

Science Understanding	Possible contexts	
Although most electricity is generated using fuels to drive steam turbines, electrical energy can be also be generated using photovoltaic cells (known as solar cells) and directly from oxidation of fuels using galvanic cells. • Explain the advantages and disadvantages of direct electricity generation (photovoltaic and fuel cells) compared to using steam turbines. Fuel cells, including flow cells, are galvanic cells in which the electrode reactants are available in continuous supply. • State the advantages and disadvantages of fuel cells compared with other galvanic cells. • Identify the anode and cathode and their charges, as well as the direction of ion and electron flow, in a fuel cell, given sufficient information. • Write electrode half-equations for a fuel cell given sufficient information. • Discuss the advantages of flow cells compared with other fuel cells. Hydrogen is a fuel that is produced from fossil fuels, biomass, or water. • Compare the benefits of producing hydrogen from each of these three sources. • Describe the benefits of using hydrogen, rather than fossil fuels, as a fuel.	*Note that this extends the work on galvanic cells introduced in Stage 1 subtopic 6.3.* Discuss discoveries, such as that at Lund University, about the mechanisms of energy transfer in photosynthetic organisms. Note that chlorophyll, which is essential for photosynthesis in green plants, absorbs light and releases electrons, similarly to a photovoltaic cell. Discuss the benefits of developing more effective materials for photovoltaic cells. View and discuss a video on hydrogen fuel cells: http://www.youtube.com/watch?v=08ZH7vwzzEg	
	Compare the advantages and disadvantages of using fuel cells to generate electricity with electricity produced by renewable energy sources, such as wind and solar energy. Evaluate the economic, social, environmental, and ethical considerations of the production of electricity from different sources.	

Subtopic 4.2: Water

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<tr><th>Science Understanding</th><th>Possible contexts</th><th></th></tr>
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Water from different sources is treated with different methods depending on its origin and intended use.

Suspended matter is commonly removed from water by flocculation and coagulation, followed by sedimentation and filtration.

The surface of fine silicate and aluminosilicate particles in clays is negatively charged and can be flocculated into larger particles by the addition of salts containing highly charged cations such as aluminium ions or polymers.
• Explain the use of aluminium ions and polymers in flocculating clay particles suspended in water.

Hard water contains high concentrations of Ca^{2+} and Mg^{2+} ions. Hard water renders soaps less effective and causes build-up of precipitates.

Natural and modified zeolites can be used in the purification and softening of water, through the exchange of cations.
• Explain the use of zeolites in water softeners.

Reverse osmosis is a filtration technique whereby water is forced, under pressure, through a semi-permeable membrane.
• Explain how reverse osmosis produces potable water from saline water.

Desalination is a process used to remove minerals from saline water to produce fresh potable water. Reverse osmosis and thermal distillation are two widely used methods for desalination.
• Describe the disadvantages of using desalination for the production of potable water.

Hypochlorous acid, chlorine, and hypochlorites are oxidisers used for water disinfection.
• Explain the effect of pH on the equilibrium between chlorine and water, and hydrochloric acid and hypochlorous acid.
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Note that this extends the work on ionic interactions introduced in Stage 1 subtopic 4.2 and on pH in Stage 1 subtopic 5.3.

Recognise that some sources distinguish between coagulation and flocculation. Coagulation involves neutralisation of the negative charge on clay minerals. This is followed by flocculation, in which neutral particles come together.

Explore SA Water’s school resources to consider how water is treated and supplied.

Visit the website LifeStraw, which reports on water filters for Majority World countries.

Visit the website of the Adelaide Desalination Plant (SA Water).
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Visit a water-treatment plant, such as the plant at Mount Pleasant, which utilises ion exchange for Murray River water (SA Water).

Conduct an online investigation on:
• water softeners used domestically in home water-filtration systems (e.g. dishwashers, coffee machines)
• reverse osmosis units utilised in, for example, school laboratories and cafes to control concentrations of dissolved salts.

Extract copper ions from solution using ion exchange resins.

Investigate coagulation and flocculation using alum and polyDADMAC.
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Subtopic 4.3: Soil

Science Understanding	Possible contexts	
Plants require nutrients, which they obtain from the soil. • Explain why plants need soil nutrients in soluble form. Soil productivity is related to the availability of plant nutrients, which need to be replenished naturally or by the addition of fertilisers. Nitrogen, phosphorus, and potassium are the major nutrients that plants require from the soil. • Explain how natural processes (including lightning, nitrogen-fixing bacteria, and decay) replenish soil nitrogen. • Explain why fertilisers are required to improve the productivity of some soils. Excess nitrogen and phosphorus can be leached from soils and can cause eutrophication in water bodies. • Explain the process and consequences of eutrophication.	Discuss why fertilisers providing calcium, magnesium, and sulfur are not usually necessary in Australian soils. Discuss what is meant by the terms ‘macronutrients’ and ‘micronutrients’. Consider the increased contribution to soil fertility of nitrogen fertilisers resulting from the Haber–Bosch process compared with the fixation of nitrogen by biological means.	
Silicon dioxide, silicates, and aluminosilicates are important components of rocks and soils. • Write the formula of the anion given the formula of a silicate or aluminosilicate. Cations adsorbed on the surface of soil silicates and aluminosilicates are in equilibrium, and can be exchanged with, the cations in soil water, which are available as sources of plant nutrients. Soil silicates and aluminosilicates are able to adsorb H^+ and release cations. • Explain how cations on the surface of soil silicates and aluminosilicates become available to plants. Nutrient cations on the surface of soil silicates and aluminosilicates are replaced if the concentrations of H^+ or Na^+ in soil water become too high. • Explain how acidic or saline conditions (i.e. high concentrations of H^+ or Na^+) deplete the nutrient value of soils.	*Note that this revisits concepts about ionic substances introduced in Stage 1 subtopics 2.2 and 4.2.* *Note that this revisits concepts of equilibrium introduced in subtopic 2.2.* Note that some sources use the term ‘soil solution’ rather than ‘soil water’ to emphasise the importance of the ions that are present in the water in the soil. Consider in more detail aspects of the absorption of nutrient cations by roots. Examples could include how: • mineral concentrations in root cells are greater than in the soil so energy is needed for their absorption • root hairs pump H^+ ions into the soil to displace cations attached to silicate and aluminosilicate minerals, so that the cations are available for uptake by the root. Consider the origin and impacts of sodic soils. www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/127278/Sodic-soil-management.pdf	

Subtopic 4.4: Materials

Science Understanding	Possible contexts
Polymers Polymers are produced from monomers by addition or condensation reactions. • Identify whether a molecule could undergo polymerisation, given its structural formula and, if so, the type of polymerisation. • Identify a polymer as being the product of an addition polymerisation or a condensation polymerisation, given its structural formula. • Identify the repeating unit of a polymer, given its structural formula.	*Note that this extends the work on materials introduced in Stage 1 subtopics 1.1 and 2.1, addition polymerisation introduced in Stage 1 subtopic 3.4, and condensation polymerisation in Stage 2 subtopics 3.7 and 3.8.* Investigate the use of polymers in examples such as medical prostheses, 3D printing, and new-generation fibres.
The production of synthetic polymers allows the manufacture of materials with a diverse range of properties. • Discuss the advantages and disadvantages of synthetic polymers. • Compare the effects of heating on thermoplastic and thermoset polymers. Organic polymers can have different properties, such as rigidity, depending on the monomers and the degree of cross-linking between chains. • Compare the physical properties of polymers with different degrees of cross-linking and secondary interactions between polymer chains.	*Note that this extends the work on polymers in Stage 2 subtopics 3.7 and 3.8.* Discuss examples of physical properties that are affected by cross-linking and secondary interactions include rigidity, strength, and elasticity
Polymers can be made from fossil resources or from renewable materials. • Discuss the advantages and disadvantages of making polymers from fossil resources or from renewable materials. Some polymers are biodegradable — being able to be broken down by microorganisms and other living things. • Explain how the structure of a polymer relates to its biodegradability. • Explain the advantages of polymers that are biodegradable.	Discuss the principle of green chemistry that, where practicable, renewable raw materials should be used for chemical processes. Examine examples of industries that have used the principles of green chemistry to benefit society and the environment.

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<tr><th>Science Understanding</th><th>Possible contexts</th></tr>
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Metals

The occurrence of metals in combined or uncombined form in the Earth’s crust is related to the reactivity of the metal.

The production of some metals requires the conversion of minerals to a form suitable for reduction.

- Explain, with the aid of equations, the methods designed for the conversion of a mineral to a metal, given sufficient information.

The method used in the reduction stage in the production of a metal is related to the reactivity of the metal and the energy requirement for the reaction.

Given the position of a metal in the activity series of metals:

- Predict whether the metal is likely to occur in nature in a combined or uncombined form.
- Predict and explain the likely method of reduction of the metal compound, including electrolysis of the molten compound, electrolysis of an aqueous solution of the metal compound, and use of carbon as a reducing agent.
- Explain the benefits of one method of reduction compared with another, given relevant information.

Electrolytic cells are used to produce required substances.

- Identify the anode and cathode and their charges, as well as the direction of ion and electron flow in an electrolytic cell, given sufficient information.
- Write electrode half-equations for an electrolytic cell, given sufficient information.

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Note that this material applies the concepts of reactions of acids from Stage 1 subtopic 5.2, and draws on concepts of redox, metal reactivity, and electrochemistry introduced in Stage 1 Topic 6.

Compare the production processes used for metals of different reactivity such as sodium and zinc. Discuss the by-products and waste products of the various processes.

Explore the electrowinning of Cu that allows recovery of Au and Ag in the ore.

Consider potential methods of extracting metals from their ores, such as phytomining and bioleaching, which limit the environmental impact of traditional mining.

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Demonstrate nickel plating or the Hofmann voltameter.

Construct electrolytic cells to produce metals from solution such as copper and zinc.

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Explore how scientific research in the nineteenth century led to the discovery and production of a new metal, aluminium.

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Science Understanding	Possible contexts
Recycling There is a finite amount of materials on Earth. Materials that can be recycled reduce the amount of new materials that need to be produced from the Earth’s crust. • Explain the advantages of recycling materials. Some objects are difficult to recycle. • Explain the difference in the ease of recycling thermoplastic and thermoset polymers. Composite materials comprise two or more constituent materials to produce a material with properties different from the individual components. • Explain the uses of composite materials in terms of the advantages offered. • Explain the difficulties associated with recycling materials and objects comprising two or more different materials with different properties.	*Note that this material draws on concepts introduced in Stage 1 subtopics 2.1, 3.2, and 3.4.* Investigate the energy requirements for recycling aluminium cans and for creating cans from bauxite. Discuss examples of: • composite materials (e.g. plywood, concrete, and carbon-fibre reinforced polymers) • objects comprising two or more materials (e.g. drink bottles and envelopes with bubble wrap).
	Explore how the ideas of chemists and other scientists have been used to improve materials for specific purposes. Consider the impacts these improvements have had on industry, the environment and society. Examples may include: • development of alternative materials that have superior properties or that can be used in place of materials that are toxic, expensive, or in short supply • processes to reclaim elements, such as phosphorus from soil and rivers, indium from electronic chips, and platinum from catalytic converters • processes to extract elements available in low concentration, such as lithium from sea water.

ASSESSMENT SCOPE AND REQUIREMENTS

All Stage 2 subjects have a school assessment component and an external assessment component.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 2 Chemistry:

School assessment (70%)

- Assessment Type 1: Investigations Folio (30%)
- Assessment Type 2: Skills and Applications Tasks (40%)

External assessment (30%)

- Assessment Type 3: Examination (30%).

Students provide evidence of their learning through eight assessments, including the external assessment component. Students complete:

- at least two practical investigations
- one investigation with a focus on science as a human endeavour
- at least three skills and applications tasks
- one examination.

At least one investigation or skills and applications task should involve collaborative work.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by:

- teachers to clarify for the student what they need to learn
- teachers and assessors to design opportunities for the student to provide evidence of their learning at the highest possible level of achievement.

The assessment design criteria consist of specific features that:

- students should demonstrate in their learning
- teachers and assessors look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:

- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described below.

The set of assessments, as a whole, must give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

IAE1 Deconstruction of a problem and design of a chemistry investigation.

IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats.

IAE3 Analysis and interpretation of data and other evidence to formulate and justify conclusions.

IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

KA1 Demonstration of knowledge and understanding of chemical concepts.

KA2 Application of chemical concepts in new and familiar contexts.

KA3 Exploration and understanding of the interaction between science and society.

KA4 Communication of knowledge and understanding of chemical concepts and information, using appropriate terms, conventions, and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio (30%)

Students undertake at least two practical investigations and one investigation with a focus on science as a human endeavour. Students may undertake more than two practical investigations within the maximum number of assessments allowed in the school assessment component. They inquire into aspects of chemistry through practical discovery and data analysis, and/or by selecting, analysing, and interpreting information.

Practical Investigations

As students design and safely carry out investigations, they demonstrate their science inquiry skills by:

- deconstructing a problem to determine the most appropriate method for investigation
- formulating investigable questions and hypotheses
- selecting and using appropriate equipment, apparatus, and techniques
- identifying variables
- collecting, representing, analysing, and interpreting data
- evaluating procedures and considering their impact on results
- drawing conclusions
- communicating knowledge and understanding of concepts.

As a set, practical investigations should enable students to:

- work both individually or collaboratively
- investigate a question or hypothesis for which the outcome is uncertain.
- investigate a question or hypothesis linked to one of the topics in Stage 2 Chemistry
- individually deconstruct a problem to design their own method and justify their plan of action.

For each investigation, students present an individual report.

Evidence of deconstruction (where applicable) should outline the deconstruction process, the method designed as most appropriate, and a justification of the plan of action, to a maximum of 4 sides of an A4 page. This evidence must be attached to the practical report.

Suggested formats for this evidence include flow charts, concept maps, tables, or notes.

In order to manage the implementation of an investigation efficiently, students could individually design investigations and then conduct one of these as a group, or design hypothetical investigations at the end of a practical activity.

A practical report should include:
- introduction with relevant chemistry concepts, and either a hypothesis and variables, or an investigable question
- materials/apparatus
- the method that was implemented
- identification and management of safety and/or ethical risks
- results, including table(s) and/or graph(s)
- analysis of results, including identifying trends and linking results to concepts
- evaluation of procedures and their effect on data, and identifying sources of uncertainty
- conclusion, with justification.

The report should be a maximum of 1500 words if written, or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

Only the following sections of the report are included in the word count:
- introduction
- analysis of results
- evaluation of procedures
- conclusion and justification.

Suggested formats for presentation of a practical investigation report include:
- a written report
- an oral presentation
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate a contemporary example of how science interacts with society. This may focus on one or more of the key concepts of science as a human endeavour described on pages 10 and 11, and may draw on a context suggested in the topics or relate to a new context.

Students select and explore a recent discovery, innovation, issue, or advance linked to one of the topics in Stage 2 Chemistry. They analyse and synthesise information from different sources to explain the science relevant to the focus of their investigation, show its connections to science as a human endeavour, and develop a conclusion.

Possible starting points for the investigation could include, for example:

- the announcement of a discovery in the field of chemistry
- an expert's point of view on a controversial innovation
- a TED talk based on a development in chemistry
- an article from a scientific publication (e.g. *Cosmos*)
- public concern about an issue that has environmental, social, economic, or political implications
- changes in government funding for chemistry-related purposes, for example, for scientific research into the molecular geometry of enzymes, corrosion of cables on suspension bridges, collision theory to enable the prediction and control of chemical reaction rates, chemical engineering, wine chemistry, uptake of anthropogenic carbon dioxide by the oceans, superacids, alcosensors and other blood analysis tests, lower-emission fuel alternatives
- innovative directions in research.

Based on their investigation, students prepare a scientific report, which must include the use of scientific terminology and:

- an introduction to identify the focus of the investigation and the key concept(s) of science as a human endeavour that it links to
- relevant chemistry concepts or background
- an explanation of how the focus of the investigation illustrates the interaction between science and society, including a discussion of the potential impact of the focus of the investigation, e.g. further development, effect on quality of life, environmental implications, economic impact, intrinsic interest
- a conclusion
- citations and referencing.

The report should be a maximum of 1500 words if written, or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

This report could take the form of, for example:

- an article for a scientific publication
- an oral or multimodal scientific presentation.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks (40%)

Students undertake at least three skills and applications tasks. Students may undertake more than three skills and applications tasks within the maximum number of assessments allowed in the school assessment component, but at least three should be under the direct supervision of the teacher. The supervised setting should be appropriate to the task. Each supervised task should be a maximum of 90 minutes of class time, excluding reading time.

Skills and applications tasks allow students to provide evidence of their learning in tasks that may:

- be applied, analytical, and/or interpretative
- pose problems in new and familiar contexts
- involve individual or collaborative assessments, depending on task design.

A skills and applications task may involve, for example:

- solving problems
- designing an investigation to test a hypothesis or investigable question
- considering different scenarios in which to apply knowledge and understanding
- graphing, tabulating, and/or analysing data
- evaluating procedures and identifying their limitations
- formulating and justifying conclusions
- representing information diagrammatically or graphically
- using chemical terms, conventions, and notations.

As a set, skills and applications tasks should be designed to enable students to apply their science inquiry skills, demonstrate knowledge and understanding of key chemical concepts and learning, and explain connections with science as a human endeavour. Problems and scenarios should be set in a relevant context, which may be practical, social, or environmental.

Skills and applications tasks may include, for example:

- developing simulations
- practical and/or graphical skills
- a multimodal product
- an oral presentation
- participation in a debate
- an extended response
- responses to short-answer questions
- a response to science in the media.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

EXTERNAL ASSESSMENT

Assessment Type 3: Examination (30%)

Students undertake a 130-minute examination.

Stage 2 science inquiry skills and science understanding from all topics may be assessed.

Questions:

- will be of different types
- may require students to show an understanding of science as a human endeavour
- may require students to apply their science understanding from more than one topic.

For the examination, students are given a sheet containing a periodic table, standard SI prefixes, symbols of common quantities, some mathematical relationships, and a table showing the relative activities of a number of metals.

All specific features of the assessment design criteria for this subject may be assessed in the external examination.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills, and understanding that teachers and assessors refer to in deciding how well students have demonstrated their learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student's completion of study of each school assessment type, the teacher makes a decision about the quality of the student's learning by:

- referring to the performance standards
- assigning a grade between A+ and E– for the assessment type.

The student's school assessment and external assessment are combined for a final result, which is reported as a grade between A+ and E–.

Performance Standards for Stage 2 Chemistry

	Investigation, Analysis, and Evaluation	Knowledge and Application
A	Critically deconstructs a problem and designs a logical, coherent, and detailed chemistry investigation. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and discusses their effect on data.	Demonstrates deep and broad knowledge and understanding of a range of chemical concepts. Applies chemical concepts highly effectively in new and familiar contexts. Critically explores and understands in depth the interaction between science and society. Communicates knowledge and understanding of chemistry coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Logically deconstructs a problem and designs a well-considered and clear chemistry investigation. Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effect on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of chemical concepts. Applies chemical concepts mostly effectively in new and familiar contexts. Logically explores and understands in some depth the interaction between science and society. Communicates knowledge and understanding of chemistry mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Deconstructs a problem and designs a considered and generally clear chemistry investigation. Obtains, records, and represents data, using generally appropriate conventions and formats, with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates procedures and some of their effect on data.	Demonstrates knowledge and understanding of a general range of chemical concepts. Applies chemical concepts generally effectively in new or familiar contexts. Explores and understands aspects of the interaction between science and society. Communicates knowledge and understanding of chemistry generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares a basic deconstruction of a problem and an outline of a chemistry investigation. Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and undertakes some basic interpretation to formulate a basic conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of chemical concepts. Applies some chemical concepts in familiar contexts. Partially explores and recognises aspects of the interaction between science and society. Communicates basic chemical information, using some appropriate terms, conventions, and/or representations.
E	Attempts a simple deconstruction of a problem and a procedure for a chemistry investigation. Attempts to record and represent some data, with limited accuracy or effectiveness. Attempts to describe results and/or interpret data to formulate a basic conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of chemical concepts. Attempts to apply chemical concepts in familiar contexts. Attempts to explore and identify an aspect of the interaction between science and society. Attempts to communicate information about chemistry.

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (www.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement in the school assessment are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 1 are available on the SACE website (www.sace.sa.edu.au).

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.edu.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website (www.sace.sa.edu.au).