Chemistry

Subject Outline
Stage 1 and Stage 2

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INTRODUCTION

SUBJECT DESCRIPTION

Chemistry may be undertaken as a 10-credit subject or a 20-credit subject at Stage 1 or as a 20-credit subject at Stage 2.

In their study of Chemistry, students develop and extend their understanding of the use that human beings make of the planet's resources and the impact of human activities on the environment. 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 an understanding of the physical world and 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 develop a range of understanding and inquiry skills that encourage and inspire them in thinking scientifically and pursuing 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 capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding.

Literacy

In this subject students develop their literacy capability by, for example:

- 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
- using appropriate structures to communicate for specific purposes and audiences.

Numeracy

In this subject students develop their numeracy capability by, for example:

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

Information and communication technology

In this subject students develop their information and communication capability by, for example:

- locating and accessing information
- collecting, analysing, and representing data electronically
- modelling concepts and relationships
- 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 develop critical and creative thinking by, for example:

- constructing, reviewing, and revising hypotheses to design-related 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 develop 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.

Ethical understanding

In this subject students develop 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
- 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 different cultural views and customs while valuing scientific evidence
- 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.

Stage 1 Chemistry

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

CONTENT

Stage 1 Chemistry may be undertaken as a 10-credit or a 20-credit subject.

Science inquiry skills and science as a human endeavour are integral to students' learning in this subject and are interwoven through the science understanding, which is organised into six topics.

In their study of these topics, students develop and extend their understanding of some of the fundamental principles and concepts of chemistry, including structure, bonding, polarity, solubility, acid-base reactions, and redox. These are introduced in the individual topics, with the mole concept and some energy concepts introduced gradually throughout these topics.

Using an inquiry approach to learning through observation, speculation, prediction, experimentation, analysis, evaluation, and communication students develop and extend their science inquiry skills and reinforce their understanding of science as a human endeavour.

The science inquiry skills and the understanding of science as a human endeavour that can be developed through practical and other learning activities in each topic are described in the *Science Inquiry Skills* and *Science as a Human Endeavour* sections which follow.

Programming

Stage 1 Chemistry consists of the following topics:

- 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 either three of the topics, or aspects of each of the topics.

For a 20-credit subject, students study all six topics.

The topics selected can be sequenced and structured to suit individual cohorts of students.

Science Inquiry Skills and *Science as a Human Endeavour* must be integrated into both 10-credit and 20-credit programs.

Stage 1 Chemistry students who intend to study Chemistry at Stage 2 would benefit from a Stage 1 program that includes all six topics.

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.

Each topic is presented in the subject outline in two columns, with the science understanding in the left-hand column supported by possible strategies, contexts, and activities in the right-hand column.

The *Science Understanding* column covers the content for teaching, learning, and assessment in this subject. The possible strategies, contexts, and activities are provided as a guide only. They are neither comprehensive nor exclusive. Teachers may select from these or choose to use others.

The following symbols have been used in the right-hand column to indicate where different kinds of suggestions have been made:

 indicates a possible teaching and learning strategy

 indicates a possible activity to develop Science Inquiry Skills

 indicates a possible Science as a Human Endeavour context

An inquiry-based approach is integral to the development of the science understanding. The *Possible Strategies, Contexts, and Activities* column presents ideas and opportunities for the integration of the science inquiry skills and the understandings related to science as a human endeavour. Teachers may use some or all of these examples, or other relevant examples, to enable students to develop and extend their knowledge, skills, and understanding.

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 involve a range of individual and collaborative activities during which students develop and extend the science inquiry skills described in the table that follows.

The practical activities may take a range of forms, such as models and simulations that enable students to develop a better understanding of particular concepts. They 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 display and analyse the data they have collected, evaluate procedures, describe their limitations, 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 8–10 hours of class time would involve practical activities.

For a 20-credit subject, it is recommended that 16–20 hours of class time would involve 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 are presented in two columns, with a range of science inquiry skills in the left-hand column side by side with possible strategies, contexts, and activities in the right-hand column. The *Science Inquiry Skills* column describes teaching, learning, and assessment in this subject.

The symbols in the *Possible Strategies, Contexts, and Activities* column in the table that follows are provided as a guide to the possible approaches, resources, and/or activities that teachers may use. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

These science inquiry skills are integrated throughout the topics that are detailed in this subject outline. In each topic, the symbols in the *Possible Strategies, Contexts, and Activities* column are provided as a guide to the possible contexts that teachers may use to develop and extend student understanding of science inquiry skills. These suggestions are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
Scientific methods enable systematic investigation to obtain measureable evidence. • Design investigations, including: – an 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 procedure to be followed – the type and amount of data to be collected – identification of ethical and safety considerations.	Class activities to develop skills could include: – designing investigations without implementation – 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.	Class activities to develop skills could include: – 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 presented in a well-organised way to allow them to be interpreted. • Present results of investigations in appropriate ways, including: – use of appropriate SI units, symbols – construction of appropriately labelled tables – drawing of graphs, linear, non-linear, lines of best fit as appropriate – use of significant figures.	Class activities to develop skills could include: – 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

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
	sources to describe as quantitative, qualitative.
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 – equations to explain concepts, solve problems, and make predictions.	Class activities to develop skills could include: – 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/extrapolation where appropriate – selection and use of evidence and scientific understanding to make and justify conclusions.	Class activities to develop skills could include: – analysing data sets to identify trends and patterns – determining relationships between independent and dependent variables – using graphs from different sources, e.g. CSIRO or ABS, to predict values other than plotted points – calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. • Evaluate the procedures and results to identify sources of uncertainty, including: – random and systematic errors – replication – sample size – accuracy – precision – validity – reliability – effective control of variables. • Discuss the impact that sources of uncertainty have on experimental results. • Recognise the limitations of conclusions.	Students could evaluate procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions. www.biologyjunction.com/sample%20ap%20lab%20reports.htm
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: – appropriate language – terminology – conventions.	Class activities could include: – reviewing scientific articles or presentations to recognise conventions – developing skills in referencing and/or footnoting – distinguishing between reference lists and

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
	bibliographies – opportunities to practise scientific communication in written, oral, and multimedia formats, e.g. presenting a podcast or writing a blog.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The *Science as a Human Endeavour* strand highlights the development of science as a way of knowing and doing, and explores the use and influence of science in society.

The development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. Science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as new technologies enable different avenues of investigation. Scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice, using international conventions and activities such as peer review.

Scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. The application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. As a result, decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Through the exploration of *Science as a Human Endeavour*, students increase their understanding of the complex ways in which science interacts with society.

The understanding of *Science as a Human Endeavour* encompasses:

1. Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- International collaboration is often required in scientific investigation.

2. 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.

3. 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.

4. Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, 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.

Science as a Human Endeavour underpins the content, strategies, contexts, and activities for all topics that are detailed in this subject outline, and the understandings should be integrated and used in a 10-credit or 20-credit program, as points of reference for student learning.

The symbols in the right-hand column of each topic, under the heading *Possible Strategies, Contexts, and Activities*, are provided as a guide to the possible contexts that teachers may use to develop student understanding of science as a human endeavour. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

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 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 develop and extend their understanding of some of the most fundamental principles of chemistry: atomic structure, the periodic table, electronegativity, and the mole concept. Through practical activities, students apply their understanding of principles, concepts, and physical properties to investigate elemental spectra and their use in analysis.

1.1: Properties and uses of materials

Science Understanding	Possible Strategies, Contexts, and Activities
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 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. In colloids, particles with a diameter 1-1000 nm are suspended throughout another substance. Discuss examples of natural (e.g. milk) and synthetic (e.g. mayonnaise) colloids. Compare sizes of atoms with nanoparticles. View and discuss an animation of a nano-robot in the bloodstream www.sciencephoto.com/media/589889/view Discuss the potential risks that may be associated with the use of nanomaterials. 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. www.aerogel.org/ www.youtube.com/watch?v=WXvar-4M6VA Investigate the influence of the

Science Understanding	Possible Strategies, Contexts, and Activities
	development of new materials on the progress of technology. Examples could include how the development of: – flexible plastics, which are commonly electrical insulators, accelerated the development of the electronics industry – an efficient technique to produce steel was crucial in the construction of railroads, ships, machines, and other contributions to the Industrial Revolution – composite materials satisfied the need for tough, light-weight materials used in cars and airplanes. Explore the influence of the collaboration of Richard Smalley (USA) and Harry Kroto (UK) who collaborated to produce C60 fullerenes.
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.	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. 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 density differences of 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.

1.2: Atomic Structure

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Perform flame tests to identify elements based on characteristic emission colours. Use spectroscopes to see individual spectral lines. Investigate evidence for, and development and limitations of, different models of the atom. Investigate the discovery of the subatomic particles and the development of the Rutherford-Bohr model of the atom. 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. They subsequently discovered the elements caesium and rubidium – the presence of an unknown element in the sun was proposed after observation of a particular spectral line in the sun's emission spectrum. Helium was subsequently discovered on Earth. Explore how colours absorbed/emitted by some metals are used to give fireworks their colours.
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. Use mass spectra to determine the isotopic composition of an element. Explore uses of radioactive isotopes. Examples could include: – use in medicine and agriculture as tracers – use of the radioisotope 14C by geologists and archaeologists – use and supply of radioisotopes by South Australian Health and Medical Research Institute (SAHMRI) www.sahmri.com/media-hub/latest-news

Science Understanding	Possible Strategies, Contexts, and Activities
The relative atomic mass of an element is determined from all the isotopes of that element.	Undertake calculations of the relative atomic mass of an element from the relative isotopic masses and their abundance.
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 thirty-eight elements in the periodic table.	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. The electron configuration of monatomic ions is considered in subtopic 2.2. Fill orbitals as an exercise on an interactive periodic table to visualise patterns and anomalies.

1.3: Quantities of atoms

Science Understanding	Possible Strategies, Contexts, and Activities
The quantities of different substances can be conveniently compared using the mole unit. 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 to demonstrate the size of the Avogadro number, e.g. 1 mole of asterisks on sheets of paper (how many sheets needed?), 1 mole sheets of paper (how far would the pile extend into space?), the number of moles of heart beats in a lifetime (how long if there are 60 beats per minute?), 1 mole of dollars (how long to give away, if giving at the rate of $1 000 000 per second?). Construct a display of 1 mole of atoms of different elements. Note that the mole concept, concentrations of solutions, and stoichiometry, are developed in Stage 1 subtopics 2.3, 4.3, 5.3, and in Stage 2 subtopic 1.3. View and discuss Quirky YouTube ‘A Mole is a Unit’ at www.youtube.com/watch?v=PvT51M0ek5c
• Undertake calculations using the relationship $n = \frac{m}{M}$ and its rearrangements.	Discuss the relationship between the number of significant figures in numerical answers and the precision and resolution of the measurements.

1.4: The Periodic Table

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Arrange cards containing data on properties of unnamed elements, and some of their compounds, in patterns, and compare these patterns with 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 an interactive 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. www.rsc.org/periodic-table The Elements: A Visual Exploration (app) 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 earlier scientists to the development of the periodic table proposed by Mendeleev. Investigate how the periodic table has evolved as new evidence has become available. Conduct an internet search to explore which elements are named after scientists, and why these scientists have been honoured in this way.
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?

Topic 2: Combining Atoms

An important facet of human endeavour is the understanding that has developed over the last two hundred or so years of the constituents of matter – the atoms that are considered in Topic 1, and the forces that hold the particles 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 the structures of the materials.

2.1: Types of materials

Science Understanding	Possible Strategies, Contexts, and Activities
The type of bonding within substances explains their physical properties, including melting and boiling points, electrical conductivity, strength, and hardness.	
Changes of state are accompanied by the gain (endothermic reactions) or loss of energy (exothermic reactions). • Identify whether particular changes of state are exothermic or endothermic.	Watch and discuss a video clip of the barking dog reaction www.sciencephoto.com/media/612108/view Note that concepts of energy and energy change are developed in Stage 1 subtopics 4.4, 6.3, and in Stage 2 subtopic 4.1. Plot a graph of temperature against time as water, lauric acid, or stearic acid freezes.
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. Materials can be classified according to their structure and bonding into four types of substances. • 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.

2.2: Bonding between atoms

Science Understanding	Possible Strategies, Contexts, and Activities
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.	This material draws subtopic 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 ability/tendency to form chemical bonds. Model electron transfer and electron sharing using computer simulations. Explore the contribution of Linus Pauling to our knowledge and understanding of the nature of chemical bonds. Explore the influence of later work of Linus Pauling, 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 positive and negative impacts of the mining of a metal to a country, 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 thirty-eight elements of the periodic table. Ionic compounds are continuous and are represented by empirical formulae. 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.	Teachers may choose to introduce only the ions of elements 1 to 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 and discuss 'Ion Bingo'.
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.	Note that the term 'Lewis structure', to refer to a structural formula, is used ambiguously in texts. Discuss the implications of this.

Science Understanding	Possible Strategies, Contexts, and Activities
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.	
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.	Explore potential uses of fullerenes formed with different numbers of C atoms. Uses could include drug delivery in the body, lubricants, catalysts, and in the form of nanotubes for reinforcing materials. www.acs.org/content/dam/acsorg/education/whatischemistry/landmarks/lesson-plans/discovery-of-fullerenes.pdf Investigate why carbon fibre has replaced metal in the construction of F1 cars. formula1.about.com/od/car1/a/carbon_fiber.htm Silicon is more abundant in the Earth’s crust than carbon. Discuss reasons why our biosphere is based on carbon and not on silicon.
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.	Explore and explain the properties of graphite in ‘lead’ pencils. Investigate the occurrence, structures, physical properties and uses of the allotropes of carbon.

2.3: Quantities of molecules and ions

Science Understanding	Possible Strategies, Contexts, and Activities
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 $n=m/M$ and its rearrangements for molecules, and for ions and their compounds.	Determine the empirical formulae of compounds (oxide of tin, oxide of magnesium, oxide of copper). Teachers may choose to introduce stoichiometry (mass-mass) here.

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.

3.1: Molecule polarity

Science Understanding	Possible Strategies, Contexts, and Activities
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.	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, and 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.	This develops the concept of polarity introduced in subtopic 2.2. 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.

3.2: Interactions Between Molecules

Science Understanding	Possible Strategies, Contexts, and Activities
The physical properties of molecular substances can be explained by considering the nature and strength of the forces of attraction between the molecules. Interactions between molecules are much weaker than primary metallic, ionic, and covalent bonds. These interactions are often called ‘secondary interactions’.	Note that the ion-dipole interaction is introduced in subtopic 4.2.
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	View and discuss an animation of hydrogen bonding in water www.sciencephoto.com-/media/609850/view Explore the effect of hydrogen-bonding on the strength of interactions by

Science Understanding	Possible Strategies, Contexts, and Activities
of the molecules, and are very weak for small molecules. 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.	plotting the boiling points of the hydrides of Groups IV, V, VI and VII. Explore the influence of molecular size on the strength of dispersion forces, by comparing boiling points of the halogens and of the noble gases. 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-2-diol and propane-1,2,3-triol. Dispersion forces are often referred to as London dispersion forces. Investigate the work of Fritz London in explaining the possible origin of forces of attraction between non-polar molecules, and who was nominated, on five different occasions, for the Nobel Prize in Chemistry. Discuss how hydrogen bonding between base pairs in the DNA strands leads to the stability of the DNA double helix structure.

3.3: Hydrocarbons

Science Understanding	Possible Strategies, Contexts, and Activities
Carbon forms hydrocarbon compounds, including alkanes and alkenes, which are used as fuels and as feedstock for the chemical industry. • Write equations for the complete combustion of hydrocarbons.	Debate the claim that burning oil in a car is like burning dollar bills in a fireplace. Design an investigation to compare the sootiness of a flame of a small hydrocarbon (e.g. a Bunsen 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 in the late 19th Century. Explore the range of uses of materials derived from the mining and processing of petroleum. Investigate how the pharmaceutical industry began in the late 19th Century with the manufacture of acetylsalicylic acid (aspirin).
The physical properties of hydrocarbons depend on the size of the molecules. • Compare the melting and boiling points	Explore the influence of molecular size on the strength of secondary interactions, by plotting the boiling

Science Understanding	Possible Strategies, Contexts, and Activities
of hydrocarbons, given relevant information.	points of hydrocarbons. View and discuss interactive animations of fractional distillation, such as: www.footprints-science.co.uk/flash/Fractional%20distillation.swf www.chem-ilp.net/labTechniques/FractionalDistillationlAnimation.htm Compare the volatility, viscosity, and solubility in water and ethanol, of petrol, kerosene, and car oil.
The chemical reactions of hydrocarbons are determined by the functional groups present. • Predict the product of an addition reaction of an alkene.	Demonstrate the behaviour of cyclohexane and cyclohexene with bromine or iodine solution.
Representation of hydrocarbon molecules Hydrocarbons can be represented by empirical formulae, molecular formulae, and structural formulae. Structural formulae include extended, condensed, and skeletal representations. Hydrocarbons exist as a number of structural isomers.	Model hydrocarbons and their isomers, using molecular model kits or software. Use information on the composition of a compound and molar mass to determine the empirical and molecular formulae of hydrocarbons.
Systematic nomenclature Hydrocarbons are named systematically to provide unambiguous identification. The structural formula of a hydrocarbon can be deduced from its systematic name. • Interpret, 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.	Recognise that IUPAC nomenclature is an example of international scientific protocols.
Organic molecules have a hydrocarbon skeleton and can contain functional groups.	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.

3.4: Polymers

Science Understanding	Possible Strategies, Contexts, and Activities
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.	
Addition polymerisation occurs when monomer molecules link without the loss of atoms. Addition polymers can be synthesised from alkene monomers. • Draw and annotate 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, 3.8.
Organic polymers have diverse properties and uses. The properties of organic polymers depend on the interactions between the polymer chains.	This subtopic builds on concepts of covalent bonding introduced in Topic 2, and secondary bonding introduced in Topic 3. Properties of polymers are also discussed in Stage 2. 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. 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. Explore the development of new applications for polymers such as hydrogels and smart materials, including shape-memory polymers. Discuss the positive and negative aspects of 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 explain the properties and uses of liquids in terms of their bonding and structure. Their study concepts explored in other topics is extended to include secondary interactions and energy changes in reactions. Students apply their understanding of the mole to describing the concentrations of solutions and examining stoichiometry of precipitation reactions.

4.1: Miscibility and solutions

Science Understanding	Possible Strategies, Contexts, and Activities
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 nonpolar solvents do not readily mix. • Identify a solvent as polar or non-polar based on its miscibility with water and hydrocarbons.	Mix different liquids and examine their properties in terms of their bonding. Make a simple lava lamp and explain the effect. www.abc.net.au/science/surfingscientist/pdf/lesson_plan17.pdf Chem Matters April 1997 pp. 4–7; available online at mcchesneychemistry.weebly.com/uploads/2/2/9/3/22938812/chemmattersapr1997.pdf Explain the need to use appropriate solvents to clean paint brushes.
Highly polar molecular substances are more soluble in water than nonpolar 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.	Compare the solubilities of methane, hydrogen fluoride and ammonia in water Compare solubilities of alcohols in water and a nonpolar solvent e.g. hexane. Discuss why ethanol can be mixed with petrol (E10 fuel) but methanol will not mix with petrol.
Compounds with non-polar and polar or ionic components facilitate the mixing of polar and non-polar substances.	Use detergents and soaps to mix oil with water. 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.

4.2: Solutions of ionic substances

Science Understanding	Possible Strategies, Contexts, and Activities
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 bonding 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, including, for example: – using types of salt with different-sized crystals – discussing the effect of extraneous variables.
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.	Prepare some substances by precipitation (e.g., barium sulfate, silver chloride, copper hydroxide, copper carbonate). Undertake simple analysis using precipitation. Prepare precipitates using footy colours. Undertake problem solving activities to identify unknown solutions Discuss: – the use of precipitation in analysis – the impact of hard water on the effectiveness of soap.

4.3: Quantities in reactions

Science Understanding	Possible Strategies, Contexts, and Activities
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 Explore instances of concepts evolving with new evidence. Examples could include: – the contributions of Gay-Lussac and Avogadro – the contribution of Lavoisier in recognising that mass is conserved in chemical reactions. Discuss the claim that Lavoisier was the 'father of modern chemistry'.
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	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

Science Understanding	Possible Strategies, Contexts, and Activities
volume, c). • Undertake calculations using the relationship $\rho = m/V$ and its rearrangements. • Undertake calculations using the relationship $c = n/V$ and its rearrangements. • Undertake conversions between mass concentrations and molar concentrations.	another. Determine concentration of solution of sodium chloride by weighing the precipitate formed with silver nitrate solution.
Chemicals react in definite proportions • Undertake stoichiometric calculations for precipitation reactions.	Teachers may choose to introduce stoichiometry at some time other than when focusing molarity; mass-mass stoichiometry could be introduced in subtopic 2.2.

4.4: Energy in reactions

Science Understanding	Possible Strategies, Contexts, and Activities
All chemical reactions involve the formation of a new substance and are accompanied by the gain (endothermic reactions) or loss of energy (exothermic reactions). The energy released 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.	Perform a range of chemical reactions and classify the reactions as exothermic or endothermic. Examples could include: – mix an acid solution with a metal hydroxide – add magnesium to hydrochloric acid – dissolve ammonium chloride and sodium thiosulfate in water – light a spirit burner. Design and undertake a collaborative design practical investigation: www.rsc.org/learn-chemistry/resource/res00001165/cooking-an-egg-by-a-chemical-reaction Investigate the heat absorbed or evolved on mixing chemicals together: media.rsc.org/Classic%20Chem%20experiments/CCE-84.pdf Discuss exothermic reactions used for cooking, heating, electricity generation.
When ionic substances dissolve in water the dissociation of 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.	Investigate the chemicals used in first aid cold packs. Investigate why ammonium nitrate in cold packs has been replaced by other chemicals. Explore hand warmers: www.rsc.org/learn-chemistry/content/filerepository/CMP/00

Science Understanding	Possible Strategies, Contexts, and Activities
• Write thermochemical equations for the dissolving of ionic substances in water.	/000/871/HAND_WARMERS_Teacher.pdf ?
Enthalpy changes for solution reactions can be determined experimentally. • Explain the following relationships and undertake calculations involving their rearrangements: $q=mC\Delta T$ $\Delta H=q/n$ • Experimentally determine enthalpies of solution. • Identify a reaction as exothermic or endothermic, given a thermochemical equation or the value of its enthalpy change.	Use these calculations to discuss the appropriate number of significant figures to give in the answers. Determine enthalpy of solution (e.g. sodium thiosulfate, ammonium chloride, sodium ethanoate) Investigate whether ammonium chloride or urea is more effective in cold packs.

Topic 5: Acids and Bases

Reactions between acids and bases occur everywhere: in our 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. They extend their understanding of the properties of acids and bases. This is important for the safe handling of many materials used every day. Through investigations, students explore the reactions of acids with bases, the differing strengths of acids, and the pH of a variety of solutions. They develop their skills in making calculations and writing equations.

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

5.1: Acid – base concepts

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Conjugate acid–base pairs may be used as an introduction to reversible reactions. View and discuss Crash Course Chemistry – Acid Base Reaction in Solution www.youtube.com/watch?v=ANi709MYnWg&index=8&list=PL8dPuuaLjXtPHzzYuWy6fYEaX9mQQ8oGr 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. Explore the contribution of scientists (e.g. Davy, Liebig, Arrhenius, Brönsted, Lowry, Lewis) to the evolution of concepts of acids and bases.
Acid-base indicators are weak acids or bases where the acidic form is of a different colour from the basic form.	Complete a table of colours obtained in acidic and basic conditions for a range of common indicators or flower petal extracts. Discuss the origins of litmus and why the metaphor ‘litmus test’ has entered common, non-chemical usage.
Acids can be classified as monoprotic or polyprotic, depending on the number of protons available for donation. • Given the structural formula of an acid, determine whether it is monoprotic, diprotic, or triprotic.	Investigate examples of: – monoprotic acids: hydrochloric, nitric and ethanoic acids; bicarbonate ion – diprotic acids: ethanedioic (= oxalic; soursobs, rhubarb), carbonic, sulfuric, sulphurous, and tartaric acids – triprotic acids: phosphoric acid. Discuss the use of historic names prior to the development of systematic nomenclature, and the retention of

Science Understanding	Possible Strategies, Contexts, and Activities
	some of these non-systematic names as preferred IUPAC names. Examples could include formic acid, acetic acid, and oxalic acid.

5.2: Reactions of acids and bases

Science Understanding	Possible Strategies, Contexts, and Activities
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_2O_5. 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 when a given acid reacts with a given metal oxide, hydroxide, or carbonate. • Write full equations for reactions between a given acid and a nominated metal oxide, hydroxide, or carbonate. • Write ionic equations for reactions between an aqueous solution of an acid and a given metal oxide, hydroxide, or carbonate. • Undertake stoichiometric calculations for reactions between acids and bases.	Explore reactions of acids with metal oxides and carbonates. Explore energy changes in neutralisation reactions. Make copper sulfate crystals from copper oxide and sulfuric acid, or from copper carbonate and sulfuric acid. Use an indicator in reaction between an acid and base. 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. Undertake titrations to investigate acid content in beverages. Participate in the RACI Titration Competition or use the resources for practical investigations. Make sherbet to explore an acid-based reaction. www.csiro.au/en/Education/DIY-science/Chemistry/Sherbet Explore uses of acidic and basic chemicals in the home. Examples could include: – phosphoric acid and oxalic acid used in commercial rust-removal products – use of vinegar for rust removal. Use of baking powder in cooking antacid preparations containing metal hydroxides, carbonates, or

Science Understanding	Possible Strategies, Contexts, and Activities
	bicarbonates.
The strength of acids is explained by the degree of ionisation in aqueous solution.	Test the conductivity of aqueous solutions of ethanoic, ethanedioic, hydrochloric, nitric, sulfuric acids, and compare with the conductivities of the pure substances. Generate hydrogen chloride gas from sulphuric acid and sodium chloride, bubble the gas into water, and test for ionisation, using litmus and silver nitrate.

5.3: The pH scale

Science Understanding	Possible Strategies, Contexts, and Activities
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 alkaline, 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 can cause rain to have a pH below 5.6. • Write equations for the reactions of oxides of sulfur and nitrogen with water that lead to acid rain.	Note that because pH is a logarithmic scale, an increase in atmospheric carbon dioxide concentration has little effect on rainfall pH. Note that acid rain is not related to the greenhouse effect. Teachers may choose to introduce the relationship $[H^+] [OH^-] = 10^{-14}$ here. 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 base is added to acid. Investigate the formation of acid rain and its harmful environmental effects. 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 other major challenges facing today's world. Acid rain media.rsc.org/Misconceptions/Miscon%20acid%20strength.pdf

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 investigate production and storage of electricity using electrochemical cells, and the production of chemicals from electrolysis. Students learn to write redox half-equations and consider the stoichiometry of redox reactions.

Students explore how the development of new electrochemical cells offers means of making more effective use of renewable energy sources, such as wind and solar power, which are intermittent.

6.1: Metal reactivity

Science Understanding	Possible Strategies, Contexts, and Activities
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. • Write equations and half-equations for reactions between a metal and the ion of a less active metal.	Note that such reactions are commonly referred to as displacement reactions. Test a range of metals and metal salt solutions for reaction (e.g. copper and copper nitrate, zinc and zinc nitrate, lead and lead nitrate, silver nitrate). Use displacement reactions to form metal ‘trees’ (e.g. a copper ‘tree’ in a solution of silver nitrate). Look at the formation of silver crystals on copper wire under a digital microscope or flexcam. Consider the exothermic reaction of magnesium powder in copper sulfate solution to boil water.
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.	Construct a metal activity series from experimental data. Consider the use of magnesium and zinc in the protection of iron and steel from corrosion.
Calcium, potassium, and sodium react with water, while magnesium reacts with steam. • Write equations for the reactions of calcium, magnesium, potassium, and sodium with water or steam.	View and discuss Braniac Alkali Metals www.youtube.com/watch?v=m55kgyApYrY Add calcium, potassium, and sodium to water, note observations, and test products. 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.

Science Understanding	Possible Strategies, Contexts, and Activities
• Metals such as magnesium, zinc, and iron react with dilute acids to form hydrogen and salts of the metals. • Name the products obtained when a nominated acid reacts with a nominated active metal. • Write equations and half-equations for reactions between a given acid and a nominated active metal.	Note that such reactions are commonly referred to as displacement reactions. Test a range of metals (e.g. copper, iron, magnesium, sodium, zinc) in water, strong acid, and weak acid.

6.2: Concepts of oxidation and reduction

Science Understanding	Possible Strategies, Contexts, and Activities
A range of reactions, including reactions of metals, combustion, and electrochemical processes, can be considered as redox reactions.	Discuss how oxidation was originally described as a substance combining with oxygen. Compare this to the current understanding that other reactions are similar, for example, combining with chlorine. Demonstrate with gas jars: burning iron (steel wool), magnesium, sulfur, and phosphorus on oxygen and chlorine. View and discuss Crash Course Chemistry: Redox www.youtube.com/watch?v=lQ6FBA1HM3s&list=PL8dPuuaLjXtPHzzYuWy6fYEaX9mQQ8oGr&index=10 Investigate rusting and metal corrosion as examples of oxidation. Explore the phlogiston theory, and the impact of the work of Lavoisier in discrediting this theory.
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. • Determine the oxidation states of atoms in elements and monatomic ions, and in compounds and polyatomic ions.	Use the rules for oxidation number that result from assigning electrons in covalent bonds to the more electronegative atom. 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. Oxygen commonly exists in the -2 state in its compounds, except in peroxides (-1), and hydrogen commonly exists in the +1 state, except in metal hydrides (-1). Discuss the use of metal hydrides in batteries in hybrid vehicles.
	Discuss the similarities of combining: – magnesium and oxygen – magnesium and chlorine to extend the definition of oxidation from to losing electrons. Discuss the similarities of combining

Science Understanding	Possible Strategies, Contexts, and Activities
	sulfur or phosphorus with oxygen or chlorine to introduce oxidation number. Discuss how rules for oxidation number result from assigning electrons in covalent bonds to the more electronegative atom.
The oxidation or reduction of a chemical species can be represented by half-equations, which can be combined to write a complete reaction equation. • Write half-equations, in neutral and acidic conditions, given reactant and product species. • Combine half-equations to write a chemical equation.	Observe changes to confirm species that have reacted such as MnO_4^-, $Cr_2O_7^{2-}$, H_2O_2 and Fe^{2+}.

6.3: Electrochemistry

Science Understanding	Possible Strategies, Contexts, and Activities
Electrochemistry involves the relationship between electric current (electron flow) and chemical reactions. In an electrochemical cell, an electric current can cause chemical reactions, or chemical reactions can cause electron flow. Electrochemical cells are conveniently divided into galvanic cells, which produce electrical energy from spontaneous redox reactions, and electrolytic cells, which use electrical energy from an external source to cause a non-spontaneous chemical reaction. Galvanic and electrolytic cells involve oxidation at the anode and reduction at the cathode, movement of ions within the cell, and electron transfer from one electrode to the other through an external circuit. • Identify a cell as galvanic or electrolytic, given sufficient information.	Investigate the influence of the research (around 1800) of one or more ofNicholson, Ritter, Cruickshank, Wollaston, Tennant, Faraday.
Galvanic cells are commonly used as portable sources of electric current. They can be represented by cell diagrams and the anode and cathode reactions written as half-equations. • Identify the anode and cathode and their charges, as well as the direction of ion and electron flow, in a galvanic cell, given sufficient information. • Write electrode half-equations for a galvanic cell given sufficient information.	Construct a galvanic cell using magnesium, copper, and a lemon connected to a large ammeter/voltmeter. View and discuss Clickview: VEA Wet Cells, Dry Cells, Fuel Cells www.vea.com.au/secondary-school/wet-cells-dry-cells-fuel-cells.html View and discuss Horizon fuel cell car www.horizoneducational.com/juniorproducts/i-h2go/ Investigate the influence of the research of one or more of Daniell, Galvani, Grove, Leclanche, Mond and Langer, Volta

Science Understanding	Possible Strategies, Contexts, and Activities
	Construct galvanic cells. Construct a galvanic cell using magnesium, copper, and a lemon connected to an ammeter/voltmeter. Investigate the uses and disposal of commercial batteries, e.g. fuel cells, cells containing lithium, mercury, or silver, and their environmental, social, economic, political, and/or ethical implications.
Some galvanic cells can be recharged by using an external electrical supply to reverse the electrode reactions. • Describe the complementary nature of the charging and discharging of rechargeable galvanic cells. • Identify the anode and cathode and their charges, as well as the direction of ion and electron flow, in a galvanic cell being recharged, given sufficient information. • Write electrode half-equations for a galvanic cell being recharged, given sufficient information.	Discuss uses of common rechargeable batteries, e.g. lead-acid batteries in cars, NiCad cells. Investigate use of TESLA cells for electricity storage, and their environmental, social, economic, political, and/or ethical implications.
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.	Construct electrolytic cells, such as producing copper from copper sulfate solution. Discuss nickel plating; Hoffman voltameter. Discuss the chemistry of aluminium, copper, and zinc production, explore risks to the environment associated with these processes, and make recommendations about more sustainable practices, such as recycling.

ASSESSMENT SCOPE AND REQUIREMENTS

At Stage 1, assessment 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
- at least one science as a human endeavour investigation
- 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 at least 20%

Students complete:

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

ASSESSMENT DESIGN CRITERIA

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

- clarify for the student what he or she needs to learn
- design opportunities for the student to provide evidence of his or her learning at the highest level of achievement.

For this subject, the assessment design criteria are:

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

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.

The specific features of these criteria are described below.

The set of assessments, as a whole 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 Design of a chemistry investigation

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

IAE3 Analysis 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 Demonstration of understanding of the development of science as a human endeavour

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.

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 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 develop and extend their science inquiry skills by 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, and communicating their knowledge and understanding of concepts.

Practical investigations may be conducted individually or collaboratively, but each student should present an individual report. Students should be given the opportunity to investigate a question or hypothesis for which the outcome is uncertain.

A practical report should include:

- introduction with relevant chemistry concepts, a hypothesis and variables, or investigable question
- materials/apparatus, method/procedure outlining steps taken*
- identification and management of safety and/or ethical risks*
- results*
- analysis of results, identifying trends, and linking results to concepts
- evaluation of procedures and data, and identifying sources of uncertainty
- conclusion.

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.

*The materials/apparatus, method/procedure outlining steps to be taken, identification and management of safety and/or ethical risks, and results sections are excluded from the word count.

Suggested formats for presentation of a practical investigation report include:

- a written report
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate an aspect of chemistry with an emphasis on science as a human endeavour. This investigation focuses on at least one aspect of science as a human endeavour described on pages 13 and 14 and may draw on a context suggested in the topics being studied, or explore a new context.

Suggested consider, for example:

- how humans seek to improve their understanding and explanation of the natural world
- how the scientific method is a unique way of obtaining knowledge that allows for the analysis of scientific claims, and also allows for change in scientific theory in the light of new evidence. These changes may be due to technological advances
- the role of social, ethical and environmental factors in advancing scientific research and debate
- how scientific theories have developed historically, and hence speculate on how theory and technology may continue to advance understanding and endeavour
- links between advances in science and their impact and influence on society.

Students access information from different sources, select relevant information, analyse their findings, and develop and explain their own conclusions from the investigation.

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

- an article from a scientific journal (e.g. Cosmos)
- critiquing a blog or TED talk based on a chemical impact
- an advertisement or a film clip in which a chemical concept is misconstrued
- an expert's point of view
- a new development in the field of chemical science endeavour
- the impact of a technique and its historical development
- concern about an issue that has environmental, social, economic, or political implications
- emerging chemistry-related careers and pathways

- changes in government funding for chemistry-related purposes, e.g. for scientific research into biotechnology, conservation planning, hormone use in food production, safe disposal of nuclear waste, bio-security, water quality, greenhouse effect, energy supplies, disease control, health.

The science as a human endeavour investigation 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, but 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, but 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:

- routine, analytical, and/or interpretative
- posed in new and familiar contexts
- individual or collaborative assessments, depending on the design of the assessment.

A skills and applications task may require students to, for example: use biological terms, conventions, and notations; demonstrate understanding; apply knowledge; graph or tabulate data; analyse data; evaluate procedures; formulate conclusions; represent information diagrammatically or graphically; design an investigation to test a hypothesis or investigable question.

Skills and applications tasks should be designed to enable students to demonstrate knowledge and understanding of the key chemical concepts and learning and the science inquiry skills covered in the program. Students use appropriate chemical terms and conventions to explain links between biological concepts, and apply this knowledge to solve problems. Some of these problems could be defined in a practical, social, or environmental context.

Skills and applications tasks may include:

- modelling or representing concepts
- developing simulations
- a practical assessment such as a ‘completion practical’ with associated questions
- a graphical skills exercise
- a multimodal product
- an oral presentation
- a video or audio recording
- participation in a debate
- an extended response
- a written assignment
- a structured interview
- an excursion report
- a historical study

- multiple-choice questions in combination with other question types
- short-answer questions
- a response to text(s).

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 a student has demonstrated his or her 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	Designs a logical, coherent, and detailed chemistry investigation. Obtains records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and discusses their effects on data.	Demonstrates a deep and broad knowledge and understanding of a range of chemical concepts. Applies chemical concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of chemistry coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear chemistry investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects 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. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of chemistry mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear chemistry investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of chemical concepts. Applies chemical concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of chemistry generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a chemistry investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple 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. Identifies some aspect of science as a human endeavour. Communicates basic chemical information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a chemistry investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of chemical concepts. Attempts to apply chemical concepts in familiar contexts. Shows some recognition of science as a human endeavour. 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 (wwww.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 ACE website (www.sace.sa.gov.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).

Stage 2 Chemistry

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. use science inquiry skills to design and conduct chemistry investigations using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, and analyse the results of chemistry investigations
3. evaluate procedures and results, and analyse evidence to formulate and justify conclusions
4. demonstrate and apply knowledge and understanding of chemical concepts in new and familiar contexts
5. demonstrate understanding of 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.

Stage 2 Chemistry builds on the principles and concepts of chemistry introduced in Stage 1 Chemistry.

Science inquiry skills and science as a human endeavour are integral to student's learning in this subject and are interwoven through the science understandings, which are organised into four topics.

Using an inquiry approach to learning through observation, speculation, prediction, experimentation, analysis, evaluation, and communication, students develop and extend their science inquiry skills and reinforce their understanding of science as a human endeavour.

The science inquiry skills and the understanding of science as a human endeavour that can be developed through practical and other learning activities in each topic are described in the *Science Inquiry Skills* and *Science as a Human Endeavour* sections that follow.

Programming

Stage 2 Chemistry consists of the following topics:

- 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 with *Science Inquiry Skills* and *Science as a Human Endeavour* integrated into the science understanding.

Each topic is presented in the subject outline in two columns, with the science understanding in the left-hand column supported by possible strategies, contexts, and activities in the right-hand column.

The *Science Understanding* column covers the prescribed content for teaching, learning, and assessment in this subject. The possible strategies, contexts, and activities are provided as a guide only. They are neither comprehensive nor exclusive. Teachers may select from these or choose to use others.

The following symbols have been used in the right-hand column to indicate where different kinds of suggestions have been made:

indicates a possible teaching strategy

indicates a possible activity to develop Science Inquiry Skills

indicates a possible Science as a Human Endeavour context

An inquiry-based approach is integral to the development of the science understanding. The Possible Strategies, Contexts, and Activities column presents ideas and opportunities for the integration of the science inquiry skills and the understandings related to science as a human endeavour. Teachers may use some or all of these examples, or other relevant examples, to enable students to develop and extend their knowledge, skills, and understanding.

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 involve a range of individual and collaborative activities during which students develop and extend the science inquiry skills described in the table that follows.

The practical activities may take a range of forms, such as developing models and simulations that enable students to develop a better understanding of particular concepts. They 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 display and analyse the data they have collected, evaluate procedures, describe their limitations, 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 16–20 hours of class time would involve 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 are presented in two columns, with a range of science inquiry skills in the left-hand column side by side with possible strategies, contexts, and activities in the right-hand column. The *Science Inquiry Skills* column describes the prescribed teaching, learning, and assessment in this subject.

The symbols in the *Possible Strategies, Contexts, and Activities* column in the table that follows are provided as a guide to the possible approaches, resources, and/or activities that teachers may use. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

These science inquiry skills are integrated throughout the topics that are detailed in this subject outline. In each topic, the symbols in the *Possible Strategies, Contexts, and Activities* column are provided as a guide to the possible contexts that teachers may use to develop and extend student understanding of science inquiry skills. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
Scientific methods enable systematic investigation to obtain measureable evidence. • Design investigations, including: – 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 procedure to be followed – the type and amount of data to be collected – identification of ethical and safety considerations.	Class activities to develop skills could include: – designing investigations without implementation – 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.	Class activities to develop skills could include: – 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 presented in a well-organised way to allow them to be interpreted. • Present results of investigations in appropriate ways, including: – use of appropriate SI units, symbols – construction of appropriately labelled tables – drawing of graphs, linear, non-linear, lines of best fit as appropriate – use of significant figures.	Class activities to develop skills could include: – 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

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
	sources to describe as quantitative, qualitative.
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 – equations. to explain concepts, solve problems and make predictions.	Class activities to develop skills could include: – 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/extrapolation where appropriate – selection and use of evidence and scientific understanding to make and justify conclusions.	Class activities to develop skills could include: – analysing data sets to identify trends and patterns – determining relationships between independent and dependent variables – using graphs from different sources, e.g. CSIRO or ABS, to predict values other than plotted points – calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. • Evaluate the procedures and results to identify sources of uncertainty, including: – random and systematic errors – replication – sample size – accuracy – precision – validity – reliability – effective control of variables. • Discuss the impact that sources of uncertainty have on experimental results. • Recognise the limitations of conclusions.	Students could evaluate procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions. www.biologyjunction.com/sample%20ap%20lab%20reports.htm
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: – appropriate language – terminology – conventions.	Class activities could include: – reviewing scientific articles or presentations to recognise conventions – developing skills in referencing and/or footnoting – distinguishing between reference lists and

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
	bibliographies – opportunities to practise scientific communication in written, oral, and multimedia formats, e.g. presenting a podcast or writing a blog.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The *Science as a Human Endeavour* strand highlights the development of science as a way of knowing and doing, and explores the use and influence of science in society.

The development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. Science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as new technologies enable different avenues of investigation. Scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice, using international conventions and activities such as peer review.

Scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. The application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. As a result, decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Through the exploration of *Science as a Human Endeavour*, students increase their understanding of the complex ways in which science interacts with society.

The understanding of *Science as a Human Endeavour* encompasses:

1. Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- International collaboration is often required in scientific investigation.

2. 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.

3. 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.

4. Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, 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.

Science as a Human Endeavour underpins the content, strategies, contexts, and activities for all topics that are detailed in this subject outline and the understandings should be integrated and used as points of reference for student learning.

The  symbols in the right-hand column of each topic, under the heading *Possible Strategies, Contexts, and Activities*, are provided as a guide to the possible contexts that teachers may use to develop student understanding of science as a human endeavour. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

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.

In this topic, students undertake practical analytical activities, including volumetric analysis, developing manipulative skills, and examining the 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.

1.1 Global Warming and Climate Change

Science Understanding	Possible Strategies, Contexts, and Activities
Some gases in the atmosphere, called ‘greenhouse gases’, serve to maintain the temperature of the Earth’s atmosphere. 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 increase in greenhouse gases disrupt the thermal balance of the atmosphere. • Explain the warming associated with global climate change and its consequences for the environment.	Plot trends in global concentration of carbon dioxide, sea surface temperature, or surface air temperature. Discuss these trends in relation to the biennial BOM Report: State of the Climate (Bureau of Meteorology). Explore sections of the documentary, An Inconvenient Truth, along with the accompanying interactive app, Our Choice. Discuss the impact of thawing permafrost using the article: Permafrost melt and thaw – releases large quantities of trapped methane. The Keeling Curve has plotted ongoing carbon dioxide levels in the Earth’s atmosphere since 1958. View and discuss the trends established from an image of the curve. Protocols and agreements, such as the United Nations Kyoto Protocol (1997) and the establishment of the Intergovernmental Panel on Climate Change (1988), have aimed to secure global commitment to targets for a significant, progressive reduction in greenhouse gas emissions. Research the contributions of one or more nations

Science Understanding	Possible Strategies, Contexts, and Activities
	and/or regions to meeting and extending these targets, and evaluate their effectiveness.
The oceans contribute to the maintenance of steady concentrations of atmospheric carbon dioxide. 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. Increased ocean acidity impacts directly on ocean calcifying organisms. Structures made of calcium carbonate are vulnerable to dissolution at low pH. • Write equations for carbonates reacting in acidic conditions.	Demonstrate the addition of universal indicator to dry ice in a large measuring cylinder containing water. Observe the range of colours associated with the changes in pH. Undertake practical investigations to establish the reactions of carbonates with various acids, and discuss their effects.
The concentrations of hydrogen ions and hydroxide ions in aqueous solution are mathematically related: $[H^+] [OH^-] = 10^{-14}$ • Given information about the concentration of H+ or OH-, calculate the pH of solutions of strong bases and strong monoprotic acids, and vice versa.	

1.2 Photochemical Smog

Science Understanding	Possible Strategies, Contexts, and Activities
Nitrogen oxides are formed in high-temperature engines and furnaces. • Write equations for the formation of nitrogen oxides NO and NO_2.	Compare live readings from around the globe, using apps and software for the monitoring of air pollution. Investigate factors contributing to one or more of the readings. Explore sources discussing air quality. These could include: – Poor air quality is of increasing concern in large cities around the world. – Nanoparticles can be used in catalytic converters to reduce demands on precious metals.
Nitrogen oxides lead to the formation ozone in the troposphere. Nitrogen oxides and ozone in the troposphere are pollutants 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.	Discuss how ozone is a pollutant in the troposphere but is beneficial in the stratosphere, absorbing solar ultraviolet radiation.

Science Understanding	Possible Strategies, Contexts, and Activities
It is possible to reduce the quantities of nitrogen oxides generated by motor vehicles. • Describe and write equations showing how catalytic converters can reduce the quantities of nitrogen oxides generated by motor vehicles.	Discuss opportunities for wider application of innovations using catalytic converters.

1.3 Volumetric Analysis

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Introduce apparatus and discuss techniques, using sites such as Interactive Lab Primer. Participate in the RACI Titration Competition or use the resources for practical investigations. Undertake titrations to investigate: acid content in beverages, calcium and magnesium concentration, waste vegetable oil in biodiesel production, dissolved oxygen in water. Use indirect titration in ozone detection and other examples of air pollution analysis. Analyse the data obtained in titrations in terms of precision and accuracy. Explore the use of back and indirect titrations in atmospheric and waste water analyses.

1.4 Chromatography

Science Understanding	Possible Strategies, Contexts, and Activities
Chromatography techniques, including thin layer (TLC), gas (GC), high-performance liquid (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.	Explain the principles of separation through the rate of movement of components, using Interactive Lab Primer for TLC and Column chromatography. Undertake investigations using TLC. These could include: – extraction and confirmation of caffeine from energy drinks – separation of individual indicators from universal indicator – identification of analgesics using R_f. Use column chromatography to separate the pigment in chlorophyll from spinach leaves. Simulate HPLC for the separation of fluorescein in glow sticks, using column chromatography. Research the contribution of Mikhail Tsvet to the development of chromatographic techniques for the separation of pigments in chlorophyll from plants. Explore applications of chromatography. Examples could include: – forensic analysis – drug analysis in sports – blood alcohol analysis – industrial espionage – analysis of residual insecticides and pesticides in the environment.
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.	
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 Topic 2.2, and the further applications of equilibrium principles explored through water treatment and soils in Topic 4. Note that Ion exchange is developed in subtopics 4.2, 4.4.

1.5 Atomic Spectroscopy

Science Understanding	Possible Strategies, Contexts, and Activities
Flame tests and atomic absorption spectroscopy are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels. 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 the effect of the absorption or emission of radiation on the energy levels of electrons in atoms or ions. • Explain why wavelengths of radiation emitted and absorbed by an element are unique to that element.	Discuss everyday examples of atomic emission such as: fireworks, sodium vapour streetlamps, or cooking with salted water over a flame. Consider connections to atomic theory established in Stage 1 subtopic 1.2. View VEA Chemical Analysis 1 and discuss the principles of atomic absorption described in the video. Perform flame tests and use spectroscopes to identify elements based on characteristic emission colours and spectra.
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.	Research the contribution of Sir Alan Walsh to the development of Atomic Absorption Spectroscopy while working at the CSIRO, and the use of AAS in industrial and environmental analyses. Explore applications of AAS. These could include: – analysis of arsenic in treated pine – water analysis for metal (or arsenic) content – percentage of metals in ore 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 production can be performed most efficiently. They explore aspects of green chemistry relating to efficient 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.

2.1: Rates of Reactions

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Investigate the change in mass of the system over time when marble chips are added to hydrochloric acid, and tabulate and graph the results.
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.	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. These provide opportunities for students to: – collect and tabulate data – draw appropriate graphs – analyse data – evaluate procedures and results. Discuss the action of enzymes in living cells. Explore: – the use of nanoparticles as catalysts – the role of chemists in the development of new catalysts for use in new and more sustainable processes.
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.	

2.2: Equilibrium and Yield

Science Understanding	Possible Strategies, Contexts, and Activities
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/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.	Introduce the concepts of reversible reactions and dynamic equilibrium, using the ionisation of weak acids and bases (see subtopic 5.2). View and discuss high speed clip of effect of pressure change on NO_2/N_2O_4 equilibrium: www.sciencephoto.com/media/627886/view View high speed clip of effect of concentration changes on equilibrium between Co^{2+} complexes in solution. www.sciencephoto.com/media/600219/view Use colour comparison to study the effect of changes in concentration on the equilibrium concentration of $Fe(SCN)^{2+}$ in solution. Simulate the effect of changes in concentration and temperature on $Fe(SCN)^{2+}$ www.mhhe.com/physsci/chemistry/essentialchemistry/flash/lechv17.swf Apply the principles of equilibrium in relevant contexts. Contexts could include: – use of chorine and hypochlorites in water treatment – the effect of pH on the equilibria established between the chlorine species and water (see subtopic 4.2) – exchange of O_2 in the blood – the cause and treatment of CO poisoning – maintenance of acidity levels in the blood – CO_2 equilibrium in effervescent soft drinks – equilibria between various forms of SO_2 in wine, and the effect of wine acidity on the equilibria – the contribution of oceans in maintaining steady concentrations of CO_2 in the atmosphere (see subtopic 1.1) the equilibrium between CO_3^{2-} and HCO_3^- in oceans, the disturbance of this equilibrium by increasing the concentration of atmospheric CO_2, and subsequent impacts on the marine environment (see subtopic 1.1). – ion exchange, e.g. use of zeolites

Science Understanding	Possible Strategies, Contexts, and Activities
	in water treatment (see subtopic 4.2), availability to plants of nutrients in soil (see subtopic 4.3), retention of toxic cations in soils, effect of soil acidity and salinity on soil fertility (see subtopic 4.3).

2.3: Optimising Production

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Illustrate the use of flow charts and of compromises involved in the selection of reaction conditions, using several industrial processes. Examples include: – the Haber-Bosch process for the production of ammonia – the Ostwald process for the production of nitric acid – the Contact process for the production of sulfuric acid. One of the principles of green chemistry is that the energy requirements of chemical processes should be minimised. 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 role that chemists could play in the development of low energy methods to produce the nitrogen and phosphorus fertilisers essential to the production of food for a growing world population. Explore: – the sites and methods of production of sulfuric acid in Australia – the production and uses of sulfuric acid in the Asian region.

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. They extend 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.

3.1: Introduction

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Note that this continues the work on organic chemistry introduced in Stage 1 subtopic 3.3. Students consider the systematic nomenclature of the classes of organic compounds listed below, in the relevant subtopics: – alcohols – aldehydes and ketones – carboxylic acids – primary amines – esters.
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 of secondary interactions introduced in Stage 1 subtopic 3.2. Relate the physical properties of compounds to their uses and/or environmental impacts. 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 waters – 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

Science Understanding	Possible Strategies, Contexts, and Activities
	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) – 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).

3.2: Alcohols

Science Understanding	Possible Strategies, Contexts, and Activities
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 dichromate oxidation of a primary or secondary alcohol, given its structural formula.	Test a range of primary, secondary, and tertiary alcohols with acidified $K_2Cr_2O_7$ solution. Consider advantages and disadvantages of using ethanol to replace fossil fuels. (The production and use of ethanol as a fuel is considered in subtopic 4.1.)

3.3: Aldehydes and Ketones

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Consider aldehydes in relevant contexts. Examples could include: – oxyen 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.
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.	Prepare an aldehyde (e.g. propanal) from the appropriate primary alcohol, implementing the necessary reaction conditions. Test the product with Tollens' reagent.

3.4: Carbohydrates

Science Understanding	Possible Strategies, Contexts, and Activities
Carbohydrates are naturally occurring sugars and their polymers. They are defined as either polyhydroxy aldehydes or polyhydroxy ketones, or substances that give these compounds on hydrolysis. • Given its structural formula, determine whether or not a molecule is a carbohydrate.	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).
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	

Science Understanding	Possible Strategies, Contexts, and Activities
structural formula of the monomer, given the structural formula of a section of a polysaccharide. In aqueous solution there is an equilibrium between a ring and a chain form of glucose. • Explain the ability of glucose to react as an aldehyde when in chain form but not when in ring form.	Perform Tollens' test on a solution of glucose and discuss the results in terms of the principles of equilibrium.

3.5: Carboxylic Acids

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Relate the oxidation of ethanol, to form ethanoic acid, to the odour of vinegar in wines exposed to air.
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.	Titrate commercial vinegars to determine the concentration of ethanoic acid in the solution. 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. Explore contemporary applications of the reactions of carboxylic acids. Examples could include how: – vinegar, a dilute solution of ethanoic acid, is used in household cleaning products designed to remove insoluble carbonates on plumbing fixtures, and as a preservative in the food industry – drugs with carboxyl groups are often taken in the form of their salts, e.g. soluble aspirin. In some drugs the carboxylate forms ionic interactions with binding sites.

3.6: Amines

Science Understanding	Possible Strategies, Contexts, and Activities
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.	View and discuss brief information about amines and their salts in drugs at courses.chem.indiana.edu/c102/documents/Amines-basicityandsalts-notes.pdf Explore the role of amines in the function of the nervous system. Explore the occurrence of amines in hormones, anaesthetics, and addictive drugs.
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.	Consider the use of amines, in the form of their salts, in drugs, e.g. lignocaine.

3.7: Esters

Science Understanding	Possible Strategies, Contexts, and Activities
Condensation reactions occur when two molecules combine to form a larger molecule, also releasing another small molecule, such as water. 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 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.	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 Na2CO3 followed by sublimation of the caffeine. One method can be found at: www.open.edu/openlearn/science-maths-technology/science/chemistry/diy-taking-the-caffeine-out-tea Discuss why, on its introduction, terylene was regarded as a miracle fibre.
Condensation reactions are slow at 25°C. • Explain the use of heating under reflux, and the use of a trace of sulfuric acid in the laboratory preparation of esters.	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.
Esters may be hydrolysed under acidic or alkaline conditions. • Identify the products of acidic or	Consider why old perfume bottles frequently have an unpleasant odour.

Science Understanding	Possible Strategies, Contexts, and Activities
alkaline hydrolysis of an ester or polyester, given the appropriate structural formula.	

3.8: Amides

Science Understanding	Possible Strategies, Contexts, and Activities
Carboxylic acids undergo condensation reactions with amines to form amides. • Draw the structural formula of the amide that could be produced by the condensation reaction between a carboxylic acid and 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.	Investigate the life of Wallace Carothers and his contribution to the development of the first synthetic fibres. Explore reasons for the nylon shortage, and subsequent ‘nylon riots’, in the United States in the period 1940–1946.
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.	Discuss the behaviour of Kevlar in persistent warm and humid conditions.

3.9: Triglycerides

Science Understanding	Possible Strategies, Contexts, and Activities
Edible oils and fats are esters of propane-1,2,3-triol (glycerol) and various carboxylic acids.	Note that the carboxylic acid components of triglycerides are unbranched and usually contain an even number of carbon atoms between twelve and twenty.
Edible oils are liquids at 25°C and are commonly obtained from plants and fish. Edible fats are solids at 25°C and are commonly obtained from land animals. • Identify the most likely biological source of a triglyceride, given its state at 25°C.	
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.	Use bromine solution to test a range of saturated and unsaturated triglycerides.
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.	Discuss methods of production of margarine.

Science Understanding	Possible Strategies, Contexts, and Activities
Alkaline hydrolysis of triglycerides produces carboxylate ions, which have both hydrophilic and hydrophobic regions. • Explain how such particles form micelles in solutions. • Explain how micelles can dissolve and move non-polar substances through an aqueous medium or vice versa.	Note that the nature and use of amphiphilic particles extends concepts introduced in Stage 1 subtopic 4.1. Consider why hydrolysis of triglycerides (e.g. in butter) over time can lead to unpleasant odours. Consider contemporary uses of amphiphilic particles. Examples could include how: – soap anions remove grease from surfaces – emulsifiers stabilise salad dressings, ice creams, cosmetics, and paints – nano-sized micelles of biocompatible polymers can be used to encapsulate, protect, and deliver hydrophobic drugs in the body.

3.10: Proteins

Science Understanding	Possible Strategies, Contexts, and Activities
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.	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. Discuss why certain amino acids are referred to as 'essential' amino acids.
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.	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. Explore the achievement of Frederick Sanger in the determination of the amino acid sequence in insulin, and his contribution to the development of ideas of how DNA codes for proteins.
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.	Note that this revisits concepts of secondary interactions (Stage 1 sub topics 3.2, 4.2) and the effect of pH on carboxyl and amino groups (Stage 2 subtopic 3.5, 3.6).

Science Understanding	Possible Strategies, Contexts, and Activities
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.	Discuss the importance of enzymes in the maintenance and regulation of life processes.

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.

4.1: Energy

Science Understanding	Possible Strategies, Contexts, and Activities
Carbon-based fuels, important as energy sources, have been created using energy from the Sun.	
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.	
Fossil fuels (coal, petroleum, and natural gas) have been formed by anaerobic decomposition of dead organisms. They are formed over geological time scales and are considered to be non-renewable because they are not readily replenished; reserves are being depleted more quickly than new ones are formed.	
Greater use of fuels has been a major factor in technological advances of recent centuries. • Identify common fuels, including coal, oil, ethanol, and nuclear fuels.	Discuss historical changes in the sources of energy used by humans, and how they may inform the development of future innovations.
Renewable energy is generated from sources over time scales of years to decades, that are replenished much more quickly than fossil fuels. • Identify coal, petroleum and natural gas as fossil fuels. • Identify bioethanol, biodiesel, sunlight, and wind as renewable energy sources. • Explain how fossil fuels contribute more	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

Science Understanding	Possible Strategies, Contexts, and Activities
than renewable energy sources to global warming.	materials should be used for chemical processes.
Biofuels are produced by present-day biological processes. • Identify bioethanol and biodiesel as biofuels. • Describe the production, from biological materials, of ethanol and biodiesel, including the writing of chemical equations for the reactions involved. • Explain how fossil fuels contribute more than biofuels to global warming.	Carry out fermentation and fractional distillation processes. Research biodiesel and prepare a sample Investigate the growing of algae as a source of biofuels such as ethanol, butanol, methane, and hydrogen. Explore the possibility of development of microbes that are able to generate hydrogen from waste.
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-hydrogen based fuels in two or more different locations, e.g. urban and rural, different countries.
Carbon dioxide and water are produced by the complete combustion of fuels containing carbon and hydrogen. • Write balanced 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.	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 high speed clip 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. • Write thermochemical equations for combustion. • Undertake thermochemical calculations involving enthalpy changes and temperature changes of a specified mass of water given the necessary data.	Note that this extends the work on enthalpy introduced in Stage 1 subtopic 4.4. 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.
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	Debate the advantages and disadvantages of various types of fuel.

Science Understanding	Possible Strategies, Contexts, and Activities
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. • State the advantages and disadvantages of direct electricity generation (photovoltaic and fuel cells) compared to using steam turbines.	Note that chlorophyll, which is essential for photosynthesis in green plants, absorbs light and releases electrons, similar to a photovoltaic cell. science.opposingviews.com/similarities-solar-cell-photosynthesis-3733.html Discuss the benefits of developing more effective materials for photovoltaic cells.
Fuel cells, including flow cells, are galvanic cells in which the electrode reactants are available in continuous supply. Flow cells have the advantage over other fuel cells of being rechargeable. • 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.	Note that this extends the work on galvanic cells introduced in Stage 1 subtopic 6.3. View and discuss a video clip on hydrogen fuel cells: www.youtube.com/watch?v=08ZH7vwzzEg Discuss the use of fuel cells to generate electricity, with using fuels such as hydrogen produced by intermittent renewable energy sources, such as wind and solar energy.

4.2: Water

Science Understanding	Possible Strategies, Contexts, and Activities
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, 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.	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. Extract copper ions from solution using ion exchange resins. Investigate coagulation and flocculation using alum and polyDADMAC. Visit the website LifeStraw, which reports on water filters for Majority World countries. Visit the website Adelaide Desalination Plant (SA Water). Visit a water treatment plant, such as the plant at Mount Pleasant, which

Science Understanding	Possible Strategies, Contexts, and Activities
• 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, water, and hydrochloric acid and hypochlorous acid.	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. dish washers, coffee machines – reverse osmosis units utilised in, for example, school laboratories and cafés to control concentrations of dissolved salts.

4.3: Soil

Science Understanding	Possible Strategies, Contexts, and Activities
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.	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.
Excess nitrogen and phosphorus can be leached from soils and can cause eutrophication in water bodies. • Explain the process and consequences of eutrophication.	
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.	Revise the writing of formulae of silicates and aluminosilicates. This revisits ionic formulae that were introduced in Stage 1 subtopic 2.2.
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	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

Science Understanding	Possible Strategies, Contexts, and Activities
soil silicates and aluminosilicates become available to plants.	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.
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.	Consider the origin and impacts of sodic soils. www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/127278/Sodic-soil-management.pdf

4.4: Materials

Science Understanding	Possible Strategies, Contexts, and Activities
Polymers Polymers are produced from monomers by addition or condensation reactions. • Identify a polymer as being the product of an addition polymerisation or a condensation polymerisation, given its structural formula. • Identify whether a molecule could undergo polymerisation, given its structural formula and, if so, the type of polymerisation.	Investigate the use of polymers in: – medical science, e.g. prostheses – 3D printing – 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.	Note that this extends the work on polymers introduced in Stage 2 subtopics 3.7, 3.8, and Stage 1 subtopic 3.3.
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.	Discuss the principle of green chemistry that, where practicable, renewable raw materials should be used for chemical processes.
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.	Discuss examples of physical properties that are affected by cross-linking and secondary interactions include rigidity, strength, and elasticity
Polymers can be classified as thermoplastic or	

Science Understanding	Possible Strategies, Contexts, and Activities
thermoset. • Compare the effects of heating on thermoplastic and thermoset polymers.	
Some polymers are biodegradable — being able to be broken down by micro-organisms and other living things. • Explain why some polymers are biodegradable but others are not. • Explain the advantages of polymers being biodegradable.	Discuss the principle of green chemistry, that chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
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 metals from their ores involves a number of stages that differ in their energy requirements. The method used in the reduction stage in the production of a metal is related to the reactivity of the metal and the availability of energy. 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.	Note that this material draws on concepts of redox, metal reactivity, and electrolysis introduced in Stage 1 Topic 6. Consider the context of the mining and extraction of a particular metal from its ore. For example, examine aspects of the production of zinc from its ore, such as: – use of froth flotation (an example of surfactant action) to concentrate ores of several metals, including zinc – reference to H_2SO_4 as a by-product and its recycling in the process – use of differences in metal reactivity to remove contaminant metals from the electrolysis solution – the possibility of using electrolysis or heat and carbon for reduction, depending on the availability of energy. Explore the electrowinning of Cu that allows recovery of Au and Ag in the ore. Consider potential methods of extracting metals from their ores that limit the environmental impact of traditional mining. Examples could include: – phytomining – plants are grown that absorb and concentrate the metal (e.g. Cu is absorbed by brassicas) and the metal is extracted from the ash after burning the plants – bioleaching – fungi or bacteria are used to extract metal from the ore. For example, bacteria can be used to convert pyrite (FeS_2), into soluble products ($FeSO_4$, H_2SO_4).
Recycling There is a finite amount of materials on Earth. Materials that can be recycled reduce the	Investigate the energy requirements for recycling aluminium cans and for creating cans from bauxite.

Science Understanding	Possible Strategies, Contexts, and Activities
amount of new materials that need to be produced from the Earth’s crust. • Explain the advantages of recycling materials.	 Explore the role of chemists in developing: – 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, platinum from catalytic converters – processes to use materials more effectively – processes to efficiently and economically extract elements available in low concentration, such as lithium from sea water.
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. • Give examples of composite materials and explain their advantages. • Explain the difficulties associated with recycling materials and objects comprising two or more different materials with different properties.	 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.

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, and 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.

It is anticipated that from 2018 all school assessments will be submitted electronically.

ASSESSMENT DESIGN CRITERIA

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

- teachers to clarify for the student what he or she needs to learn
- teachers and assessors to design opportunities for the student to provide evidence of his or her 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 in the list below.

The set of assessments, as a whole, 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 Design of a safe chemistry investigation

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

IAE3 Analysis 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 Demonstration of understanding of science as human endeavour

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. 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 develop and extend their science inquiry skills by formulating investigable questions and hypotheses, selecting, trialling, 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, and communicating their knowledge and understanding of concepts.

Practical investigations may be conducted individually or collaboratively, but each student should present an individual report. Students should be given the opportunity to investigate a question or hypothesis for which the outcome is uncertain.

A practical report should include:

- introduction with relevant chemistry concepts, a hypothesis and variables, or investigable question
- materials/apparatus, method/procedure outlining and trials and steps taken*
- identification and management of safety and/or ethical risks*
- results*
- analysis of results, identifying trends, and linking results to concepts
- evaluation of procedures and data, and identifying sources of uncertainty
- conclusion.

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.

*The materials/apparatus, method/procedure outlining trials and steps to be taken, identification and management of safety and/or ethical risks, and results sections are excluded from the word count.

At least one practical investigation must give each student the opportunity to design the method.

Suggested formats for presentation of a practical investigation report include:

- a written report
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate an aspect of chemistry with an emphasis on science as a human endeavour. The investigation focuses on at least one aspect of science as a human endeavour described on pages 51 and 52 and may draw on a context suggested in the topics being studied or explore a new context.

Students consider, for example:

- how humans seek to improve their understanding and explanation of the natural world
- how working scientifically is a way of obtaining knowledge that allows for the analysis of scientific claims, and also allows change in scientific theory in the light of new evidence. These changes may be due to technological advances.
- the role of social, ethical, and environmental factors in advancing scientific research and debate
- how scientific theories have developed historically, and hence speculate on how theory and technology may continue to advance understanding and endeavour
- links between advances in science and their impact on society.

Students access information from different sources, select relevant information, analyse their findings, and develop and explain their own conclusions from the investigation.

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

- an article from a scientific journal (e.g. Cosmos)
- critiquing a blog or TED talk based on a chemical impact
- an advertisement or a film clip in which a chemical concept is misconstrued
- an expert's point of view
- a new development in the field of chemistry endeavour
- the impact of a technique and its historical development
- concern about issue that has environmental, social, economic, or political implications
- emerging chemistry-related careers and pathways
- changes in government funding for chemistry-related purposes, e.g. 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.

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

- an introduction to identify the focus of the investigation and how it links to science as a human endeavour
- relevant chemistry concepts or background
- an explanation of the impact or significance of the focus of the investigation, e.g. potential of new development, effect on quality of life, environmental implications, economic impact, intrinsic interest
- a conclusion with justification
- citations and referencing.

The communication 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 communication could take the form of, for example:

- an article for a scientific journal
- a letter to the editor
- a report.

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%)

Skills and applications tasks require students to use their knowledge and understanding of relevant chemical ideas, facts, and relationships in a range of tasks that may be:

- routine, analytical, and/or interpretative
- posed in new and familiar contexts
- individual or collaborative assessments, depending on the design of the assessment.

Students undertake at least three skills and applications tasks. Students may undertake more than three skills and applications tasks within the maximum number of tasks allowed in the school assessment component, but at least two 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.

A skills and applications task may require student to, for example: use chemical terms, conventions, and notations; demonstrate understanding; apply knowledge; graph or tabulate data; analyse data; evaluate procedures; formulate conclusions; represent information diagrammatically; design an investigation to test a hypothesis.

Skills and applications tasks should be designed to enable students to demonstrate knowledge and understanding of the key chemical concepts and learning covered in the program, and to apply this knowledge to solve problems. Some of these problems could be defined in a practical, social, or environmental context. Tasks should also enable students to demonstrate science inquiry skills. Students use appropriate chemical terms and conventions to explain links between chemical concepts and demonstrate an understanding of science as a human endeavour.

Skills and applications tasks may include:

- modelling or simulation
- a data interpretation exercise
- a multimodal product
- a practical assessment such as a ‘completion practical’ with associated questions
- an oral presentation
- an extended response
- a written assignment
- multiple-choice questions in combination with other question types
- short-answer questions.

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 one 2½ hour examination.

Questions of different types cover all topics and the science inquiry skills. Some questions may require students to integrate their knowledge from more than one topic and show an understanding of science as a human endeavour as described on pages 51 and 52.

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

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 and assessors refer to in deciding how well a student has demonstrated his or her 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 leaning 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	Designs a logical, coherent, and detailed chemistry investigation. Obtains records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and discusses their effects on data.	Demonstrates a deep and broad knowledge and understanding of a range of chemical concepts. Applies chemical concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of chemistry coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear chemistry investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects 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. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of chemistry mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear chemistry investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of chemical concepts. Applies chemical concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of chemistry generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a chemistry investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple 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. Identifies some aspect of science as a human endeavour. Communicates basic chemical information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a chemistry investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of chemical concepts. Attempts to apply chemical concepts in familiar contexts. Shows some recognition of science as a human endeavour. 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 both the school assessment and the external 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 2 are available on the SACE website (www.sace.sa.gov.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.

REFERENCE LIST

See 1.2.4 *Chemical Biology in EuCheMS Chemistry for a Changing World*

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).