Chemistry 2019 v1.4

General Senior Syllabus

This syllabus is for implementation with Year 11 students in 2019.

Queensland Government
Queensland Curriculum & Assessment Authority

220802

For all Queensland schools

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1 Course overview

1.1 Introduction

1.1.1 Rationale

At the core of all science endeavour is the inquiry into the nature of the universe. Science uses a systematic way of thinking, involving creative and critical reasoning, in order to acquire better and more reliable knowledge. Scientists recognise that knowledge is not fixed, but is fallible and open to challenge. As such, scientific endeavour is never conducted in isolation, but builds on and challenges an existing body of knowledge in the pursuit of more reliable knowledge. This collaborative process, whereby new knowledge is gained, is essential to the cooperative advancement of science, technology, health and society in the 21st century.

Tertiary study in any field will be aided by the transferable skills developed in this senior Science subject. It is expected that an appreciation of, and respect for, evidence-based conclusions and the processes required to gather, scrutinise and use evidence, will be carried forward into all aspects of life beyond the classroom.

The purpose of senior Science subjects in Queensland is to introduce students to a scientific discipline. Students will be required to learn and apply aspects of the knowledge and skills of the discipline (thinking, experimentation, problem-solving and research skills), understand how it works and how it may impact society.

Upon completion of the course, students will have an appreciation for a body of scientific knowledge and the process that is undertaken to acquire this knowledge. They will be able to distinguish between claims and evidence, opinion and fact, and conjecture and conclusions.

In each of the senior Science subjects, students will develop:

- a deep understanding of a core body of discipline knowledge
- aspects of the skills used by scientists to develop new knowledge, as well as the opportunity to refine these skills through practical activities
- the ability to coordinate their understanding of the knowledge and skills associated with the discipline to refine experiments, verify known scientific relationships, explain phenomena with justification and evaluate claims by finding evidence to support or refute the claims.

Chemistry is the study of materials and their properties and structure. In Unit 1, students study atomic theory, chemical bonding, and the structure and properties of elements and compounds. In Unit 2, students explore intermolecular forces, gases, aqueous solutions, acidity and rates of reaction. In Unit 3, students study equilibrium processes and redox reactions. In Unit 4, students explore organic chemistry, synthesis and design to examine the characteristic chemical properties and chemical reactions displayed by different classes of organic compounds.

Chemistry aims to develop students':

- interest in and appreciation of chemistry and its usefulness in helping to explain phenomena and solve problems encountered in their ever-changing world
- understanding of the theories and models used to describe, explain and make predictions about chemical systems, structures and properties
- understanding of the factors that affect chemical systems and how chemical systems can be controlled to produce desired products

- appreciation of chemistry as an experimental science that has developed through independent and collaborative research, and that has significant impacts on society and implications for decision-making
- expertise in conducting a range of scientific investigations, including the collection and analysis of qualitative and quantitative data, and the interpretation of evidence
- ability to critically evaluate and debate scientific arguments and claims in order to solve problems and generate informed, responsible and ethical conclusions
- ability to communicate chemical understanding and findings to a range of audiences, including through the use of appropriate representations, language and nomenclature.

Assumed knowledge, prior learning or experience

The Australian Curriculum: Science P–10 is assumed knowledge for this syllabus.

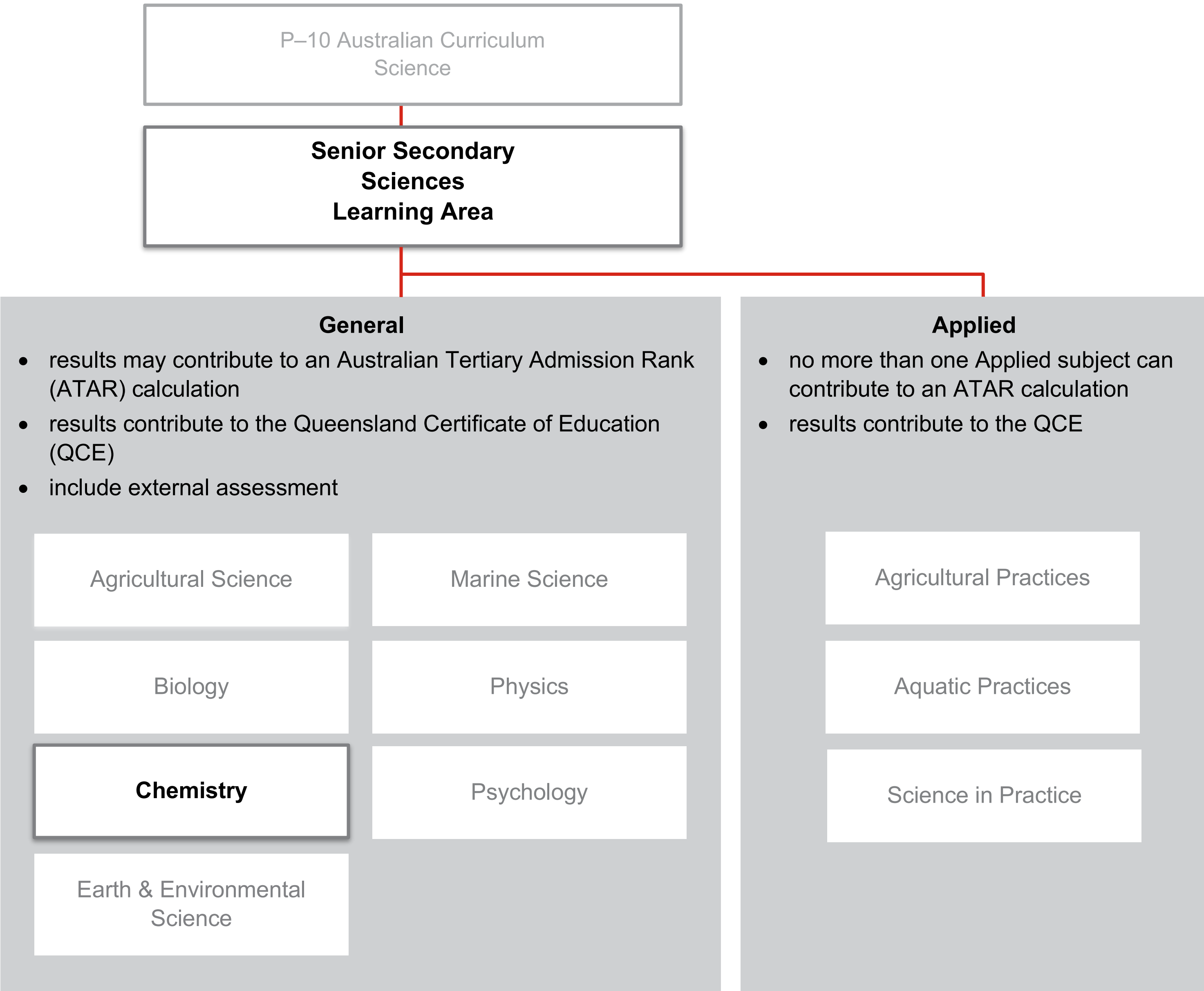
Pathways

Chemistry is a General subject suited to students who are interested in pathways beyond school that lead to tertiary studies, vocational education or work. A course of study in Chemistry can establish a basis for further education and employment in the fields of forensic science, environmental science, engineering, medicine, pharmacy and sports science.

1.1.2 Learning area structure

All learning areas build on the P–10 Australian Curriculum.

Figure 1: Learning area structure



1.1.3 Course structure

Chemistry is a course of study consisting of four units. Subject matter, learning experiences and assessment increase in complexity from Units 1 and 2 to Units 3 and 4 as students develop greater independence as learners.

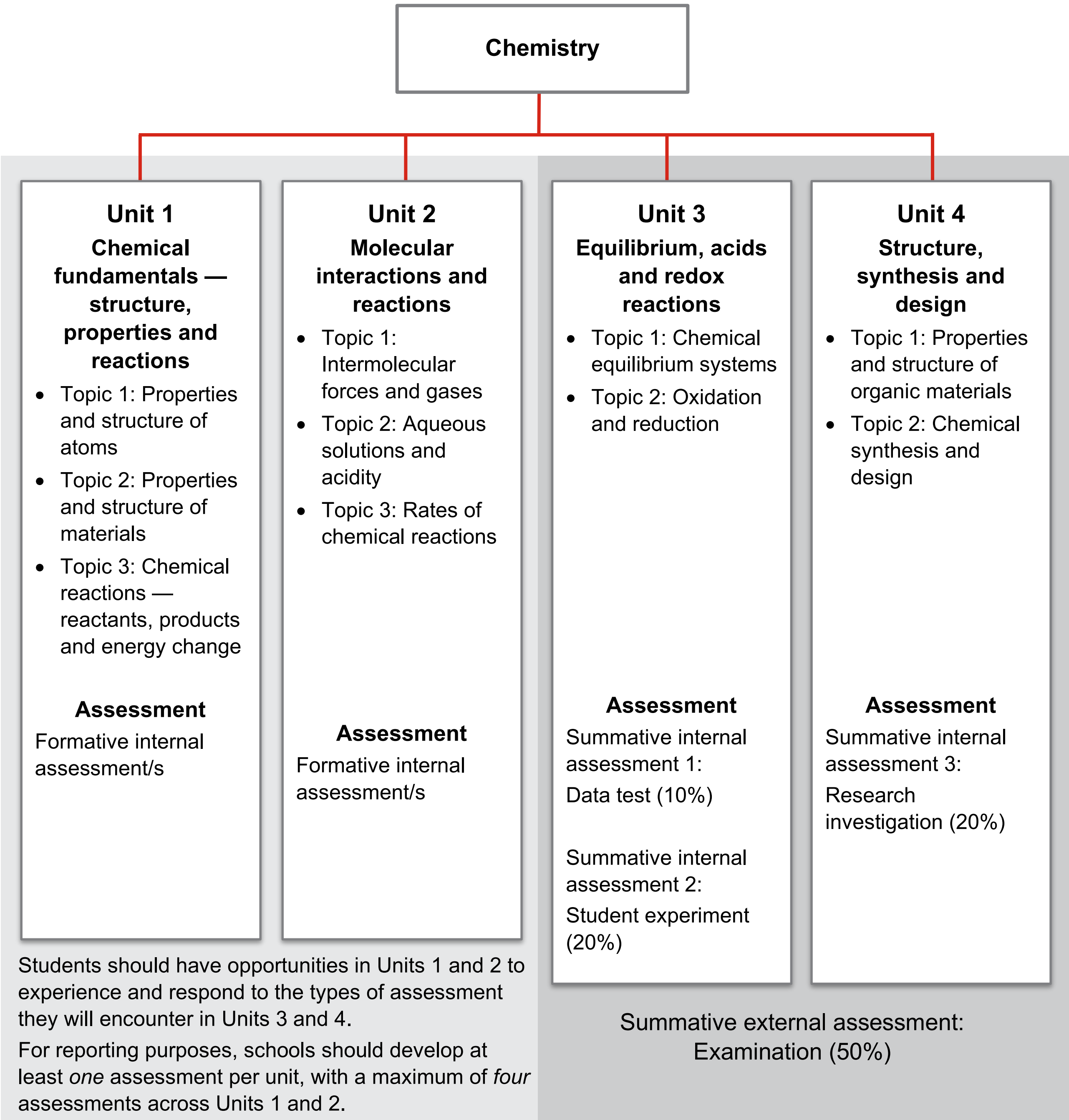
Units 1 and 2 provide foundational learning, which allows students to experience all syllabus objectives and begin engaging with the course subject matter. Students should complete Units 1 and 2 before beginning Units 3 and 4.

Units 3 and 4 consolidate student learning. Only the results from Units 3 and 4 will contribute to ATAR calculations.

Figure 2 outlines the structure of this course of study.

Each unit has been developed with a notional time of 55 hours of teaching and learning, including assessment.

Figure 2: Course structure



1.2 Teaching and learning

1.2.1 Syllabus objectives

The syllabus objectives outline what students have the opportunity to learn. Assessment provides evidence of how well students have achieved the objectives.

Syllabus objectives inform unit objectives, which are contextualised for the subject matter and requirements of the unit. Unit objectives, in turn, inform the assessment objectives, which are further contextualised for the requirements of the assessment instruments. The number of each objective remains constant at all levels, i.e. Syllabus objective 1 relates to Unit objective 1 and to Assessment objective 1 in each assessment instrument.

Syllabus objectives are described in terms of actions that operate on the subject matter. Students are required to use a range of cognitive processes in order to demonstrate and meet the syllabus objectives. These cognitive processes are described in the explanatory paragraph following each objective in terms of four levels: retrieval, comprehension, analytical processes (analysis), and knowledge utilisation, with each process building on the previous processes (see Marzano & Kendall 2007, 2008). That is, comprehension requires retrieval, and knowledge utilisation requires retrieval, comprehension and analytical processes (analysis).

By the conclusion of the course of study, students will:

Syllabus objective	Unit 1	Unit 2	Unit 3	Unit 4
1. describe and explain scientific concepts, theories, models and systems and their limitations	●	●	●	●
2. apply understanding of scientific concepts, theories, models and systems within their limitations	●	●	●	●
3. analyse evidence	●	●	●	●
4. interpret evidence	●	●	●	●
5. investigate phenomena	●	●	●	●
6. evaluate processes, claims and conclusions	●	●	●	●
7. communicate understandings, findings, arguments and conclusions	●	●	●	●

1. describe and explain scientific concepts, theories, models and systems and their limitations

When students describe and explain scientific concepts, theories, models and systems and their limitations, they give a detailed account of a concept, theory, model or system by making relationships, reasons or causes evident. They reflect on relevant social, economic, ethical and cultural factors.

2. apply understanding of scientific concepts, theories, models and systems within their limitations

When students apply their understanding of scientific concepts, theories, models and systems within their limitations, they explain local, regional and global phenomena and determine outcomes, behaviours and implications. They use algebraic, visual and graphical representations of scientific relationships and data to determine unknown scientific quantities or variables. They recognise the limitations of models and theories when discussing results.

3. **analyse evidence**

   When students analyse evidence, they recognise the variety of forms of evidence, and distinguish between quantitative, qualitative, primary and secondary evidence. When students analyse evidence in the form of qualitative data, they identify the essential elements, features or components of the data. When students analyse evidence in the form of quantitative data, they use mathematical processes to identify trends, patterns, relationships, limitations and uncertainty in the data.

4. **interpret evidence**

   When students interpret evidence, they use their knowledge and understanding of scientific concepts, theories, models and systems and their limitations to draw conclusions based on their analysis of qualitative and quantitative evidence and established criteria.

5. **investigate phenomena**

   When students investigate phenomena, they plan and carry out experimental and/or research activities in order to obtain evidence for the purpose of reaching a conclusion. They collect, collate and process evidence. Students ensure that relevant ethical, environmental and safety considerations have been incorporated into their practice.

6. **evaluate processes, claims and conclusions**

   When students evaluate processes, claims and conclusions, they critically reflect on the available evidence and make judgments about its application to a research question, and its use to inform further investigation. When students evaluate processes, they use the quality of the evidence to evaluate the validity and reliability of the method used, the appropriateness of assumptions made and possible refinements required. When students evaluate claims, they identify the evidence that would be required to support or refute the claim. They scrutinise evidence for bias, conjecture, alternatives or inaccuracies. When students evaluate conclusions, they consider the credibility of the supporting evidence.

7. **communicate understandings, findings, arguments and conclusions**

   When students communicate, they use scientific representations and language within appropriate genres to present information. They use technology to share knowledge by exchanging information and creating information products.

1.2.2 Underpinning factors

There are three skill sets that underpin senior syllabuses and are essential for defining the distinctive nature of subjects:

- literacy — the set of knowledge and skills about language and texts essential for understanding and conveying Chemistry content
- numeracy — the knowledge, skills, behaviours and dispositions that students need to use mathematics in a wide range of situations, to recognise and understand the role of mathematics in the world, and to develop the dispositions and capacities to use mathematical knowledge and skills purposefully
- 21st century skills — the attributes and skills students need to prepare them for higher education, work and engagement in a complex and rapidly changing world.

These skill sets, which overlap and interact, are derived from current education, industry and community expectations. They encompass the knowledge, skills, capabilities, behaviours and dispositions that will help students live and work successfully in the 21st century.

Together these three skill sets shape the development of senior subject syllabuses. Although coverage of each skill set may vary from syllabus to syllabus, students should be provided with opportunities to learn through and about these skills over the course of study. Each skill set contains identifiable knowledge and skills that can be directly assessed.

Literacy in Chemistry

The skills of literacy in science (distinct from 'scientific literacy') are essential for successful scientific inquiry (Douglas et al 2006, Saul 2004, Yore et al 2003). In any scientific inquiry activity, literacy skills support students by enabling them to grapple with ideas, conduct research, discuss their thoughts, enhance conceptual understanding and solve problems (Krajcik & Southerland 2010).

The literacy skills important to this subject are those related to the comprehension and composition of texts that provide information, describe and explain events and phenomena, report on experiments, present and analyse data, and offer opinions or claims (ACARA 2015a). Chemistry students comprehend and compose multimedia texts, such as reports, charts, graphs, diagrams, pictures, maps, animations, models and other visual media. They understand and apply language structures that are used to link information and ideas, give descriptions and explanations, formulate research questions and construct evidence-based arguments capable of expressing an informed position (ACARA 2015a).

Students learn these skills by having opportunity to engage with:

- rich and varied science and media texts
- class activities that use literacy as a tool for learning
- strategies for reading scientific texts (Moore 2009).

The learning opportunities described above can be integrated with stimulus questions, Science as a Human Endeavour (SHE) subject matter and mandatory practicals. Students could be asked to:

- explain links between new ideas and prior knowledge and experiences
- engage in learning experiences directed by a question that is meaningful to their lives
- connect multiple representations of a concept (e.g. written texts, formulas, graphs or diagrams of the same concept)
- use scientific ideas to compose evidence-based conclusions in the mandatory practicals
- engage with the discourses of science such as those found in scientific literature and media texts (Krajcik & Southerland 2010).

These strategies will promote students' ability to read, write and communicate about science so that they can engage with science-related issues throughout their lives.

These aspects of literacy knowledge and skills are embedded in the syllabus objectives, unit objectives and subject matter, and instrument-specific marking guides (ISMGs) for Chemistry.

Numeracy in Chemistry

The skills of numeracy in Chemistry are essential for successful scientific inquiry. In any scientific inquiry activity, numeracy skills support students by enabling them to make and record observations; order, represent and analyse data; and interpret trends and relationships (ACARA 2015b).

The numeracy skills important to this subject are those related to the interpretation of complex spatial and graphical representations, and the appreciation of the ways in which scientific concepts, theories, systems and models are structured, communicated, interact or change across spatial and temporal scales (ACARA 2015b). Students will use knowledge and skills in areas such as:

- graphing
- ratio and proportion
- converting from one unit to another
- scientific notation
- an understanding of place in number (significant figures)
- estimation and calculation in order to analyse data
- determining the reliability of data
- interpreting and manipulating mathematical relationships in order to calculate and predict values (ACARA 2009, 2015b).

Students will learn these skills as they:

- measure and record data during the mandatory practicals
- use or interpret meaning from formulas
- interpret graphical information presented in science and media texts
- undertake class activities that use numeracy as a tool for learning
- use mathematics or equations as justification or evidence for conclusions
- interpret and represent information in a variety of forms.

These opportunities will promote students' ability to develop and use numeracy skills in Chemistry.

These aspects of numeracy knowledge and skills are embedded in the syllabus objectives, unit objectives and subject matter, and ISMGs for Chemistry.

21st century skills

The 21st century skills identified in the following table reflect a common agreement, both in Australia and internationally, on the skills and attributes students need to prepare them for higher education, work and engagement in a complex and rapidly changing world.

21st century skills	Associated skills	21st century skills	Associated skills
critical thinking	• analytical thinking • problem-solving • decision-making • reasoning • reflecting and evaluating • intellectual flexibility	creative thinking	• innovation • initiative and enterprise • curiosity and imagination • creativity • generating and applying new ideas • identifying alternatives • seeing or making new links
communication	• effective oral and written communication • using language, symbols and texts • communicating ideas effectively with diverse audiences	collaboration and teamwork	• relating to others (interacting with others) • recognising and using diverse perspectives • participating and contributing • community connections
personal and social skills	• adaptability/flexibility • management (self, career, time, planning and organising) • character (resilience, mindfulness, open- and fair-mindedness, self-awareness) • leadership • citizenship • cultural awareness • ethical (and moral) understanding	information & communication technologies (ICT) skills	• operations and concepts • accessing and analysing information • being productive users of technology • digital citizenship (being safe, positive and responsible online)

Chemistry helps develop the following 21st century skills:

- critical thinking
- creative thinking
- communication
- collaboration and teamwork
- personal and social skills
- information & communication technologies (ICT) skills.

These elements of 21st century skills are embedded in the syllabus objectives, unit objectives and subject matter, and ISMGs for Chemistry.

1.2.3 Aboriginal perspectives and Torres Strait Islander perspectives

The QCAA is committed to reconciliation in Australia. As part of its commitment, the QCAA affirms that:

- Aboriginal peoples and Torres Strait Islander peoples are the first Australians, and have the oldest living cultures in human history
- Aboriginal peoples and Torres Strait Islander peoples have strong cultural traditions and speak diverse languages and dialects, other than Standard Australian English
- teaching and learning in Queensland schools should provide opportunities for students to deepen their knowledge of Australia by engaging with the perspectives of Aboriginal peoples and Torres Strait Islander peoples
- positive outcomes for Aboriginal students and Torres Strait Islander students are supported by successfully embedding Aboriginal perspectives and Torres Strait Islander perspectives across planning, teaching and assessing student achievement.

Guidelines about Aboriginal perspectives and Torres Strait Islander perspectives and resources for teaching are available at www.qcaa.qld.edu.au/k-12-policies/aboriginal-torres-strait-islander-perspectives.

Where appropriate, Aboriginal perspectives and Torres Strait Islander perspectives have been embedded in the subject matter.

1.2.4 Pedagogical and conceptual frameworks

Defining *inquiry* in science education

This syllabus provides guidance to support schools in aligning a chosen pedagogical framework with the curriculum and assessment expectations outlined in this syllabus. This guidance clarifies the use of the term *inquiry* and articulates a framework to describe the process of inquiry. The purpose of this guidance is to prevent misunderstandings and problematic conflations and their subsequent negative impact on student learning. As Abrams, Southerland and Silva (2008, p. xv) stated in their book, *Inquiry in the Classroom: Realities and opportunities*:

> Inquiry in the classroom can be conceived as a complex set of ideas, beliefs, skills, and/or pedagogies. It is evident that attempting to select a singular definition of inquiry may be an insurmountable and fruitless task. Any single definition of inquiry in the classroom would necessarily reflect the thinking of a particular school of thought, at a particular moment in time, or a particular goal, and such a singular definition may serve to limit legitimate and necessary components of science learning. **However, operating without a firm understanding of the various forms of inquiry leaves science educators often ‘talking past’ one another, and often results in very muddled attempts in the classroom.**

Uses of the term *inquiry*

Common phrases involving the term *inquiry* have been listed below:

- science inquiry
- science inquiry skills
- the inquiry process
- inquiry-based learning.

This syllabus refers to the first three uses listed above. The first, *science inquiry*, defines the practical work of a scientist (Harlen 2013). The second, *science inquiry skills*, refers to the skills required to do the work of a scientist (Harlen 2013). The third, *the inquiry process*, is a framework that can be used to describe the process of asking a question and then answering it.

The final phrase, *inquiry-based learning*, refers to a variety of teaching and learning strategies an educator may choose to use within their school's pedagogical framework. Although a school may choose to adopt an inquiry-based pedagogy, this syllabus is *not* intended to endorse or recommend an inquiry-based learning approach.

Science inquiry and science inquiry skills

Science inquiry involves identifying and posing questions and working to answer them. It is concerned with evaluating claims, investigating ideas, solving problems, reasoning, drawing valid conclusions and developing evidence-based arguments. It can easily be summarised as the 'work of a scientist' (Hackling 2005).

Within this syllabus, it is expected that students will engage in *aspects* of the work of a scientist by engaging in science inquiry (Tytler 2007). This expectation can be seen, for example, in the inclusion of the student experiment, research investigation, and mandatory practicals.

Science inquiry skills are the skills required to do the work of a scientist. They include writing research questions, planning, conducting, recording information and reflecting on investigations; processing, analysing and interpreting evidence; evaluating conclusions, processes and claims; and communicating findings (ACARA 2015c).

It is expected that students are taught science inquiry skills (Krajcik et al 2000). The syllabus outlines a number of these skills in the subject matter. Some science inquiry skills will be used to complete the mandatory and suggested practicals. The selection, application and coordination of science inquiry skills will be required in the student experiment and research investigation.

Teachers decide how the science inquiry skills are to be developed. For example, teachers will determine how mandatory practicals are used as opportunities to:

- develop, rehearse and refine science inquiry skills
- engage students in scaffolded or open-ended science inquiry tasks
- formatively assess science inquiry skills.

Framework to describe the inquiry process

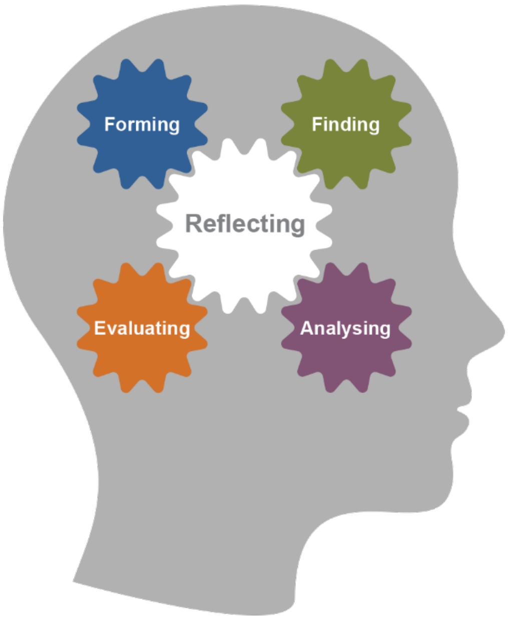
In order to support student engagement in activities involving inquiry, it is useful to establish a common language or framework to distinguish between stages of the process.

The stages involved in any inquiry are:

- forming and describing the inquiry activity
- finding valid and reliable evidence for the inquiry activity
- analysing and interpreting the evidence selected
- evaluating the conclusions, processes or claims.

This framework uses reflection as the connection between, and driver of, all the stages. The progression through the inquiry process requires reflection on the decisions made and any new information that has emerged during the process to inform the next stage. Each stage of the inquiry process is worthy of reflection, the result of which may be the revision of previous stages (Marzano & Kendall 2007).

Figure 3: Stages of inquiry process



Safety and ethics

Workplace health and safety

Chemistry is designed to expose students to the practical components of science through practical experiences in the laboratory and the field. These experiences expose students to a variety of hazards, from biological and poisonous substances to injury from equipment. Besides a teacher's duty of care that derives from the *Education (General Provisions) Act 2006*, there are other legislative and regulatory requirements, for example the *Work Health and Safety Act 2011*, which will influence the nature and extent of practical work.

All practical work must be organised with student safety in mind. The *Department of Education and Training (DET) Policy and Procedure Register* provides guidance about current science safety protocols.

It is the responsibility of all schools to ensure that their practices meet current legislation requirements. References to relevant legislation and regulations are supported by the Reference list located on the Chemistry subject page of the QCAA website.

1.2.5 Subject matter

Subject matter is the body of information, mental procedures and psychomotor procedures (see Marzano & Kendall 2007, 2008) that are necessary for students' learning and engagement with Chemistry. It is particular to each unit in the course of study and provides the basis for student learning experiences.

Subject matter has a direct relationship to the unit objectives, but is of a finer granularity and is more specific. These statements of learning are constructed in a similar way to objectives. Each statement:

- describes an action (or combination of actions) — what the student is expected to do
- describes the element — expressed as information, mental procedures and/or psychomotor procedures
- is contextualised for the topic or circumstance particular to the unit.

Organisation of subject matter

The subject matter is organised as topics within each unit.

The subject matter indicates the required knowledge and skills that students must acquire. Students should experience the mandatory practicals.

The subject matter from Units 3 and 4 will be assessed by the external examination.

Science as a Human Endeavour

Each Queensland senior science subject requires students to learn and apply aspects of the knowledge and skills of the discipline. It is recognised that students should also develop an appreciation for the *nature* and *development* of science, and its *use* and *influence* on society.

While this appreciation will not be assessed, the syllabus provides guidance about where it may be developed. Importantly, this guidance draws students' attention to the way in which science operates, both in relation to the development of understanding and explanations about the world and to its influence on society.

Students should become familiar with the following Science as a Human Endeavour (SHE) concepts:

- Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility.
- Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines.
- Advances in science understanding in one field can influence other areas of science, technology and engineering.
- The use and acceptance of scientific knowledge is influenced by social, economic, cultural and ethical contexts.
- The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences.
- Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions.
- Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability.
- ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work.
- Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power.
- Scientific knowledge can be used to inform the monitoring, assessment and evaluation of risk.
- Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question.
- International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia–Pacific region.

To support the development of these concepts, this syllabus identifies SHE guidance in each topic. This highlights opportunities for teachers to contextualise the associated subject matter and provides stimulus for the development of claims and research questions for investigation.

Additional opportunities include:

- mandatory and suggested practicals that provide opportunities for students to witness the *nature* of science
- a student experiment that provides opportunities for students to experience how the *development* of new science knowledge is built upon existing knowledge
- a research investigation that provides an opportunity for students to appreciate the *use* and *influence* of scientific evidence to make decisions or to contribute to public debate about a claim.

Finally, the SHE statements at the end of each topic may be used to support the development and interrogation of claims, and be useful as a starting point for the research investigation.

Guidance

The guidance included with each topic is designed to clarify the scope of the subject matter and identify opportunities to integrate science inquiry skills and SHE strands into the subject matter. A number of tags are used to highlight aspects of the guidance:

- **Notional time:** the depth of subject matter coverage is indicated by the amount of time needed to cover this subject matter in the sequence presented in the syllabus.
- **Formula:** defines a formula described in the subject matter.
- **SHE:** identifies an opportunity to integrate an aspect of the Science as a Human Endeavour strand and may also be used as a starting point for a research investigation.
- **Suggested practical:** identifies an opportunity for inquiry skills to be developed and may be used as a starting point for a student experiment.
- **Syllabus links:** identifies links between syllabus units.

1.3 Assessment — general information

Assessments are formative in Units 1 and 2, and summative in Units 3 and 4.

Assessment	Unit 1	Unit 2	Unit 3	Unit 4
Formative assessments	•	•		
Summative internal assessment 1			•	
Summative internal assessment 2			•	
Summative internal assessment 3				•
Summative external assessment			•	•

1.3.1 Formative assessments — Units 1 and 2

Formative assessments provide feedback to both students and teachers about each student's progress in the course of study.

Schools develop internal assessments for each senior subject, based on the learning described in Units 1 and 2 of the subject syllabus. Each unit objective must be assessed at least once.

For reporting purposes, schools should devise at least *two* but no more than *four* assessments for Units 1 and 2 of this subject. At least *one* assessment must be completed for *each* unit.

The sequencing, scope and scale of assessments for Units 1 and 2 are matters for each school to decide and should reflect the local context.

Teachers are encouraged to use the A–E descriptors in the reporting standards (Section 1.4) to provide formative feedback to students and to report on progress.

1.3.2 Summative assessments — Units 3 and 4

Students will complete a total of *four* summative assessments — three internal and one external — that count towards their final mark in each subject.

Schools develop *three* internal assessments for each senior subject, based on the learning described in Units 3 and 4 of the syllabus.

The three summative internal assessments will be endorsed and the results confirmed by the QCAA. These results will be combined with a single external assessment developed and marked by the QCAA. The external assessment results for Chemistry will contribute 50% towards a student's result.

Summative internal assessment — instrument-specific marking guides

This syllabus provides ISMGs for the three summative internal assessments in Units 3 and 4.

The ISMGs describe the characteristics evident in student responses and align with the identified assessment objectives. Assessment objectives are drawn from the unit objectives and are contextualised for the requirements of the assessment instrument.

Criteria

Each ISMG groups assessment objectives into criteria. An assessment objective may appear in multiple criteria, or in a single criterion of an assessment.

Making judgments

Assessment evidence of student performance in each criterion is matched to a performance-level descriptor, which describes the typical characteristics of student work.

Where a student response has characteristics from more than one performance level, a best-fit approach is used. Where a performance level has a two-mark range, it must be decided if the best fit is the higher or lower mark of the range.

Authentication

Schools and teachers must have strategies in place for ensuring that work submitted for internal summative assessment is the student's own. Authentication strategies outlined in QCAA guidelines, which include guidance for drafting, scaffolding and teacher feedback, must be adhered to.

Summative external assessment

The summative external assessment adds valuable evidence of achievement to a student's profile. External assessment is:

- common to all schools
- administered under the same conditions at the same time and on the same day
- developed and marked by the QCAA according to a commonly applied marking scheme.

The external assessment contributes 50% to the student's result in Chemistry. It is not privileged over the summative internal assessments.

1.4 Reporting standards

Reporting standards are summary statements that succinctly describe typical performance at each of the five levels (A–E). They reflect the cognitive taxonomy and objectives of the course of study.

The primary purpose of reporting standards is for twice-yearly reporting on student progress. These descriptors can also be used to help teachers provide formative feedback to students and to align ISMGs.

Reporting standards

A
The student accurately describes and explains a variety of concepts, theories, models and systems, and their limitations. They give clear and detailed accounts of a variety of concepts, theories, models and systems by making relationships, reasons or causes evident. The student accurately applies their understanding of scientific concepts, theories, models and systems within their limitations to explain a variety of phenomena, and predict outcomes, behaviours and implications. They accurately use representations of scientific relationships and data to determine a variety of unknown scientific quantities and perceptively recognise the limitations of models and theories when discussing results. The student analyses evidence systematically and effectively by identifying the essential elements, features or components of qualitative data. They use relevant mathematical processes to appropriately identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence insightfully by using their knowledge and understanding to draw justified conclusions based on their thorough analysis of evidence and established criteria. The student investigates phenomena by carrying out effective experiments and research investigations. They efficiently collect, collate and process relevant evidence. They critically evaluate processes, claims and conclusions by insightfully scrutinising evidence, extrapolating credible findings, and discussing the reliability and validity of experiments. The student communicates effectively by using scientific representations and language accurately and concisely within appropriate genres.

B
The student accurately describes and explains concepts, theories, models and systems, and their limitations. They give clear and detailed accounts of concepts, theories, models and systems by making relationships, reasons or causes evident. The student accurately applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcomes, behaviours and implications. They accurately use representations of scientific relationships and data to determine unknown scientific quantities, and accurately recognise the limitations of models and theories when discussing results. The student analyses evidence by effectively identifying the essential elements, features or components of qualitative data. They use mathematical processes to appropriately identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence by using their knowledge and understanding to draw reasonable conclusions based on their accurate analysis of evidence and established criteria. The student investigates phenomena by carrying out effective experiments and research investigations. They collect, collate and process relevant evidence. They evaluate processes, claims and conclusions by scrutinising evidence, applying relevant findings and discussing the reliability and validity of experiments. The student communicates accurately by using scientific representations and language within appropriate genres to present information.
C
The student describes and explains concepts, theories, models and systems, and their limitations. They give detailed accounts of concepts, theories, models and systems by making relationships, reasons or causes evident. The student applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcomes, behaviours and implications. They use representations of scientific relationships and data to determine unknown scientific quantities and recognise the limitations of models and theories when discussing results. The student analyses evidence by identifying the essential elements, features or components of qualitative data. They use mathematical processes to identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence by using their knowledge and understanding to draw conclusions based on their analysis of evidence and established criteria. The student investigates phenomena by carrying out experiments and research investigations. They collect, collate and process evidence. They evaluate processes, claims and conclusions by describing the quality of evidence, applying findings, and describing the reliability and validity of experiments. The student communicates using scientific representations and language within appropriate genres to present information.
D
The student describes and gives accounts of aspects of concepts, theories, models and systems. They use rudimentary representations of scientific relationships or data to determine unknown scientific quantities or variables. The student analyses evidence by identifying the elements, features or components of qualitative data. They use parts of mathematical processes to identify trends, patterns, relationships, limitations or uncertainty in quantitative data. They interpret evidence by drawing conclusions based on evidence or established criteria. The student carries out aspects of experiments and research investigations. They discuss processes, claims or conclusions. They consider the quality of evidence and conclusions. The student uses scientific representations or language to present information.
E
The student describes scenarios and refers to representations of information. They discuss physical phenomena and evidence. They follow established methodologies in research situations. They discuss evidence. The student carries out elements of experiments and research investigations. The student communicates information.

2 Unit 1: Chemical fundamentals — structure, properties and reactions

2.1 Unit description

In Unit 1, students relate matter and energy in chemical reactions as they consider the breaking and reforming of bonds as new substances are produced. The properties of a material depend on, and can be explained by, the material's structure. A range of models at the atomic and molecular scale enable explanation and prediction of the structure of materials, and how this structure influences properties and reactions.

Students conduct investigations to develop their understanding of patterns in the properties and composition of materials. They explore the structure of materials by describing physical and chemical properties at the macroscopic scale, and use models of structure and primary bonding at the atomic and subatomic scale to explain these properties. They are introduced to the mole concept as a means of quantifying matter in chemical reactions.

Contexts that could be investigated in this unit include history of atomic model development, use of radioisotopes, energy transfers in industry and the human body, and analysis of elements in living things. Students can also use materials that they encounter in their lives as a context for investigating the relationships between structure and properties.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of chemical structure and properties, and reaction enthalpy. Collaborative experimental work also helps students to develop communication, interaction, and self-management skills.

Throughout the unit, students develop skills in observation, experimentation and data analysis to describe and explain periodicity, material chemistry and energy transfers in chemical reactions.

2.2 Unit objectives

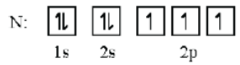
Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

1. describe and explain the properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change
2. apply understanding of the properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change
3. analyse evidence about the properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy
4. interpret evidence about the properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change
5. investigate phenomena associated with properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change
6. evaluate processes, claims and conclusions about the properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change
7. communicate understandings, findings, arguments and conclusions about the properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.

2.3 Topic 1: Properties and structure of atoms

In this topic, students will:

Subject matter	Guidance
Periodic table and trends • recall that elements are represented by symbols and recognise that the structure of the periodic table is based on the atomic number and the properties of the elements • describe and explain that elements of the periodic table show trends across periods and down groups, including atomic radii, valencies, ionic radii, 1st ionisation energy and electronegativities as exemplified by groups 1, 2, 13–18 and period 3 • explain how successive ionisation energy data is related to the electron configuration of an atom • compare and explain the metallic and non-metallic behaviours of elements, including group trends and the reactivity for the alkali metals (Li–Cs) and the halogens (F–I) • recognise that oxides change from basic through amphoteric to acidic across a period • analyse, evaluate and interpret data to explain and justify conclusions for periodic trends, patterns and relationships.	• **Notional time:** 4 hours • The group numbering scheme from group 1 to group 18, as recommended by the International Union of Pure and Applied Chemistry (IUPAC), should be used. • Trends in chemical and physical properties should be considered. • Data for atomic radii, ionic radii, 1st ionisation energy and electronegativities are given in the *Chemistry data booklet*. • **Syllabus link:** Unit 2 Topic 2: Aqueous solutions and acidity. • **Suggested practical:** Models and databases could be used to investigate periodic trends, pattern and relationships.
Atomic structure • understand that atoms can be modelled as a nucleus surrounded by electrons in distinct energy levels held together by electrostatic forces of attraction between the nucleus and electrons; the location of electrons within atoms can be represented using electron configurations; and the structure of the periodic table is based on the electronic configuration of atoms • use and apply the nuclear symbol notation $^{A}_{Z}\mathrm{M}$ to determine the number of protons, neutrons and electrons in atoms, ions and isotopes • recall the relative energies of the s, p and d orbitals in energy levels to construct electron configurations for atoms and ions up to *Z* = 36 and recognise that the periodic table is arranged into four blocks associated with the four sub-levels — s, p, d and f • apply the Aufbau principle, Hund's rule and the Pauli exclusion principle to write electron configurations for atoms and ions up to *Z* = 36 and use orbital diagrams to represent the character and relative energy of orbitals • recognise the electron configuration of Cr and Cu as exceptions.	• **Notional time:** 4 hours • Full electron configuration, e.g. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$, and condensed electron configuration, e.g. $[Ne]3s^23p^5$ should be covered. • Orbital diagrams refer to arrow-in-box diagrams, such as the one given below.  • **Suggested practical:** Simulations of Rutherford's gold foil experiment could be used.

Subject matter	Guidance
Introduction to bonding • recognise that the properties of atoms, including their ability to form chemical bonds, are explained by the arrangement of electrons in the atom and by the stability of the valence electron shell • understand that the number of electrons lost, gained or shared is determined by the electron configuration of the atom and recall that transitional elements can form more than one ion • recognise that ions are atoms or groups of atoms that are electrically charged due to an imbalance in the number of electrons and protons and recognise that ions are represented by formulas which include the number of constituent atoms and the charge of the ion • understand that chemical bonds are caused by electrostatic attractions that arise because of the sharing or transfer of electrons between participating atoms and the valency is a measure of the number of bonds that an atom can form • determine the formula of an ionic compound from the charges on the relative ions and name the compound • deduce Lewis (electron dot) structure of molecules and ions showing all valence electrons for up to four electron pairs for each atom • identify the numbers of bonding and lone pairs of electrons around each atom in a molecule.	• **Notional time:** 3 hours • **Syllabus link:** Unit 2 Topic 1: Intermolecular forces and gases.
Isotopes • recall isotopes are atoms of the same element that have different numbers of neutrons and can be represented in the form ^{A}X (IUPAC) or X-A • recognise that isotopes of an element have the same electron configuration and possess similar chemical properties but have different physical properties • understand that the relative atomic mass of an element is the ratio of the weighted average mass per atom of the naturally occurring form of the element to 1/12 the mass of an atom of carbon-12.	• **Notional time:** 1 hour

Subject matter	Guidance
Analytical techniques • understand that mass spectrometry involves the ionisation of substances and the separation and detection of the resulting ions, and that the spectra generated can be analysed to determine the isotopic composition of elements, and interpreted to determine relative atomic mass (analysis to determine) • understand that flame tests and atomic absorption spectroscopy (AAS) are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels and are shown by line spectra • distinguish between absorption and emission spectra and recognise that the emission spectrum of hydrogen provides evidence for the existence of electrons in discrete energy levels (Bohr model), which converge at higher energies. Explain that emission spectra are produced when photons are emitted from atoms when excited electrons return to a lower energy level. • analyse, interpret and evaluate data from flame tests and atomic absorption spectroscopy (AAS) to determine the presence and concentration of metallic ions in solution • use appropriate mathematical representations to make inferences and to solve problems, including calculating the relative atomic mass of an element and percentage abundances of the isotopes of an element from data.	• **Notional time:** 4 hours • The operation of the mass spectrometer is not required. • **Suggested practical:** Flame test. • **Suggested practical:** Simulations could be used to examine atomic absorption spectroscopy, mass spectrometry, and absorption and emission spectra. • Students should recognise the Lyman, Balmer and Paschen series in the hydrogen spectrum. • Students are not required to calculate the energy of photons using the formula $E = hf$. • **Syllabus link:** Unit 2 Topic 2: Aqueous solutions and acidity.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Models of the atom:** Experiments provided evidence that enabled scientists to develop models. • **Radioisotopes:** Radioisotopes require careful evaluation and monitoring because of the potential harmful effects to humans and/or the environment. • **Distribution of elements in the universe:** Analysis of the distribution of elements in living things, Earth and the universe has informed a wide range of scientific understandings.

2.4 Topic 2: Properties and structure of materials

In this topic, students will:

Subject matter	Guidance
Compounds and mixtures • recall that pure substances may be elements or compounds • recognise that materials are either pure substances with distinct measurable properties (e.g. melting and boiling point, reactivity, strength, density) or mixtures with properties dependent on the identity and relative amounts of the substances that make up the mixture • distinguish between heterogeneous and homogeneous mixtures • recognise that nanomaterials are substances that contain particles in the size range 1–100 nm and have specific properties relating to the size of these particles. • analyse and interpret given data to evaluate the physical properties of pure substances and mixtures.	• **Notional time:** 3 hours • **Suggested practical:** Separate mixtures into pure substances or simpler mixtures based on the physical properties of the substances in the mixture, including boiling point (distillation). • **Syllabus links:** – Unit 2 Topic 1: Intermolecular forces and gases. – Unit 2 Topic 3: Rates of chemical reactions. – Unit 4 Topic 2: Chemical synthesis and design.
Bonding and properties • recognise that the properties of ionic compounds, including high melting point, brittleness, and ability to conduct electricity when liquid or an aqueous solution, can be explained by modelling ionic bonding as ions arranged in a crystalline lattice structure with strong electrostatic forces of attraction between oppositely charged ions (metallic lattice, giant covalent networks, allotropes — carbon) • understand that the type of bonding within ionic, metallic and covalent substances explains their physical properties, including melting and boiling point, thermal and electrical conductivity, strength and hardness • understand that hydrocarbons, including alkanes (saturated), alkenes (unsaturated) and benzene, have different chemical properties that are determined by the nature of the bonding within the molecules • analyse and interpret given data to evaluate the properties, structure and bonding of ionic, covalent and metallic compounds.	• **Notional time:** 3 hours • Students should be familiar with the term formula unit. • Formula and charges for polyatomic ions are given in the *Chemistry formula and data booklet*. • **Syllabus links:** – Unit 4 Topic 1: Properties and structure of organic materials – Unit 4 Topic 2: Chemical synthesis and design. • **Suggested practical:** Test for saturation.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Nanomaterials:** Development of organic and inorganic nanomaterials is important to meet a range of contemporary needs, including consumer products, health care, transportation, energy and agriculture. • **The importance of purity:** Impurities can affect the physical and chemical properties of substances, resulting in inefficient or unwanted chemical reactions. • **Carbon based life and astrobiology:** If life exists elsewhere in the universe, it will be carbon-based as it is on Earth.

2.5 Topic 3: Chemical reactions — reactants, products and energy change

In this topic, students will:

Subject matter	Guidance
Chemical reactions • recall that chemical reactions and phase changes involve energy changes commonly observable as changes in the temperature of the surroundings and/or the emission of light • deduce and construct balanced chemical equations when reactants and products are specified and apply state symbols (s), (l), (g) and (aq).	• **Notional time:** 2 hours • Balancing equations should cover a variety of reactions, e.g. single displacement, double-displacement, acid-base, combustion, combination, decomposition and simple redox reactions. • Names of the change of states should be covered: melting, freezing, vaporisation (evaporation and boiling) condensation, sublimation and deposition. • **Syllabus link:** Unit 2 Topic 3: Rates of chemical reactions.
Exothermic and endothermic reactions • explain how endothermic and exothermic reactions relate to the law of conservation of energy and the breaking and reforming of bonds; understand that heat energy is released or absorbed by the system to or from the surrounds • understand that heat is a form of energy and that temperature is a measure of the average kinetic energy of the particles • apply the relationship between temperature and enthalpy changes to identify thermochemical reactions as exothermic or endothermic; deduce from enthalpy level diagrams and thermochemical equations the relative stabilities of reactants and products, and the sign of the enthalpy change (ΔH) for a reaction • explain, in terms of average bond enthalpies, why reactions are exothermic or endothermic • construct and use appropriate representations (including chemical symbols and formulas, and chemical and thermochemical equations) to communicate conceptual understanding, solve problems and make predictions • calculate the heat change for a substance given the mass, specific heat capacity and temperature change • use data to calculate the enthalpy change (ΔH) for a reaction. • **Mandatory practical:** Conduct a calorimetry experiment to measure the enthalpy of a reaction.	• **Notional time:** 6 hours • Average bond enthalpy values are given in the *Chemistry formula and data booklet*. • Students should be aware of the limitations of using average bond enthalpies to calculate enthalpy change. • Consider reactions in aqueous solutions and combustion reactions. • **Formulas:** $\Delta H = H_{(products)} - H_{(reactants)}$ $\triangle H = \Sigma$(bonds broken) - Σ(bonds formed). • **Formula:** $Q = mc\Delta T$ • **Suggested practicals:** – Apply Hess's Law. Data loggers could be used here. – Measure the molar heat of a chemical reaction. • **Syllabus link:** Unit 2 Topic 3: Rates of chemical reactions. • The enthalpy change (ΔH) for chemical reactions is indicated in kJ mol^{-1}. • Specific heat capacity of water is given in the *Chemistry formula and data booklet*. Assume aqueous solutions other than water have the same specific heat capacity as water.

Subject matter	Guidance
Measurement uncertainty and error • distinguish between precision and accuracy and appreciate that all measurements have limits to their precision and accuracy that must be considered when evaluating experimental results • distinguish between qualitative and quantitative data; appreciate that quantitative data obtained from measurements is always associated with random error/measurement uncertainties • communicate measurement uncertainties as a range (±) to an appropriate precision • understand that propagation of random error in data processing shows the impact of measurement uncertainties on the final result • calculate the measurement uncertainties in processed data, including the use of absolute uncertainties and percentage uncertainties • construct and use appropriate graphical representations to communicate understanding, solve problems and make predictions; interpret graphs in terms of the relationship between dependent and independent variables; draw and interpret best-fit lines or curves through data points, including evaluating when it can and cannot be considered as a linear function • calculate the percentage error when the experimental result can be compared with a theoretical or accepted result (value) • distinguish between random and systematic errors; understand that experimental design and procedure usually leads to systematic errors in measurement, which causes a deviation in a direction and appreciate that repeated trials and measurements will reduce random error but not systematic error • analyse the impact of random error/measurement uncertainties and systematic errors in experimental work and evaluate how these errors/measurement uncertainties can be reduced • understand that the number of significant figures in a result is based on the figures given in the data and determine results of calculations to the appropriate number of significant figures.	• **Notional time:** 5 hours • Only a simple treatment of error analysis is required. For functions such as addition or subtraction, absolute uncertainties should be added. For multiplication, division and powers, percentage uncertainties can be added. • **Formula:** $Percentage\ uncertainty\ (\%) = \frac{absolute\ uncertainty}{measurement} \times \frac{100}{1}$ • When adding or subtracting, the final answer should be given to the least number of decimal places. When multiplying or dividing, the final answer should be given to the least number of significant figures. • **Formula:** $Percentage\ error\ (\%) = \left\lvert\frac{measured\ value - true\ value}{true\ value}\right\rvert \times 100$
Fuels • compare fuels, including fossil fuels and biofuels, in terms of their energy output, and evaluate their suitability for purpose, and the nature of products of combustion.	• **Notional time:** 2 hours • **Syllabus link:** Unit 4 Topic 2: Chemical synthesis and design.

Subject matter	Guidance
Mole concept and law of conservation of mass • recognise that a mole is a precisely defined quantity of matter equal to Avogadro's number of particles • appreciate the law of conservation of mass and understand that the mole concept relates mass, moles and molar mass • understand that the empirical formula expresses the simplest whole number ratio of elements in a compound • use the appropriate stoichiometric ratio to determine that reactants can be limiting • appreciate that experimental yield can be different from theoretical yield • use appropriate mathematical representation to solve problems and make predictions, including using the mole concept to calculate the mass of reactants and products; amount of substance in moles; number of representative particles; and molar mass of atoms, ions, molecules and formula units • use appropriate mathematical representation to solve problems and make predictions, including determining the percentage composition from relative atomic masses; empirical formula of a compound from the percentage composition by mass; and molecular formula of a compound from its empirical formula and molar mass • calculate percentage yield from experimental or given data. • **Mandatory practical:** Derive the empirical formula of a compound from reactions involving mass changes.	• **Notional time:** 8 hours • Avogadro's constant is given in the *Chemistry formula and data booklet*. • **Syllabus links:** – Unit 2 Topic 1: Intermolecular forces and gases – Unit 2 Topic 2: Aqueous solutions and acidity – Unit 3 Topic 1: Chemical equilibrium systems – Unit 3 Topic 2: Oxidation and reduction – Unit 4 Topic 2: Chemical synthesis and design. • **Formula:** $percentage\ yield\ (\%) = \frac{experimental\ yield}{theoretical\ yield} \times \frac{100}{1}$ • **Suggested practical:** Investigating limiting reagents. • Simulations can also be used.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Minimising use of energy in industry**: Green chemistry principles can be applied to industrial processes to reduce energy requirements. • **Energy in the body:** Our bodies rely on the exothermic reaction of respiration to provide us with sufficient energy. • **Use of fuels in society:** Biofuels are more efficient and have less environmental impact than fossil fuels.

2.6 Assessment guidance

In constructing assessment instruments for Unit 1, schools should ensure that the objectives cover, or are chosen from, the unit objectives. If one assessment instrument is developed for a unit, it must assess all the unit objectives; if more than one assessment instrument is developed, the unit objectives must be covered across those instruments.

It is suggested that student performance on Unit 1 is assessed using techniques modelled on the techniques used in Unit 4:

- a research investigation
- an examination that includes some items modelled on the data test.

3 Unit 2: Molecular interactions and reactions

3.1 Unit description

In Unit 2, students develop their understanding of the physical and chemical properties of materials including gases, water, aqueous solutions, acids and bases. Students explore the characteristic properties of water that make it essential for physical, chemical and biological processes on Earth, including the properties of aqueous solutions. They investigate and explain the solubility of substances in water, and compare and analyse a range of solutions. They learn how rates of reaction can be measured and altered to meet particular needs, and use models of energy transfer and the structure of matter to explain and predict changes to rates of reaction. Students gain an understanding of how to control the rates of chemical reactions, including through the use of a range of catalysts.

Students conduct investigations of chemical reactions, including the prediction and identification of products, and the measurement of the rate of reaction. They investigate the behaviour of gases, and use the kinetic theory to predict the effects of changing temperature, volume and pressure in gaseous systems.

Contexts that could be investigated in this unit include forensic chemistry, and acids in the atmosphere and ocean, such as rain, blood chemistry, water quality and the importance of enzymes. Through appropriate contexts, students explore how evidence from multiple disciplines and individuals and the development of ICT, and other technologies have contributed to developing understanding of intermolecular forces and chemical reactions.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of materials, mixtures, reactions and underpinning models and theories. Collaborative experimental work also helps students to develop communication, interaction, and self-management skills.

Throughout the unit, students develop skills in observation, design, experimentation and data analysis to describe and explain material chemistry, solutions and rates of reactions.

3.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

1. describe and explain intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions
2. apply understanding of intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions
3. analyse evidence about intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions
4. interpret evidence about intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions
5. investigate phenomena associated with intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions
6. evaluate processes, claims and conclusions about intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions
7. communicate understandings, findings, arguments and conclusions about intermolecular forces and gases, aqueous solutions and acidity, and rates of chemical reactions.

3.3 Topic 1: Intermolecular forces and gases

In this topic, students will:

Subject matter	Guidance
Intermolecular forces • apply the valence shell electron pair repulsion (VSEPR) theory to predict, draw and explain the shapes of molecules • use molecular shape, understanding of symmetry, and comparison of the electronegativity of elements to explain and predict the polarity of molecules • explain the relationship between observable properties, including vapour pressure, melting point, boiling point and solubility, and the nature and strength of intermolecular forces, including dispersion forces, dipole–dipole attractions and hydrogen bonding within molecular covalent substances • **Mandatory practical:** Construct 3D models (real or virtual) of linear, bent, trigonal planar, tetrahedral and pyramidal molecules.	• **Notional time:** 6 hours • **Syllabus links:** − Unit 3 Topic 1: Chemical equilibrium systems − Unit 4 Topic 1: Properties and structure of organic materials. • Approximate bond angles that should be covered include: 180° (linear), 104.5° (bent), 120° (trigonal planar), 109° (tetrahedral) and 107° (pyramidal). • Hybridization involving d-orbitals (e.g. trigonal bipyramidal and octahedral) are not required.
Chromatography techniques • recognise that chromatography techniques, including paper, thin layer, gas and high-performance liquid chromatography, can be used to determine the composition and purity of substances • describe and explain how variations in the strength of the interactions between atoms, molecules or ions in the mobile and stationary phases can be used to separate components • analyse, interpret and evaluate data from chromatographs to determine the composition and purity of substances, including calculating R_f values.	• **Notional time:** 3 hours • **Suggested practical:** Separate the components of a mixture using paper chromatography and/or thin layer chromatography (TLC). Simulation could be used. • **Syllabus link:** Unit 4 Topic 1: Properties and structure of organic materials.

Subject matter	Guidance
Gases • consider the relationship between the volume, number of moles and molar volume at standard temperature and pressure (STP) • use the kinetic theory of gases to describe and explain the behaviour of gases, including the qualitative relationships between pressure, temperature and volume • appreciate that the kinetic theory of gases applies to ideal gases and solve problems related to the ideal gas equation • use appropriate mathematical representation to solve problems and make predictions, including the mole concept, to calculate the mass of chemicals and/or the volume of a gas (at standard temperature and pressure) involved in a chemical reaction. • **Mandatory practical:** Investigate the properties of gases to determine the molar volume of a gas.	• **Notional time:** 4 hours • **Syllabus links:** − Unit 3 Topic 1: Chemical equilibrium systems − Unit 4 Topic 1: Properties and structure of organic materials − Unit 4 Topic 2: Chemical synthesis and design. • **Suggested practical:** Boyle's law. Simulations could be used here.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Analysing the structure of materials:** Forensic science relies on chemical processes to analyse materials in order to determine the identity, nature or source of the material. • **Scuba diving and the behaviour of gases**: Safe scuba diving requires knowledge of the behaviour of gases. • **Development of VSEPR theory:** Two- and three-dimensional graphical models have been developed and adopted by chemists to represent and communicate the shapes of molecules.

3.4 Topic 2: Aqueous solutions and acidity

In this topic, students will:

Subject matter	Guidance
Aqueous solutions and molarity • understand that the unique properties of water, including boiling point, density in solid and liquid phases, surface tension and ability to act as a solvent can be explained by its molecular shape and hydrogen bonding between molecules • distinguish between the terms *solute*, *solvent*, *solution,* and *concentration* • recall that concentration can be represented in a variety of ways including the number of moles of the solute per litre of solution (mol L^{-1}) and the mass of the solute per litre of solution (g L^{-1}) or parts per million (ppm) • distinguish between unsaturated, saturated and supersaturated solutions • use appropriate mathematical representations to solve and make predictions (including using the mole concept and the relationship between the number of moles of solute, concentration and volume of a solution) to calculate unknown values.	• **Notional time:** 6 hours • The use of square brackets to denote concentration is required. • **Formula:** $\text{Molarity} = \frac{\text{moles of solute } (n)}{\text{volume of solution } (V)}$ • The distinction between strength and concentration of an acidic/basic solution should be covered.
Identifying ions in solution • apply solubility rules to determine the products of reactions and to predict if a precipitate will form • determine the presence of specific ions in solutions based on evidence derived from chemical reactions, including precipitation and acid-carbonate reactions • construct and use appropriate representations, including ionic formulas, chemical formulas, chemical equations and phase descriptions for chemical species to communicate conceptual understanding, solve problems and make predictions. • **Mandatory practical:** Precipitation reactions to identify cations and anions.	• **Notional time:** 5 hours • Solubility table is given in the *Chemistry formula and data booklet*.

Subject matter	Guidance
Solubility • explain the relationship between the solubility of substances in water, including ionic and molecular substances, and the intermolecular forces between species in the substances and water molecules • recognise that changes in temperature can affect solubility and recall that most gases become less soluble as solvent temperature increases while most solutes become more soluble as the solvent temperature increases • interpret, analyse and evaluate data and solubility curves to communicate conceptual understanding, solve problems and make predictions.	• **Notional time:** 3 hours • **Suggest practical:** Investigate the effect of temperature on solubility. • **Syllabus links:** – Unit 3 Topic 1: Chemical equilibrium systems – Unit 4 Topic 1: Properties and structure of organic materials.
pH • recall that pH is dependent on the concentration of hydrogen ions in solution • use the pH scale to compare the levels of acidity or alkalinity of aqueous solutions • use the Arrhenius model to explain the behaviour of strong and weak acids and bases in aqueous solutions. • **Mandatory practical:** Investigate the properties of strong and weak acids.	• **Notional time:** 3 hours • **Syllabus links:** Unit 3 Topic 1: Chemical equilibrium systems. • pH calculations are covered in Unit 3 Topic 1: Chemical equilibrium systems. • Data loggers could be used here.
Reaction of acids • understand and apply the reactions of acids with bases, metals and carbonates to determine reactants and products • construct and use appropriate representations, including ionic formulas, chemical formulas and chemical equations, to symbolise the reactions of acids and bases; and ionic equations to represent the reacting species and products in these reactions.	• **Notional time:** 5 hours • **Syllabus links:** – Unit 3 Topic 1: Chemical equilibrium systems – Unit 4 Topic 1: Properties and structure of organic materials – Unit 4 Topic 2: Chemical synthesis and design. • **Suggested practical:** Reactions of acids with bases, metals and carbonates.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Acid rain:** Most sulfur dioxide released to the atmosphere comes from burning coal or oil in electric power stations. • **Blood chemistry:** Blood plasma is an aqueous solution containing a range of ionic and molecular substances. • **Water quality:** Knowledge of the composition of water from different sources informs decisions about how that water is treated and used.

3.5 Topic 3: Rates of chemical reactions

In this topic, students will:

Subject matter	Guidance

Rates of reactions
• explain how varying the conditions present during chemical reactions, including temperature, surface area, pressure (gaseous systems), concentration and the presence of a catalyst can affect the rate of the reaction
• use the collision theory to explain and predict the effect of concentration, temperature, pressure and surface area on the rate of chemical reactions by considering the structure of the reactants and the energy of particles
• construct and explain Maxwell-Boltzmann distribution curves for reactions with and without catalysts
• recognise that activation energy (E_a) is the minimum energy required for a chemical reaction to occur and is related to the strength and number of the existing chemical bonds; the magnitude of the activation energy influences the rate of a chemical reaction
• sketch and use energy profile diagrams, including the transitional state and catalysed and uncatalysed pathways, to represent the enthalpy changes and activation energy associated with a chemical reaction
• explain how catalysts, including enzymes and metal nanoparticles, affect the rate of certain reactions by providing an alternative reaction pathway with a reduced activation energy, hence increasing the proportion of collisions that lead to a chemical change
• use appropriate mathematical representations to calculate the rate of chemical reactions by measuring the rate of formation of products or the depletion of reactants
• analyse experimental data, including constructing and using appropriate graphical representations of relative changes in the concentration, volume and mass against time.
• **Mandatory practical:** Investigate the rate of chemical reactions.
	• **Notional time:** 10 hours
	• **Syllabus links:**
	  – Unit 3 Topic 1: Chemical equilibrium systems
	  – Unit 4 Topic 1: Properties and structure of organic materials
	  – Unit 4 Topic 2: Chemical synthesis and design.
	• Simulations could be used. Data loggers can be used.
	• Order of reaction is not required.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **The importance of enzymes:** Catalysts work in a variety of ways, and knowledge of the structure of enzyme molecules helps scientists to explain and predict how they are able to lower the activation energy for reactions. • **Cost of corrosion:** Most contemporary methods of corrosion prevention rely on knowledge of chemical and electrochemical redox processes. • **Development of collision theory:** Collision theory enables chemists to explain and predict the rates of a vast range of chemical reactions in many different contexts.

3.6 Assessment guidance

In constructing assessment instruments for Unit 2, schools should ensure that the objectives cover, or are chosen from, the unit objectives. If one assessment instrument is developed for a unit, it must assess all the unit objectives; if more than one assessment instrument is developed, the unit objectives must be covered across those instruments.

It is suggested that student performance on Unit 2 is assessed using techniques modelled on the techniques used in Unit 3:

- a student experiment
- an examination that includes some items modelled on the data test.

4 Unit 3: Equilibrium, acids and redox reactions

4.1 Unit description

In Unit 3, students explore the reversibility of reactions in a variety of chemical systems at different scales; acid-base equilibrium systems and their applications; the principles of oxidation and reduction reactions; and the production of electricity from electrochemical cells. Processes that are reversible will respond to a range of factors and can achieve a state of dynamic equilibrium, while contemporary models can be used to explain the nature of acids and bases, and their properties and uses.

Students conduct investigations on electrochemical cells and volumetric analysis applications. They examine qualitative and quantitative data about acids, equilibrium and redox to analyse trends and draw conclusions.

They participate in experiments and investigations related to the principles of dynamic chemical equilibrium and how these can be applied to chemical processes and systems; electrochemical cells, the choice of materials used and the voltage produced by these cells; pH scale and the extent of dissociation of acids and bases; and the concentrations of ions in an aqueous solution. Collaborative experimental work allows students to progressively develop their science inquiry skills, while gaining an enhanced appreciation of the importance of equilibrium and redox in the real world.

Contexts that could be investigated include environmental issues, such as acid rain and oceanic acidification; food or wine production; the historical development of theories about acids, corrosion and corrosion prevention; fuel cells; and uses of electrochemistry. Through the investigation of appropriate contexts, students explore the ways in which models and theories related to acid-base and redox reactions, and their applications, have developed over time, and the ways in which chemistry contributes to contemporary debate in industrial and environmental contexts, including the use of energy, evaluation of risk and action for sustainability.

4.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

Unit objective	IA1	IA2	EA
1. describe and explain chemical equilibrium systems and oxidation and reduction			•
2. apply understanding of chemical equilibrium systems and oxidation and reduction	•	•	•
3. analyse evidence about chemical equilibrium systems and oxidation and reduction	•	•	•
4. interpret evidence about chemical equilibrium systems and oxidation and reduction	•	•	•
5. investigate phenomena associated with chemical equilibrium systems and oxidation and reduction		•	
6. evaluate processes, claims and conclusions about chemical equilibrium systems and oxidation and reduction		•	
7. communicate understandings, findings, arguments and conclusions about chemical equilibrium systems and oxidation and reduction.		•	

4.3 Topic 1: Chemical equilibrium systems

In this topic, students will:

Subject matter	Guidance
Chemical equilibrium • recognise that chemical systems may be open (allowing matter and energy to be exchanged with the surroundings) or closed (allow energy, but not matter, to be exchanged with the surroundings) • understand that physical changes are usually reversible, whereas only some chemical reactions are reversible • appreciate that observable changes in chemical reactions and physical changes can be described and explained at an atomic and molecular level • symbolise equilibrium equations by using $\rightleftharpoons$ in balanced chemical equations • understand that, over time, physical changes and reversible chemical reactions reach a state of dynamic equilibrium in a closed system, with the relative concentrations of products and reactants defining the position of equilibrium • explain the reversibility of chemical reactions by considering the activation energies of the forward and reverse reactions • analyse experimental data, including constructing and using appropriate graphical representations of relative changes in the concentration of reactants and product against time, to identify the position of equilibrium.	• **Notional time:** 3 hours • **Syllabus links:** – Unit 1 Topic 3: Chemical reactions: reactants, products and energy change – Unit 2 Topic 3: Rates of chemical reactions – Unit 4 Topic 2: Chemical synthesis and design. • **Suggested practicals:** – Investigate reversible reactions. – Investigate factors that affect equilibrium. Simulations could be used.
Factors that affect equilibrium • explain and predict the effect of temperature change on chemical systems at equilibrium by considering the enthalpy change for the forward and reverse reactions • explain the effect of changes of concentration and pressure on chemical systems at equilibrium by applying collision theory to the forward and reverse reactions • apply Le Châtelier's principle to predict the effect changes of temperature, concentration of chemicals, pressure and the addition of a catalyst have on the position of equilibrium and on the value of the equilibrium constant.	• **Notional time:** 2 hours • **Syllabus link:** Unit 4 Topic 2: Chemical synthesis and design. • **Suggested practical:** Investigate Le Châtelier's principle.

Subject matter	Guidance
Equilibrium constants • understand that equilibrium law expressions can be written for homogeneous and heterogeneous systems and that the equilibrium constant (K_c), at any given temperature, indicates the relationship between product and reactant concentrations at equilibrium • deduce the equilibrium law expression from the equation for a homogeneous reaction and use equilibrium constants (K_c), to predict qualitatively, the relative amounts of reactants and products (equilibrium position) • deduce the extent of a reaction from the magnitude of the equilibrium constant • use appropriate mathematical representation to solve problems, including calculating equilibrium constants and the concentration of reactants and products.	• **Notional time:** 4 hours • The use of quadratic equations is not required; when K_c is very small the follow assumption can be made: $[\text{reactants}]_{\text{initial}} \approx [\text{reactants}]_{\text{equilibrium}}$ • **Formula:** $K_c = \frac{[\mathrm{C}]^{\mathrm{c}}}{[\mathrm{A}]^{\mathrm{a}}}\frac{[\mathrm{D}]^{\mathrm{d}}}{[\mathrm{B}]^{\mathrm{b}}}$ for the reaction: aA + bB $\rightleftharpoons$ cC + dD • Students should state when assumptions are used.
Properties of acids and bases • understand that acids are substances that can act as proton (hydrogen ion) donors and can be classified as monoprotic or polyprotic depending on the number of protons donated by each molecule of the acid • distinguish between strong and weak acids and bases in terms of the extent of dissociation, reaction with water and electrical conductivity and distinguish between the terms strong and concentrated for acids and bases.	• **Notional time:** 1 hour • The distinction between strength and concentration should be covered.
pH scale • understand that water is a weak electrolyte and the self-ionisation of water is represented by $K_w = [H^+][OH^-]$; K_w can be used to calculate the concentration of hydrogen ions from the concentration of hydroxide ions in a solution • understand that the pH scale is a logarithmic scale and the pH of a solution can be calculated from the concentration of hydrogen ions using the relationship pH $= -\log_{10} [H^+]$ • use appropriate mathematical representation to solve problems for hydrogen ion concentration $[H^+_{(aq)}]$, pH, hydroxide ion concentrations $[OH^-_{(aq)}]$ and pOH.	• **Notional time:** 3 hours • K_w is taken to be 1×10^{-14} at 25°C and is given in the *Chemistry formula and data booklet.* • **Formulas:** $K_w = [H^+][OH^-]$. pH $= -\log_{10}[H^+]$ pOH $= -\log_{10}[OH^-]$. • **Suggested practical:** Measure pH of a substance.

Subject matter	Guidance
Brønsted-Lowry model • recognise that the relationship between acids and bases in equilibrium systems can be explained using the Brønsted-Lowry model and represented using chemical equations that illustrate the transfer of hydrogen ions (protons) between conjugate acid-base pairs • recognise that amphiprotic species can act as Brønsted-Lowry acids and bases • identify and deduce the formula of the conjugate acid (or base) of any Brønsted-Lowry base (or acid) • appreciate that buffers are solutions that are conjugate in nature and resist a change in pH when a small amount of an acid or base is added; Le Châtelier's principle can be applied to predict how buffer solutions respond to the addition of hydrogen ions and hydroxide ions.	• **Notional time:** 2 hours • Buffer calculations are not required.
Dissociation constants • recognise that the strength of acids is explained by the degree of ionisation at equilibrium in aqueous solution, which can be represented with chemical equations and equilibrium constants (K_a) • determine the expression for the dissociation constant for weak acids (K_a) and weak bases (K_b) from balanced chemical equations • analyse experimental data to determine and compare the relative strengths of acids and bases • use appropriate mathematical representation to solve problems, including calculating dissociation constants (K_a and K_b) and the concentration of reactants and products.	• **Notional time:** 4 hours • Students should consider hydrochloric, nitric and sulfuric acids as examples of strong acids, and carboxylic and carbonic acids (aqueous carbon dioxide) as weak acids. • Students should consider all group 1 hydroxides and barium hydroxide as strong bases, and ammonia and amines as weak bases. • **Suggested practical:** Investigate the electrical conductivity of strong and weak acids and bases (simulation can be used). • **Syllabus links:** – Unit 4 Topic 1: Properties and structure of organic materials – Unit 4 Topic 2: Chemical synthesis and design. • **Formulas:** $K_w = K_a \times K_b$ $K_a = \frac{[H_3O^+][A^-]}{[HA]}$ $K_b = \frac{[BH^+][OH^-]}{[B]}$

Subject matter	Guidance
Acid-base indicators • understand that an acid-base indicator is a weak acid or a weak base where the components of the conjugate acid-base pair have different colours; the acidic form is of a different colour to the basic form • explain the relationship between the pH range of an acid-base indicator and its pK_a value • recognise that indicators change colour when the pH = pK_a and identify an appropriate indicator for a titration, given equivalence point of the titration and pH range of the indicator.	• **Notional time:** 1 hour • For an indicator that is a weak acid: $HIn_{(aq)} \rightleftharpoons H^+_{(aq)} + In^-_{(aq)}$ Colour A Colour B • For an indicator that is a weak base: $BOH_{(aq)} \rightleftharpoons B^+_{(aq)} + OH^-_{(aq)}$ Colour A Colour B • The colour change can be considered to take place over a range of pK_a ± 1. • Examples of indicators and their pK_a values are listed in the *Chemistry formula and data booklet*.
Volumetric analysis • distinguish between the terms *end point* and *equivalence point* • recognise that acid-base titrations rely on the identification of an equivalence point by measuring the associated change in pH, using chemical indicators or pH meters, to reveal an observable end point • sketch the general shapes of graphs of pH against volume (titration curves) involving strong and weak acids and bases. Identify and explain their important features, including the intercept with pH axis, equivalence point, buffer region and points where pK_a = pH or pK_b = pOH • use appropriate mathematical representations and analyse experimental data and titration curves to solve problems and make predictions, including using the mole concept to calculate moles, mass, volume and concentration from volumetric analysis data. • **Mandatory practical:** Acid-base titration to calculate the concentration of a solution with reference to a standard solution.	• **Notional time:** 5 hours • Titration of weak acid to weak base is not required.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Chemical balance in wine:** The production of wine, along with that of many other food products, relies on the successful control of a range of reversible reactions in order to maintain the required chemical balance within the product. • **Carbon dioxide in the atmosphere and hydrosphere:** The oceans contribute to the maintenance of steady concentrations of atmospheric carbon dioxide because the gas can dissolve in seawater through a range of reversible processes. • **Development of acid/base models:** ‘Superacids’, such as carborane acids, have been found to be a million times stronger than sulfuric acid when the position of equilibrium in aqueous solution is considered.

4.4 Topic 2: Oxidation and reduction

In this topic, students will:

Subject matter	Guidance
Redox reactions • recognise that a range of reactions, including displacement reactions of metals, combustion, corrosion and electrochemical processes, can be modelled as redox reactions involving oxidation of one substance and reduction of another substance • understand that the ability of an atom to gain or lose electrons can be predicted from the atom's position in the periodic table, and explained with reference to valence electrons, consideration of energy and the overall stability of the atom • identify the species oxidised and reduced, and the oxidising agent and reducing agent, in redox reactions • understand that oxidation can be modelled as the loss of electrons from a chemical species, and reduction can be modelled as the gain of electrons by a chemical species; these processes can be represented using balanced half-equations and redox equations (acidic conditions only) • deduce the oxidation state of an atom in an ion or compound and name transitional metal compounds from a given formula by applying oxidation numbers represented as roman numerals • use appropriate representations, including half-equations and oxidation numbers, to communicate conceptual understanding, solve problems and make predictions. • **Mandatory practical:** Perform single displacement reactions in aqueous solutions.	• **Notional time:** 8 hours • *Oxidation numbers* and *oxidation states* are often interchanged. IUPAC distinguishes between the two terms by using roman numerals for oxidation numbers. • Oxidation states should be represented with the sign given before the number, i.e. +2 *not* 2+ • The oxidation state of hydrogen in metal hydrides (–1) and oxygen in peroxides (–1) should be covered. • A simple activity series is given in the *Chemistry formula and data booklet*.
Electrochemical cells • understand that electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit that allows electrons to move from the anode (oxidation reaction) to the cathode (reduction reaction).	• **Notional time:** 1 hour

Subject matter	Guidance
Galvanic cells • understand that galvanic cells, including fuel cells, generate an electrical potential difference from a spontaneous redox reaction which can be represented as cell diagrams including anode and cathode half-equations • recognise that oxidation occurs at the negative electrode (anode) and reduction occurs at the positive electrode (cathode) and explain how two half-cells can be connected by a salt bridge to create a voltaic cell (examples of half-cells are Mg, Zn, Fe and Cu and their solutions of ions) • describe, using a diagram, the essential components of a galvanic cell; including the oxidation and reduction half-cells, the positive and negative electrodes and their solutions of their ions, the flow of electrons and the movement of ions, and the salt bridge. • **Mandatory practical:** Construct a galvanic cell using two metal/metal-ion half cells.	• **Notional time:** 5 hours • Simulations could be used.
Standard electrode potential • determine the relative strength of oxidising and reducing agents by comparing standard electrode potentials • recognise that cell potentials at standard conditions can be calculated from standard electrode potentials; these values can be used to compare cells constructed from different materials • recognise the limitation associated with standard reduction potentials • use appropriate mathematical representation to solve problems and make predictions about spontaneous reactions, including calculating cell potentials under standard condition.	• **Notional time:** 2 hours • A table of standard reduction potentials is given in the *Chemistry formula and data booklet*.

Subject matter	Guidance
Electrolytic cells • understand that electrolytic cells use an external electrical potential difference to provide the energy to allow a non-spontaneous redox reaction to occur, and appreciate that these can be used in small-scale and industrial situations, including metal plating and the purification of copper • predict and explain the products of the electrolysis of a molten salt and aqueous solutions of sodium chloride and copper sulfate. Explanations should refer to E° values, the nature of the electrolyte and the concentration of the electrolyte • describe, using a diagram, the essential components of an electrolytic cell; including source of electric current and conductors, positive and negative electrodes, and the electrolyte.	• **Notional time:** 4 hours • **Syllabus link:** Unit 4 Topic 2: Chemical synthesis and design • **Suggested practicals:** – Use an electrolytic cell to carry out metal plating. – Carry out electrolysis of water or copper sulfate. Simulations could be used. • Products of dilute and concentrated solutions of sodium chloride and copper sulfate should be considered.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Breathalysers and measurement of blood alcohol levels:** The level of alcohol in the body can be measured by testing breath or blood alcohol concentrations. • **Fuel cells and their uses:** Fuel cells are a potential lower-emission alternative to the internal combustion engine and are already being used to power buses, boats, trains and cars. • **Electrochemistry for clean water:** Electrochemistry has a wide range of uses, ranging from industrial scale metal extraction to personal cosmetic treatments.

4.5 Assessment

4.5.1 Summative internal assessment 1 (IA1): Data test (10%)

Description

This assessment focuses on the application of a range of cognitions to multiple provided items.

Student responses must be completed individually, under supervised conditions, and in a set timeframe.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of chemical equilibrium systems or oxidation and reduction to given algebraic, visual or graphical representations of scientific relationships and data to determine unknown scientific quantities or features
3. analyse evidence about chemical equilibrium systems or oxidation and reduction to identify trends, patterns, relationships, limitations or uncertainty in datasets
4. interpret evidence about chemical equilibrium systems or oxidation and reduction to draw conclusions based on analysis of datasets.

Note: Objectives 1, 5, 6 and 7 are not assessed in this instrument.

Specifications

Description

Students respond to items using qualitative data and/or quantitative data derived from the mandatory or suggested practicals, activities or case studies from the unit being studied.

The data test contains two to four datasets and consists of a number of different types of items, which include:

- short response items requiring single-word, sentence or short paragraph responses
- calculating using algorithms
- interpreting datasets.

Mark allocations

Percentage of marks	Objective	Cognition and nature of response
~ 30%	2. apply understanding of chemical equilibrium systems or oxidation and reduction to given algebraic, visual or graphical representations of scientific relationships and data to determine unknown scientific quantities or features	Students calculate, identify, recognise and use evidence to determine unknown scientific quantities or features.
~ 30%	3. analyse evidence about chemical equilibrium systems or oxidation and reduction to identify trends, patterns, relationships, limitations or uncertainty in datasets	Students categorise, classify, contrast, distinguish, organise or sequence evidence to identify trends, patterns, relationships, limitations or uncertainty in datasets.
~ 40%	4. interpret evidence about chemical equilibrium systems or oxidation and reduction to draw conclusions based on analysis of datasets	Students compare, deduce extrapolate, infer, justify or predict using evidence to draw conclusions based on analysis of the datasets.

Conditions

- Time: 60 minutes plus 10 minutes perusal.
- Length: up to 500 words in total, consisting of
  - short responses, i.e. single words, sentences or short paragraphs (fewer than 50 words)
  - paragraphs, 50–250 words per item
  - other types of item responses (e.g. interpreting and calculating) should allow students to complete the response in the set time.
- Other:
  - QCAA-approved graphics calculator permitted
  - Chemistry formula and data booklet permitted
  - unseen stimulus.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the data test.

Criterion	Objectives	Marks
Data test	2, 3, 4	10
Total		**10**

Note: Unit objectives 1, 5, 6 and 7 are not assessed in this instrument.

Instrument-specific marking guide

Criterion: Data test

Assessment objectives

2. apply understanding of chemical equilibrium systems or oxidation and reduction to given algebraic, visual or graphical representations of scientific relationships and data to determine unknown scientific quantities or features
3. analyse evidence about chemical equilibrium systems or oxidation and reduction to identify trends, patterns, relationships, limitations or uncertainty in datasets
4. interpret evidence about chemical equilibrium systems or oxidation and reduction to draw conclusions based on analysis of datasets

<table>
<tr><th>The student work has the following characteristics:</th><th>Cut-off</th><th>Marks</th></tr>
<tr><td rowspan="2">• consistent demonstration, across a range of scenarios about chemical equilibrium systems or oxidation and reduction, of
– selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications
– correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data
– correct and appropriate use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty
– correct interpretation of evidence to draw valid conclusions.</td><td>> 90%</td><td>10</td></tr>
<tr><td>> 80%</td><td>9</td></tr>
<tr><td rowspan="2">• consistent demonstration, in scenarios about chemical equilibrium systems or oxidation and reduction, of
– selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications
– correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data
– correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty
– correct interpretation of evidence to draw valid conclusions.</td><td>> 70%</td><td>8</td></tr>
<tr><td>> 60%</td><td>7</td></tr>
<tr><td rowspan="2">• adequate demonstration, in scenarios about chemical equilibrium systems or oxidation and reduction, of
– selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications
– correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data
– correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty
– correct interpretation of evidence to draw valid conclusions.</td><td>> 50%</td><td>6</td></tr>
<tr><td>> 40%</td><td>5</td></tr>
<tr><td rowspan="2">• demonstration, in scenarios about chemical equilibrium systems or oxidation and reduction, of elements of
– selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications
– correct calculation of quantities through the use of algebraic, visual or graphical representations of scientific relationships or data
– correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations or uncertainty
– correct interpretation of evidence to draw valid conclusions.</td><td>> 30%</td><td>4</td></tr>
<tr><td>> 20%</td><td>3</td></tr>
</table>

<table>
<tr><th>The student work has the following characteristics:</th><th>Cut-off</th><th>Marks</th></tr>
<tr><td rowspan="2">• demonstration, in scenarios about chemical equilibrium systems or oxidation and reduction, of elements of
– application of scientific concepts, theories, models or systems to predict outcomes, behaviours or implications
– calculation of quantities through the use of algebraic or graphical representations of scientific relationships and data
– use of analytical techniques to identify trends, patterns, relationships, limitations or uncertainty
– interpretation of evidence to draw conclusions.</td><td>> 10%</td><td>2</td></tr>
<tr><td>> 1%</td><td>1</td></tr>
<tr><td>• does not satisfy any of the descriptors above.</td><td>≤ 1%</td><td>0</td></tr>
</table>

4.5.2 Summative internal assessment 2 (IA2): Student experiment (20%)

Description

This assessment requires students to research a question or hypothesis through collection, analysis and synthesis of primary data. A student experiment uses investigative practices to assess a range of cognitions in a particular context. Investigative practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies and process primary data
3. analyse experimental evidence about chemical equilibrium systems or oxidation and reduction
4. interpret experimental evidence about chemical equilibrium systems or oxidation and reduction
5. investigate phenomena associated with chemical equilibrium systems or oxidation and reduction through an experiment
6. evaluate experimental processes and conclusions about chemical equilibrium systems or oxidation and reduction
7. communicate understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction.

Note: Objective 1 is not assessed in this instrument.

Specifications

Description

In the student experiment, students modify (i.e. refine, extend or redirect) an experiment in order to address their own related hypothesis or question. It is sufficient that students use a practical performed in class or a simulation as the basis for their methodology and research question.

In order to complete the assessment task, students must:

- identify an experiment to modify*
- develop a research question to be investigated*
- research relevant background scientific information to inform the modification of the research question and methodology
- conduct a risk assessment and account for risks in the methodology*
- conduct the experiment*
- collect sufficient and relevant qualitative data and/or quantitative data to address the research question*
- process and present the data appropriately
- analyse the evidence to identify trends, patterns or relationships

- analyse the evidence to identify uncertainty and limitations
- interpret the evidence to draw conclusion/s to the research question
- evaluate the reliability and validity of the experimental process
- suggest possible improvements and extensions to the experiment
- communicate findings in an appropriate scientific genre (e.g. report, poster presentation, journal article, conference presentation).

*The steps indicated with an asterisk above may be completed in groups. All other elements must be completed individually.

Scientific inquiry is a non-linear, iterative process. Students will not necessarily complete these steps in the stated order; some steps may be repeated or revisited.

Conditions

- Time: 10 hours class time. This time will not necessarily be sequential. Students must perform the majority of the task during class time, including
  - performing background research and developing the methodology
  - conducting the experiment
  - processing and analysing evidence and evaluating the methodology
  - preparing and presenting the response (e.g. writing the scientific report, constructing and presenting the scientific poster).
- Length:
  - written (e.g. scientific report), 1500–2000 words

    or

    - multimodal presentation (e.g. scientific poster presentation), 9–11 minutes.
- Other:
  - students may work collaboratively with other students to develop the methodology and perform the experiment; all other stages (e.g. processing of data, analysis of evidence and evaluation of the experimental process) must be carried out individually
  - the response must be presented using an appropriate scientific genre (e.g. report, poster presentation, journal article, conference presentation) and contain
    - a research question
    - a rationale for the experiment
    - reference to the initial experiment and identification and justification of modifications to the methodology
    - raw and processed qualitative data and/or quantitative data
    - analysis of the evidence
    - conclusion/s based on the interpretation of the evidence
    - evaluation of the methodology and suggestions of improvements and extensions to the experiment
    - a reference list.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the student experiment.

Criterion	Objectives	Marks
Research and planning	2, 5	6
Analysis of evidence	2, 3, 5	6
Interpretation and evaluation	4, 6	6
Communication	7	2
Total		**20**

Note: Unit objective 1 is not assessed in this instrument.

Instrument-specific marking guide

Criterion: Research and planning

Assessment objectives

2. apply understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies and process primary data
5. investigate phenomena associated with chemical equilibrium systems or oxidation and reduction through an experiment

The student work has the following characteristics:	Marks
• informed application of understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies demonstrated by – a considered rationale for the experiment – justified modifications to the methodology • effective and efficient investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by – a specific and relevant research question – a methodology that enables the collection of sufficient, relevant data – considered management of risks and ethical or environmental issues.	5–6
• adequate application of understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies demonstrated by – a reasonable rationale for the experiment – feasible modifications to the methodology • effective investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by – a relevant research question – a methodology that enables the collection of relevant data – management of risks and ethical or environmental issues.	3–4

The student work has the following characteristics:	Marks
• rudimentary application of understanding of chemical equilibrium systems or oxidation and reduction demonstrated by – a vague or irrelevant rationale for the experiment – inappropriate modifications to the methodology • ineffective investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by – an inappropriate research question – a methodology that causes the collection of insufficient and irrelevant data – inadequate management of risks and ethical or environmental issues.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis of evidence

Assessment objectives

2. apply understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies and process primary data
3. analyse experimental evidence about chemical equilibrium systems or oxidation and reduction
5. investigate phenomena associated with chemical equilibrium systems or oxidation and reduction through an experiment

The student work has the following characteristics:	Marks
• appropriate application of algorithms, visual and graphical representations of data about chemical equilibrium systems or oxidation and reduction demonstrated by correct and relevant processing of data • systematic and effective analysis of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of the uncertainty and limitations of evidence • effective and efficient investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by the collection of sufficient and relevant raw data.	5–6
• adequate application of algorithms, visual and graphical representations of data about chemical equilibrium systems or oxidation and reduction demonstrated by basic processing of data • effective analysis of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by – identification of obvious trends, patterns or relationships – basic identification of uncertainty and limitations of evidence • effective investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by the collection of relevant raw data.	3–4
• rudimentary application of algorithms, visual and graphical representations of data about chemical equilibrium systems or oxidation and reduction demonstrated by incorrect or irrelevant processing of data • ineffective analysis of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of uncertainty and limitations of evidence • ineffective investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by the collection of insufficient and irrelevant raw data.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Interpretation and evaluation

Assessment objectives

4. interpret experimental evidence about chemical equilibrium systems or oxidation and reduction
6. evaluate experimental processes and conclusions about chemical equilibrium systems or oxidation and reduction

<table>
<tr><th>The student work has the following characteristics:</th><th>Marks</th></tr>
<tr><td>insightful interpretation of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by justified conclusion/s linked to the research question
critical evaluation of experimental processes about chemical equilibrium systems or oxidation and reduction demonstrated by
justified discussion of the reliability and validity of the experimental process
suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence.</td><td>5–6</td></tr>
<tr><td>adequate interpretation of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by reasonable conclusion/s relevant to the research question
basic evaluation of experimental processes about chemical equilibrium systems or oxidation and reduction demonstrated by
reasonable description of the reliability and validity of the experimental process
suggested improvements and extensions to the experiment that are related to the analysis of evidence.</td><td>3–4</td></tr>
<tr><td>invalid interpretation of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by inappropriate or irrelevant conclusion/s
superficial evaluation of experimental processes about chemical equilibrium systems or oxidation and reduction demonstrated by
cursory or simplistic statements about the reliability and validity of the experimental process
ineffective or irrelevant suggestions.</td><td>1–2</td></tr>
<tr><td>does not satisfy any of the descriptors above.</td><td>0</td></tr>
</table>

Criterion: Communication

Assessment objective

7. communicate understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction

The student work has the following characteristics:	Marks
• effective communication of understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

4.5.3 Summative external assessment (EA): Examination (50%)

General information

Summative external assessment is developed and marked by the QCAA. In Chemistry it contributes 50% to a student's overall subject result.

Summative external assessment assesses learning from both Units 3 and 4.

The external assessment in Chemistry is common to all schools and administered under the same conditions, at the same time, on the same day.

See Section 5.5.2.

5 Unit 4: Structure, synthesis and design

5.1 Unit description

In Unit 4, students explore the ways in which models and theories relate to chemical synthesis, structure and design, and associated applications; and the ways in which chemistry contributes to contemporary debate regarding current and future uses of local, regional and international resources. Students focus on the principles and application of chemical synthesis, particularly in organic chemistry, and consider where and how functional groups can be incorporated into already existing carbon compounds in order to generate new substances with properties that enable them to be used in a range of contexts. Current and future applications of chemistry include the development of specialised techniques to create or synthesise new substances to meet the specific needs of society, such as pharmaceuticals, fuels, polymers and nanomaterials.

Contexts that could be investigated in this unit include green polymer chemistry, insecticides and herbicides, biofuels and molecular synthesis. Through the investigation of these contexts, students may explore the contradiction between organic chemistry advances and the environmental impact accompanying these practices.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of organic structure, reactions and syntheses. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students develop skills in experimental methodology, qualitative and quantitative data analysis and current organic developments to describe and explain the importance of this branch of chemistry to society.

5.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

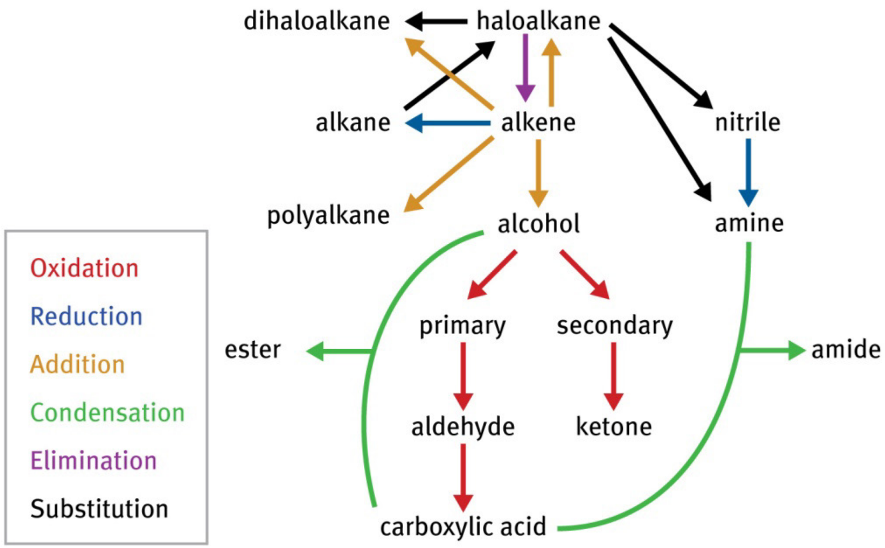
Unit objective	IA3	EA
1. describe and explain the properties and structure of organic materials and chemical synthesis and design		•
2. apply understanding of the properties and structure of organic materials and chemical synthesis and design	•	•
3. analyse evidence about the properties and structure of organic materials and chemical synthesis and design	•	•
4. interpret evidence about the properties and structure of organic materials and chemical synthesis and design	•	•
5. investigate phenomena associated with the properties and structure of organic materials and chemical synthesis and design	•	
6. evaluate processes, claims and conclusions about the properties and structure of organic materials and chemical synthesis and design	•	
7. communicate understandings, findings, arguments and conclusions about the properties and structure of organic materials and chemical synthesis and design.	•	

5.3 Topic 1: Properties and structure of organic materials

In this topic, students will:

Subject matter	Guidance
Structure of organic compounds • recognise that organic molecules have a hydrocarbon skeleton and can contain functional groups, including alkenes, alcohols, aldehydes, ketones, carboxylic acids, haloalkanes, esters, nitriles, amines, amides and that structural formulas (condensed and extended) can be used to show the arrangement of atoms and bonding in organic molecules • deduce the structural formulas and apply IUPAC rules in the nomenclature of organic compounds (parent chain up to 10 carbon atoms) with simple branching for alkanes, alkenes, alkynes, alcohols, aldehydes, ketones, carboxylic acids, haloalkanes, esters, nitriles, amines and amides • identify structural isomers as compounds with the same molecular formula but different arrangement of atoms; deduce the structural formulas and apply IUPAC rules in the nomenclature for isomers of the non-cyclic alkanes up to C_6 • identify stereoisomers as compounds with the same structural formula but with different arrangement of atoms in space; describe and explain geometrical (*cis* and *trans*) isomerism in non-cyclic alkenes. • **Mandatory practical:** Construct 3D models of organic molecules.	• **Notional time:** 8 hours • **Suggested practical:** Identify different typical functional groups in molecules. • Models or simulation could be used here.

Subject matter	Guidance
Physical properties and trends • recognise that organic compounds display characteristic physical properties, including melting point, boiling point and solubility in water and organic solvents that can be explained in terms of intermolecular forces (dispersion forces, dipole-dipole interactions and hydrogen bonds), which are influenced by the nature of the functional groups • predict and explain the trends in melting and boiling point for members of a homologous series • discuss the volatility and solubility in water of alcohols, aldehydes, ketones, carboxylic acids and halides.	• **Notional time:** 2 hours • Physical properties of hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, amines, amides and esters should be considered.
Organic reactions and reaction pathways • appreciate that each class of organic compound displays characteristic chemical properties and undergoes specific reactions based on the functional group present; these reactions, including acid-base and oxidation reactions, can be used to identify the class of the organic compound • understand that saturated compounds contain single bonds only and undergo substitution reactions, and that unsaturated compounds contain double or triple bonds and undergo addition reactions • determine the primary, secondary and tertiary carbon atoms in halogenoalkanes and alcohols and apply IUPAC rules of nomenclature • describe, using equations: – oxidation reactions of alcohols and the complete combustion of alkanes and alcohols – substitution reactions of alkanes with halogens – substitution reactions of haloalkanes with halogens, sodium hydroxide, ammonia and potassium cyanide – addition reactions of alkenes with water, halogens and hydrogen halides – addition reactions of alkenes to form poly(alkenes) • recall the acid-base properties of carboxylic acids and explain, using equations, that esterification is a reversible reaction between an alcohol and a carboxylic acid • recognise the acid-base properties of amines and explain, using equations, the reaction with carboxylic acids to form amides • recognise reduction reactions and explain, using equations, the reaction of	• **Notional time**: 7 hours • The distinction between class and functional group should be made, e.g. for OH, hydroxyl is the functional group whereas alcohol is the class. • Conversions with more than two stages will not be assessed. • Reagents, conditions and equations should be included, e.g. the reaction of 1-bromopropane to 1-butylamine can be done in two stages: 1-bromopropane can be reacted with potassium cyanide to form butanenitrile, which can then be reduced by heating with hydrogen and a nickel catalyst to form 1-butylamine. • Students are not required to recall reaction mechanisms for substitution and elimination reactions. • Addition reactions with alkenes: reactions with H_2, Br_2, H_2O and HBr (Markovnikov's rule) should be covered. • **Suggested practicals:** – Chemical tests to distinguish between alkanes and alkenes. – Chemical tests to distinguish primary, secondary and tertiary alcohols. • Summary of pathways:

Subject matter	Guidance
nitriles to form amines and alkenes to form alkanes • recognise and explain, using equations, that: – esters and amides are formed by condensation reactions – elimination reactions can produce unsaturated molecule and explain, using equations, the reaction of haloalkanes to form alkenes • understand that organic reactions can be identified using characteristic observations and recall tests to distinguish between: – alkanes and alkenes using bromine water – primary, secondary and tertiary alcohols using acidified potassium dichromate (VI) and potassium manganate (VII) • understand that the synthesis of organic compounds often involves constructing reaction pathways that may include more than one chemical reaction • deduce reaction pathways, including reagents, condition and chemical equations, given the starting materials and the product.	 Modified from: Brown, C and Ford, M 2009, *Chemistry*, 1st edition, Pearson Education, Marlow, Essex.
Organic materials: structure and function • appreciate that organic materials including proteins, carbohydrates, lipids and synthetic polymers display properties including strength, density and biodegradability that can be explained by considering the primary, secondary and tertiary structures of the materials • describe and explain the primary, secondary (α-helix and β-pleated sheets), tertiary and quaternary structure of proteins • recognise that enzymes are proteins and describe the characteristics of biological catalysts (enzymes) including that activity depends on the structure and the specificity of the enzyme action • recognise that monosaccharides contain either an aldehyde group (aldose) or a ketone group (ketose) and several -OH groups, and have the empirical formula CH_2O • distinguish between α-glucose and β-glucose, and compare and explain the structural properties of starch (amylose and amylopectin) and cellulose	• **Notional time:** 5 hours • The straight chain and α-ring forms of glucose and fructose are given in the *Chemistry data booklet*. • The common names, symbol, structural formula and pH of isoelectric point for amino acids are given in the *Chemistry data booklet*. • **Suggested practical:** Use enzymes as catalysts.

Subject matter	Guidance
• recognise that triglycerides (lipids) are esters and describe the difference in structure between saturated and unsaturated fatty acids • describe, using equations, the base hydrolysis (saponification) of fats (triglycerides) to produce glycerol and its long chain fatty acid salt (soap), and explain how their cleaning action and solubility in hard water is related to their chemical structure • explain how the properties of polymers depends on their structural features including; the degree of branching in polyethene (LDPE and HDPE), the position of the methyl group in polypropene (syntactic, isotactic and atactic) and polytetrafluorethene.	
Analytical techniques • explain how proteins can be analysed by chromatography and electrophoresis • select and use data from analytical techniques, including mass spectrometry, x-ray crystallography and infrared spectroscopy, to determine the structure of organic molecules • analyse data from spectra, including mass spectrometry and infrared spectroscopy, to communicate conceptual understanding, solve problems and make predictions.	• **Notional time:** 6 hours • **Suggested practicals:** – Separate and identify components of amino acid mixtures using chromatography and or electrophoresis. Simulations could be used. Data loggers could be used. – Identify organic compounds using mass spectrometry and infrared. Simulations could be used.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for the research investigation.	• **Functional groups and organic chemistry:** Developments in computer modelling enabled more accurate visualisation and prediction of three-dimensional organic structures, such as proteins, which is critical in drug design and biotechnology. • **Green polymer chemistry:** Synthetic polymers often have large 'ecological footprints' as they are synthesised from fossil fuels and do not biodegrade. Therefore, sustainable polymers, produced from renewable sources such as plants, waste products and waste gases are 'greener'. • **Use of organochlorine compounds as insecticides:** Organochlorine compounds, such as DDT, chlordane and lindane, were identified as powerful insecticides in the 1950s because their structure makes them chemically unreactive.

5.4 Topic 2: Chemical synthesis and design

In this topic, students will:

Subject matter	Guidance
Chemical synthesis • appreciate that chemical synthesis involves the selection of particular reagents to form a product with specific properties • understand that reagents and reaction conditions are chosen to optimise the yield and rate for chemical synthesis processes, including the production of ammonia (Haber process), sulfuric acid (contact process) and biodiesel (base-catalysed and lipase-catalysed methods) • understand that fuels, including biodiesel, ethanol and hydrogen, can be synthesised from a range of chemical reactions including, addition, oxidation and esterification • understand that enzymes can be used on an industrial scale for chemical synthesis to achieve an economically viable rate, including fermentation to produce ethanol and lipase-catalysed transesterification to produce biodiesel • describe, using equations, the production of ethanol from fermentation and the hydration of ethene • describe, using equations, the transesterification of triglycerides to produce biodiesel • discuss, using diagrams and relevant half-equations, the operation of a hydrogen fuel cell under acidic and alkaline conditions. • calculate the yield of chemical synthesis reactions by comparing stoichiometric quantities with actual quantities and by determining limiting reagents.	• **Notional time:** 6 hours • **Suggested practicals:** – simulations of the Haber process could be used – simulations of contact process could be used.

Subject matter	Guidance
Green chemistry • appreciate that green chemistry principles include the design of chemical synthesis processes that use renewable raw materials, limit the use of potentially harmful solvents and minimise the amount of unwanted products • outline the principles of green chemistry and recognise that the higher the atom economy, the 'greener' the process • calculate atom economy and draw conclusions about the economic and environmental impact of chemical synthesis processes.	• **Notional time:** 1 hour • 100% atom economy equates to all the atoms in the reactants being converted to the desired product.
Macromolecules: polymers, proteins and carbohydrates • describe, using equations, how addition polymers can be produced from their monomers including polyethene (LDPE and HDPE), polypropene and polytetrafluorethene • describe, using equations, how condensation polymers, including polypeptides (proteins), polysaccharides (carbohydrates) and polyesters, can be produced from their monomers • discuss the advantages and disadvantages of polymer use, including strength, density, lack of reactivity, use of natural resources and biodegradability • describe the condensation reaction of 2-amino acids to form polypeptides (involving up to three amino acids), and understand that polypeptides (proteins) are formed when amino acid monomers are joined by peptide bonds • describe the condensation reaction of monosaccharides to form disaccharides (lactose, maltose and sucrose) and polysaccharides (starch, glycogen and cellulose), and understand that polysaccharides are formed when monosaccharides monomers are joined by glycosidic bonds.	• **Notional time:** 7 hours • The common names, symbol, structural formula and pH of isoelectric point for amino acids are given in the *Chemistry data booklet*.
Molecular manufacturing • appreciate that molecular manufacturing processes involve the positioning of molecules to facilitate a specific chemical reaction; such methods have the potential to synthesise specialised products, including proteins, carbon nanotubes, nanorobots and chemical sensors used in medicine.	• **Notional time:** 3 hours

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for the research investigation.	• **Green synthesis methods and atom economy:** Green chemistry aims to increase the atom economy of chemical processes by designing novel reactions that can maximise the desired products and minimise by-products. Designing new synthetic schemes that can simplify operations in chemical productions, and seeking greener solvents that are inherently environmentally and ecologically benign, are also important in developing sustainable chemical industries. • **Biofuel synthesis:** Dwindling supplies of economically viable sources of fossil fuels and concerns related to carbon emissions have prompted research into the synthesis of biofuels from plant feedstocks, such as algae, oil seeds and wood waste, or from waste materials, such as food industry waste oils. • **Development of molecular manufacturing processes:** Molecular manufacturing (or molecular assembly) involves building objects to atomic precision using robotic mechanisms to position and react molecules. Molecular manufacturing arguably has the potential to quickly develop products (such as stronger materials, and smaller, faster and more energy-efficient computers) and address a range of global issues through provision of vital materials and products at a greatly reduced cost and environmental impact.

5.5 Assessment

5.5.1 Summative internal assessment 3 (IA3): Research investigation (20%)

Description

This assessment requires students to evaluate a claim. They will do this by researching, analysing and interpreting secondary evidence from scientific texts to form the basis for a justified conclusion about the claim. A research investigation uses research practices to assess a range of cognitions in a particular context. Research practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of the properties and structure of organic materials or chemical synthesis and design to develop research questions
3. analyse research evidence about the properties and structure of organic materials or chemical synthesis and design
4. interpret research evidence about the properties and structure of organic materials or chemical synthesis and design
5. investigate phenomena associated with the properties and structure of organic materials or chemical synthesis and design through research
6. evaluate research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design
7. communicate understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design.

Note: Objective 1 is not assessed in this instrument.

Specifications

Description

In the research investigation, students gather secondary evidence related to a research question in order to evaluate the claim. The students develop their research question based on a number of possible claims provided by their teacher. Students work individually throughout this task.

Evidence must be obtained by researching scientifically credible sources, such as scientific journals, books by well-credentialed scientists and websites of governments, universities, independent research bodies or science and technology manufacturers.

In order to complete the assessment task, students must:

- select a claim to be evaluated
- identify the relevant scientific concepts associated with the claim
- pose a research question addressing an aspect of the claim

- conduct research to gather scientific evidence that may be used to address the research question and subsequently evaluate the claim
- analyse the data to identify sufficient and relevant evidence
- identify the trends, patterns or relationships in the evidence
- analyse the evidence to identify limitations
- interpret the evidence to construct justified scientific arguments
- interpret the evidence to form a justified conclusion to the research question
- discuss the quality of the evidence
- evaluate the claim by extrapolating the findings of the research question to the claim
- suggest improvements and extensions to the investigation
- communicate findings in an appropriate scientific genre (e.g. report, journal article, essay, conference presentation).

Scientific inquiry is a non-linear, iterative process. Students will not necessarily complete these steps in the stated order; some steps may be repeated or revisited.

Conditions

- Time: 10 hours class time. This time will not necessarily be sequential. Students must perform the majority of the task during class time, including
  - performing background research
  - developing the research question
  - collecting scientific evidence
  - analysing and interpreting evidence and evaluating the claim
  - preparing and presenting the response (e.g. writing the scientific essay).
- Length:
  - written (e.g. scientific essay), 1500–2000 words

  or

  - multimodal presentation (e.g. scientific conference presentation), 9–11 minutes.
- Other:
  - students are to work individually throughout this task
  - the response must be presented using an appropriate scientific genre (e.g. report, journal article, essay, conference presentation) and contain
    - a claim
    - a research question
    - a rationale for the investigation
    - justified scientific arguments using evidence
    - a conclusion to the research question based on the interpretation of the evidence
    - evaluation of the claim and suggestions of improvements and extensions to the investigation
    - a reference list.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the research investigation.

Criterion	Objectives	Marks
Research and planning	2, 5	6
Analysis and interpretation	3, 4	6
Conclusion and evaluation	4, 6	6
Communication	7	2
Total		**20**

Note: Unit objective 1 is not assessed in this instrument.

Instrument-specific marking guide

Criterion: Research and planning

Assessment objectives

2. apply understanding of the properties and structure of organic materials or chemical synthesis and design to develop research questions
5. investigate phenomena associated with the properties and structure of organic materials or chemical synthesis and design through research

The student work has the following characteristics:	Marks
• informed application of understanding of the properties and structure of organic materials or chemical synthesis and design demonstrated by a considered rationale identifying clear development of the research question from the claim • effective and efficient investigation of phenomena associated with the properties and structure of organic materials or chemical synthesis and design demonstrated by – a specific and relevant research question – selection of sufficient and relevant sources.	5–6
• adequate application of understanding of the properties and structure of organic materials or chemical synthesis and design demonstrated by a reasonable rationale that links the research question and the claim • effective investigation of phenomena associated with the properties and structure of organic materials or chemical synthesis and design demonstrated by – a relevant research question – selection of relevant sources.	3–4
• rudimentary application of understanding of the properties and structure of organic materials or chemical synthesis and design demonstrated by a vague or irrelevant rationale for the investigation • ineffective investigation of phenomena associated with the properties and structure of organic materials or chemical synthesis and design demonstrated by – an inappropriate research question – selection of insufficient and irrelevant sources.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis and interpretation

Assessment objectives

3. analyse research evidence about the properties and structure of organic materials or chemical synthesis and design
4. interpret research evidence about the properties and structure of organic materials or chemical synthesis and design

The student work has the following characteristics:	Marks
• systematic and effective analysis of qualitative data and/or quantitative data within the sources about the properties and structure of organic materials or chemical synthesis and design demonstrated by – the identification of sufficient and relevant evidence – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of limitations of evidence • insightful interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by justified scientific argument/s.	5–6
• effective analysis of qualitative data and/or quantitative data within the sources about the properties and structure of organic materials or chemical synthesis and design demonstrated by – the identification of relevant evidence – identification of obvious trends, patterns or relationships – basic identification of limitations of evidence • adequate interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by reasonable scientific argument/s.	3–4
• rudimentary analysis of qualitative data and/or quantitative data within the sources about the properties and structure of organic materials or chemical synthesis and design demonstrated by – the identification of insufficient and irrelevant evidence – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of limitations of evidence • invalid interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by inappropriate or irrelevant argument/s.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Conclusion and evaluation

Assessment objectives

4. interpret research evidence about the properties and structure of organic materials or chemical synthesis and design
6. evaluate research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design

The student work has the following characteristics:	Marks
• insightful interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by justified conclusion/s linked to the research question • critical evaluation of the research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by – insightful discussion of the quality of evidence – extrapolation of credible findings of the research to the claim – suggested improvements and extensions to the investigation that are considered and relevant to the claim.	5–6
• adequate interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of the research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by – reasonable description of the quality of evidence – application of relevant findings of the research to the claim – suggested improvements and extensions to the investigation that are relevant to the claim.	3–4
• invalid interpretation of research evidence about the properties and structure of organic materials or chemical synthesis and design demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of the research processes, claims and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by – cursory or simplistic statements about the quality of evidence – application of insufficient or inappropriate findings of the research to the claim – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design

The student work has the following characteristics:	Marks
• effective communication of understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and research findings, arguments and conclusions about the properties and structure of organic materials or chemical synthesis and design demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

5.5.2 Summative external assessment (EA): Examination (50%)

General information

Summative external assessment is developed and marked by the QCAA. In Chemistry, it contributes 50% to a student's overall subject result.

Summative external assessment assesses learning from both Units 3 and 4.

The external assessment in Chemistry is common to all schools and administered under the same conditions, at the same time, on the same day.

Description

The examination assesses the application of a range of cognitions to multiple provided items — questions, scenarios and problems.

Student responses must be completed individually, under supervised conditions and in a set timeframe.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

1. describe and explain chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design
2. apply understanding of chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design
3. analyse evidence about chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design to identify trends, patterns, relationships, limitations or uncertainty
4. interpret evidence about chemical equilibrium systems, oxidation and reduction, properties and structure of organic materials, and chemical synthesis and design to draw conclusions based on analysis.

Note: Objectives 5, 6 and 7 are not assessed in this instrument.

Specifications

Description

This examination will include two papers. Each paper consists of a number of different types of possible items:

- multiple choice
- short response items requiring single-word, sentence or paragraph responses
- calculating using algorithms
- interpreting graphs, tables or diagrams
- responding to unseen data and/or stimulus.

Conditions

Paper 1

- Time: 90 minutes plus 10 minutes perusal.

- Other:
  - QCAA-approved graphics calculator permitted
  - seen Chemistry formula and data booklet provided.

Paper 2

- Time: 90 minutes plus 10 minutes perusal.
- Other:
  - QCAA-approved graphics calculator permitted
  - seen Chemistry formula and data booklet provided.

Instrument-specific marking guide

No ISMG is provided for the external assessment.

6 Glossary

Term	Explanation
A	
absolute measurement uncertainty	an estimate of the dispersion of the measurement result; the range of values around the measurement result that is most likely to include the true value (ACARA 2015c)
absolute uncertainty of the mean	the absolute uncertainty of the mean is $\pm\frac{(x_{max}-x_{min})}{2}$
accomplished	highly trained or skilled in a particular activity; perfected in knowledge or training; expert
accuracy	the condition or quality of being true, correct or exact; freedom from error or defect; precision or exactness; correctness; in science, the extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty
accurate	precise and exact; to the point; consistent with or exactly conforming to a truth, standard, rule, model, convention or known facts; free from error or defect; meticulous; correct in all details
acknowledgment	recognition of the authority or validity of something
adept	very/highly skilled or proficient at something; expert
adequate	satisfactory or acceptable in quality or quantity equal to the requirement or occasion
algebraic representation	a set of symbols linked by mathematical operations; the set of symbols summarises relationships between variables (ACARA 2015c)
algorithm	an effective procedure for solving a particular mathematical problem in a finite number of steps
analyse	dissect to ascertain and examine constituent parts and/or their relationships; break down or examine in order to identify the essential elements, features, components or structure; determine the logic and reasonableness of information; examine or consider something in order to explain and interpret it, for the purpose of finding meaning or relationships and identifying patterns, similarities and differences
analysis	examination of evidence to identify the essential features, components, elements or structure; identification of patterns, similarities and differences
analytical technique	a procedure or method for analysing data
anomaly	something that deviates from what is standard, normal or expected (Taylor 1982)

Term	Explanation
applied learning	the acquisition and application of knowledge, understanding and skills in real-world or lifelike contexts that may encompass workplace, industry and community situations; it emphasises learning through doing and includes both theory and the application of theory, connecting subject knowledge and understanding with the development of practical skills
Applied subject	a subject whose primary pathway is work and vocational education; it emphasises applied learning and community connections; a subject for which a syllabus has been developed by the QCAA with the following characteristics: results from courses developed from Applied syllabuses contribute to the QCE; results may contribute to ATAR calculations
apply	use knowledge and understanding in response to a given situation or circumstance; carry out or use a procedure in a given or particular situation
appraise	evaluate the worth, significance or status of something; judge or consider a text or piece of work
appreciate	recognise or make a judgment about the value or worth of something; understand fully; grasp the full implications of
appropriate	acceptable; suitable or fitting for a particular purpose, circumstance, context, etc.
apt	suitable to the purpose or occasion; fitting, appropriate
area of study	a division of, or a section within a unit
argue	give reasons for or against something; challenge or debate an issue or idea; persuade, prove or try to prove by giving reasons
argument	process of reasoning; series of reasons; a statement or fact tending to support a point
aspect	a particular part of a feature of something; a facet, phase or part of a whole
assess	measure, determine, evaluate, estimate or make a judgment about the value, quality, outcomes, results, size, significance, nature or extent of something
assessment	purposeful and systematic collection of information about students' achievements
assessment instrument	a tool or device used to gather information about student achievement
assessment objectives	drawn from the unit objectives and contextualised for the requirements of the assessment instrument (see also 'syllabus objectives', 'unit objectives')
assessment technique	the method used to gather evidence about student achievement (e.g. examination, project, investigation)
astute	showing an ability to accurately assess situations or people; of keen discernment
ATAR	Australian Tertiary Admission Rank

Term	Explanation
authoritative	able to be trusted as being accurate or true; reliable; commanding and self-confident; likely to be respected and obeyed
B	
balanced	keeping or showing a balance; not biased; fairly judged or presented; taking everything into account in a fair, well-judged way
basic	fundamental
behaviour	in science, the action of any material; the action or activity of an individual
C	
calculate	determine or find (e.g. a number, answer) by using mathematical processes; obtain a numerical answer showing the relevant stages in the working; ascertain/determine from given facts, figures or information
categorise	place in or assign to a particular class or group; arrange or order by classes or categories; classify, sort out, sort, separate
challenging	difficult but interesting; testing one's abilities; demanding and thought-provoking; usually involving unfamiliar or less familiar elements
characteristic	a typical feature or quality
claim	an assertion made without any accompanying evidence to support it
clarify	make clear or intelligible; explain; make a statement or situation less confused and more comprehensible
clarity	clearness of thought or expression; the quality of being coherent and intelligible; free from obscurity of sense; without ambiguity; explicit; easy to perceive, understand or interpret
classify	arrange, distribute or order in classes or categories according to shared qualities or characteristics
clear	free from confusion, uncertainty, or doubt; easily seen, heard or understood
clearly	in a clear manner; plainly and openly, without ambiguity
coherent	having a natural or due agreement of parts; connected; consistent; logical, orderly; well-structured and makes sense; rational, with parts that are harmonious; having an internally consistent relation of parts
cohesive	characterised by being united, bound together or having integrated meaning; forming a united whole
collate	to put together; to compare
collection	in science, a systematic approach to gathering and measuring evidence from a variety of sources in order to evaluate outcomes and make predictions

Term	Explanation
comment	express an opinion, observation or reaction in speech or writing; give a judgment based on a given statement or result of a calculation
communicate	convey knowledge and/or understandings to others; make known; transmit
compare	display recognition of similarities and differences and recognise the significance of these similarities and differences
competent	having suitable or sufficient skills, knowledge, experience, etc. for some purpose; adequate but not exceptional; capable; suitable or sufficient for the purpose; having the necessary ability, knowledge or skill to do something successfully; efficient and capable (of a person); acceptable and satisfactory, though not outstanding
competently	in an efficient and capable way; in an acceptable and satisfactory, though not outstanding, way
complex	composed or consisting of many different and interconnected parts or factors; compound; composite; characterised by an involved combination of parts; complicated; intricate; a complex whole or system; a complicated assembly of particulars
comprehend	understand the meaning or nature of; grasp mentally
comprehensive	inclusive; of large content or scope; including or dealing with all or nearly all elements or aspects of something; wide-ranging; detailed and thorough, including all that is relevant
concept	in science, an idea or model explaining some natural phenomenon; a theoretical construct; a thought, idea or notion
concise	expressing much in few words; giving a lot of information clearly and in a few words; brief, comprehensive and to the point; succinct, clear, without repetition of information
concisely	in a way that is brief but comprehensive; expressing much in few words; clearly and succinctly
conclusion	a judgment based on evidence (ACARA 2015c)
conduct	direct in action or course; manage; organise; carry out
consider	think deliberately or carefully about something, typically before making a decision; take something into account when making a judgment; view attentively or scrutinise; reflect on
considerable	fairly large or great; thought about deliberately and with a purpose
considered	formed after careful and deliberate thought

Term	Explanation
consistent	agreeing or accordant; compatible; not self-opposed or self-contradictory, constantly adhering to the same principles; acting in the same way over time, especially so as to be fair or accurate; unchanging in nature, standard, or effect over time; not containing any logical contradictions (of an argument); constant in achievement or effect over a period of time
construct	create or put together (e.g. an argument) by arranging ideas or items; display information in a diagrammatic or logical form; make; build
contrast	display recognition of differences by deliberate juxtaposition of contrary elements; show how things are different or opposite; give an account of the differences between two or more items or situations, referring to both or all of them throughout
controlled	shows the exercise of restraint or direction over; held in check; restrained, managed or kept within certain bounds
convincing	persuaded by argument or proof; leaving no margin of doubt; clear; capable of causing someone to believe that something is true or real; persuading or assuring by argument or evidence; appearing worthy of belief; credible or plausible
correct	conforming to fact or truth; accurate
course	a defined amount of learning developed from a subject syllabus
create	bring something into being or existence; produce or evolve from one's own thought or imagination; reorganise or put elements together into a new pattern or structure or to form a coherent or functional whole
creative	resulting from originality of thought or expression; relating to or involving the use of the imagination or original ideas to create something; having good imagination or original ideas
credible	capable or worthy of being believed; believable; convincing
criterion/criteria	the property or characteristic by which something is judged or appraised
critical	involving skilful judgment as to truth, merit, etc.; involving the objective analysis and evaluation of an issue in order to form a judgment; expressing or involving an analysis of the merits and faults of a work of literature, music, or art; incorporating a detailed and scholarly analysis and commentary (of a text); rationally appraising for logical consistency and merit
critique	review (e.g. a theory, practice, performance) in a detailed, analytical and critical way
cursory	hasty, and therefore not thorough or detailed; performed with little attention to detail; going rapidly over something, without noticing details; hasty; superficial
D	
data	in science, measurements of an attribute or attributes; data may be quantitative or qualitative and be from primary or secondary sources (ACARA 2015c)

Term	Explanation
dataset	qualitative data and/or quantitative data (e.g. diagram, graph, image, map, photograph, table) derived from a practical, activity or case study
decide	reach a resolution as a result of consideration; make a choice from a number of alternatives
deduce	reach a conclusion that is necessarily true, provided a given set of assumptions is true; arrive at, reach or draw a logical conclusion from reasoning and the information given
defensible	justifiable by argument; capable of being defended in argument
define	give the meaning of a word, phrase, concept or physical quantity; state meaning and identify or describe qualities
demonstrate	prove or make clear by argument, reasoning or evidence, illustrating with practical example; show by example; give a practical exhibition
derive	arrive at by reasoning; manipulate a mathematical relationship to give a new equation or relationship; in mathematics, obtain the derivative of a function
describe	give an account (written or spoken) of a situation, event, pattern or process, or of the characteristics or features of something
design	produce a plan, simulation, model or similar; plan, form or conceive in the mind; in English, select, organise and use particular elements in the process of text construction for particular purposes; these elements may be linguistic (words), visual (images), audio (sounds), gestural (body language), spatial (arrangement on the page or screen) and multimodal (a combination of more than one)
detailed	executed with great attention to the fine points; meticulous; including many of the parts or facts
determine	establish, conclude or ascertain after consideration, observation, investigation or calculation; decide or come to a resolution
develop	elaborate, expand or enlarge in detail; add detail and fullness to; cause to become more complex or intricate
devise	think out; plan; contrive; invent
differentiate	identify the difference/s in or between two or more things; distinguish, discriminate; recognise or ascertain what makes something distinct from similar things; in mathematics, obtain the derivative of a function
discerning	discriminating; showing intellectual perception; showing good judgment; making thoughtful and astute choices; selected for value or relevance
discriminate	note, observe or recognise a difference; make or constitute a distinction in or between; differentiate; note or distinguish as different

Term	Explanation
discriminating	differentiating; distinctive; perceiving differences or distinctions with nicety; possessing discrimination; perceptive and judicious; making judgments about quality; having or showing refined taste or good judgment
discuss	examine by argument; sift the considerations for and against; debate; talk or write about a topic, including a range of arguments, factors or hypotheses; consider, taking into account different issues and ideas, points for and/or against, and supporting opinions or conclusions with evidence
disjointed	disconnected; incoherent; lacking a coherent order/sequence or connection
distinguish	recognise as distinct or different; note points of difference between; discriminate; discern; make clear a difference/s between two or more concepts or items
diverse	of various kinds or forms; different from each other
document	support (e.g. an assertion, claim, statement) with evidence (e.g. decisive information, written references, citations)
draw conclusions	make a judgment based on reasoning and evidence
E	
effective	successful in producing the intended, desired or expected result; meeting the assigned purpose
efficient	working in a well-organised and competent way; maximum productivity with minimal expenditure of effort; acting or producing effectively with a minimum of waste, expense or unnecessary effort
element	a component or constituent part of a complex whole; a fundamental, essential or irreducible part of a composite entity
elementary	simple or uncompounded; relating to or dealing with elements, rudiments or first principles (of a subject); of the most basic kind; straightforward and uncomplicated
erroneous	based on or containing error; mistaken; incorrect
essential	absolutely necessary; indispensable; of critical importance for achieving something
evaluate	make an appraisal by weighing up or assessing strengths, implications and limitations; make judgments about ideas, works, solutions or methods in relation to selected criteria; examine and determine the merit, value or significance of something, based on criteria
evidence	in science, evidence is data that has been selected as it is considered reliable and valid and can be used to support a particular idea, conclusion or decision; evidence gives weight or value to data by considering its credibility, acceptance, bias, status, appropriateness and reasonableness (ACARA 2015c)

Term	Explanation
examination	a supervised test that assesses the application of a range of cognitions to one or more provided items such as questions, scenarios and/or problems; student responses are completed individually, under supervised conditions, and in a set timeframe
examine	investigate, inspect or scrutinise; inquire or search into; consider or discuss an argument or concept in a way that uncovers the assumptions and interrelationships of the issue
experiment	try out or test new ideas or methods, especially in order to discover or prove something; undertake or perform a scientific procedure to test a hypothesis, make a discovery or demonstrate a known fact in science, an investigation that involves carrying out a practical activity
experimental	relating to, derived from, or founded on experiment
explain	make an idea or situation plain or clear by describing it in more detail or revealing relevant facts; give an account; provide additional information
explicit	clearly and distinctly expressing all that is meant; unequivocal; clearly developed or formulated; leaving nothing merely implied or suggested
explore	look into both closely and broadly; scrutinise; inquire into or discuss something in detail
express	convey, show or communicate (e.g. a thought, opinion, feeling, emotion, idea or viewpoint); in words, art, music or movement, convey or suggest a representation of; depict
extend	in science, to extend an experiment is to modify the methodology to overcome limitations of the scope or applicability of the data
extended response	an open-ended assessment technique that focuses on the interpretation, analysis, examination and/or evaluation of ideas and information in response to a particular situation or stimulus; while students may undertake some research when writing the extended response, it is not the focus of this technique; an extended response occurs over an extended and defined period of time; an item on an examination may also require an extended response, either written or oral
Extension subject	a two-unit subject for which a syllabus has been developed by QCAA; it is an extension of one or more general or alternative sequence subject/s; studied concurrently with the final two units of that subject/s or after completion of, the final two units of that subject/s
extensions	in science, modifications to an investigation that could be used to further examine a claim
extensive	of great extent; wide; broad; far-reaching; comprehensive; lengthy; detailed; large in amount or scale

Term	Explanation
external assessment	summative assessment that occurs towards the end of a course of study and is common to all schools; developed and marked by the QCAA according to a commonly applied marking scheme
external examination	a supervised test, developed and marked by the QCAA, that assesses the application of a range of cognitions to multiple provided items such as questions, scenarios and/or problems; student responses are completed individually, under supervised conditions, and in a set timeframe
extrapolate	infer or estimate by extending or projecting known information; conjecture; infer from what is known; extend the application of something (e.g. a method or conclusion) to an unknown situation by assuming that existing trends will continue or similar methods will be applicable
extrapolation	extension of a conclusion to a new situation with the assumption that existing trends will continue
F	
factual	relating to or based on facts; concerned with what is actually the case; actually occurring; having verified existence
familiar	well-acquainted; thoroughly conversant with; well known from long or close association; often encountered or experienced; common; (of materials, texts, skills or circumstances) having been the focus of learning experiences or previously encountered in prior learning activities
feasible	capable of being achieved, accomplished or put into effect; reasonable enough to be believed or accepted; probable; likely
feature	distinctive attribute, characteristic, property or quality of evidence
findings	in science, the outcomes of research, investigation or experimentation, including facts or principles established in these ways
fluent	spoken or written with ease; able to speak or write smoothly, easily or readily; articulate; eloquent; in artistic performance, characteristic of a highly developed and excellently controlled technique; flowing; polished; flowing smoothly, easily and effortlessly
fluently	in a graceful and seemingly effortless manner; in a way that progresses smoothly and readily
formative assessment	assessment whose major purpose is to improve teaching and student achievement
fragmented	disorganised; broken down; disjointed or isolated
frequent	happening or occurring often at short intervals; constant, habitual, or regular
fundamental	forming a necessary base or core; of central importance; affecting or relating to the essential nature of something; part of a foundation or basis

Term	Explanation
G	
General subject	a subject for which a syllabus has been developed by the QCAA with the following characteristics: results from courses developed from General syllabuses contribute to the QCE; General subjects have an external assessment component; results may contribute to ATAR calculations
generate	produce; create; bring into existence
genre conventions	agreed and acceptable conditions; a style or category
graphical representation	in science, a visual representation of the relationship between quantities plotted with reference to a set of axes; also known as a graph (ACARA 2015c)
green chemistry	chemistry that aims to design products and processes that minimise the use and generation of hazardous substances and wastes. Principles of green chemistry include prevention of waste; atom economy; design of less toxic chemicals and synthesis methods; use of safer solvents and auxiliaries; design for energy efficiency; use of renewable feedstocks; reduction of unnecessary derivatives; use of catalytic reagents rather than stoichiometric reagents; design for degradation; design of in-process analysis for pollution prevention; and safer chemistry for accident prevention. (ACARA 2015c)
H	
hypothesis	in science, a tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement that can be supported or refuted by experiment (ACARA 2015c)
hypothesise	formulate a supposition to account for known facts or observed occurrences; conjecture, theorise, speculate; especially on uncertain or tentative grounds
I	
identify	distinguish; locate, recognise and name; establish or indicate who or what someone or something is; provide an answer from a number of possibilities; recognise and state a distinguishing factor or feature
illogical	lacking sense or sound reasoning; contrary to or disregardful of the rules of logic; unreasonable
implement	put something into effect, e.g. a plan or proposal
implication	a likely consequence of something; a conclusion that may be drawn though it is implied rather than explicit
implicit	implied, rather than expressly stated; not plainly expressed; capable of being inferred from something else
improbable	not probable; unlikely to be true or to happen; not easy to believe
improvements	in science, modifications to an investigation that mitigate the limitations of the evidence, method or design
inaccurate	not accurate

Term	Explanation
inadequate	not satisfactory or acceptable in quality and/or quantity to the requirements of the situation
inappropriate	not suitable or proper in the circumstances
inconsistent	lacking agreement, as one thing with another, or two or more things in relation to each other; at variance; not consistent; not in keeping; not in accordance; incompatible, incongruous
incorrect	not conforming to fact or truth
independent	thinking or acting for oneself, not influenced by others
in-depth	comprehensive and with thorough coverage; extensive or profound; well-balanced or fully developed
ineffective	not producing a result, or not producing any significant result; not producing the intended, desired or expected result
infer	derive or conclude something from evidence and reasoning, rather than from explicit statements; listen or read beyond what has been literally expressed; imply or hint at
informed	knowledgeable; learned; having relevant knowledge; being conversant with the topic; based on an understanding of the facts of the situation (of a decision or judgment)
innovative	new and original; introducing new ideas; original and creative in thinking
insightful	showing understanding of a situation or process; understanding relationships in complex situations; informed by observation and deduction
instrument-specific marking guide	ISMG; a tool for marking that describes the characteristics evident in student responses and aligns with the identified objectives for the assessment (see 'assessment objectives')
insufficient	not enough; inadequate for the purpose
integral	*adjective* necessary for the completeness of the whole; essential or fundamental; *noun* in mathematics, the result of integration; an expression from which a given function, equation, or system of equations is derived by differentiation
intended	designed; meant; done on purpose; intentional
internal assessment	assessments that are developed by schools; summative internal assessments are endorsed by the QCAA before use in schools and results externally confirmed; contributes towards a student's final result

Term	Explanation
interpret	use knowledge and understanding to recognise trends and draw conclusions from given information; make clear or explicit; elucidate or understand in a particular way; bring out the meaning of, e.g. a dramatic or musical work, by performance or execution; bring out the meaning of an artwork by artistic representation or performance; give one's own interpretation of; identify or draw meaning from, or give meaning to, information presented in various forms, such as words, symbols, pictures or graphs
invalid	not sound, just or well-founded; not having a sound basis in logic or fact (of an argument or point); not reasonable or cogent; not able to be supported; not legitimate or defensible; not applicable
investigate	carry out an examination or formal inquiry in order to establish or obtain facts and reach new conclusions; search, inquire into, interpret and draw conclusions about data and information
investigation	an assessment technique that requires students to research a specific problem, question, issue, design challenge or hypothesis through the collection, analysis and synthesis of primary and/or secondary data; it uses research or investigative practices to assess a range of cognitions in a particular context; an investigation occurs over an extended and defined period of time in science, a scientific process of answering a question, exploring an idea or solving a problem that requires activities such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities (ACARA 2015c)
irrelevant	not relevant; not applicable or pertinent; not connected with or relevant to something
ISMG	instrument-specific marking guide; a tool for marking that describes the characteristics evident in student responses and aligns with the identified objectives for the assessment (see ‘assessment objectives’)
isolated	detached, separate, or unconnected with other things; one-off; something set apart or characterised as different in some way
J	
judge	form an opinion or conclusion about; apply both procedural and deliberative operations to make a determination
justified	sound reasons or evidence are provided to support an argument, statement or conclusion
justify	give reasons or evidence to support an answer, response or conclusion; show or prove how an argument, statement or conclusion is right or reasonable

Term	Explanation
L	
learning area	a grouping of subjects, with related characteristics, within a broad field of learning, e.g. the Arts, sciences, languages
limitation	a weak point or disadvantage that makes evidence less effective
link	anything serving to connect one part or thing with another
logical	rational and valid; internally consistent; reasonable; reasoning in accordance with the principles/rules of logic or formal argument; characterised by or capable of clear, sound reasoning; (of an action, decision, etc.) expected or sensible under the circumstances
logically	according to the rules of logic or formal argument; in a way that shows clear, sound reasoning; in a way that is expected or sensible
M	
make decisions	select from available options; weigh up positives and negatives of each option and consider all the alternatives to arrive at a position
management	handling, direction or control
manipulate	adapt or change to suit one's purpose
matter	a physical substance; anything that has mass and occupies space (Macquarie 1981)
measurement uncertainty	the measure of doubt associated with the measured result due to imprecision; it may be represented as an absolute uncertainty or as a percentage uncertainty (Taylor 1982)
mental procedures	a domain of knowledge in Marzano's taxonomy, and acted upon by the cognitive, metacognitive and self-systems; sometimes referred to as 'procedural knowledge' there are three distinct phases to the acquisition of mental procedures — the cognitive stage, the associative stage, and the autonomous stage; the two categories of mental procedures are skills (single rules, algorithms and tactics) and processes (macroprocedures)
methodical	performed, disposed or acting in a systematic way; orderly; characterised by method or order; performed or carried out systematically
methodology	a systematic, ordered approach to gathering data in a scientific experiment or investigation
minimal	least possible; small, the least amount; negligible
model	in science, a representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea (ACARA 2015c)

Term	Explanation
modifications	in science, changes to methodology to extend, refine or redirect the research focus
modify	change the form or qualities of; make partial or minor changes to something
multimodal	uses a combination of at least two modes (e.g. spoken, written), delivered at the same time, to communicate ideas and information to a live or virtual audience, for a particular purpose; the selected modes are integrated so that each mode contributes significantly to the response
N	
narrow	limited in range or scope; lacking breadth of view; limited in amount; barely sufficient or adequate; restricted
nuanced	showing a subtle difference or distinction in expression, meaning, response, etc.; finely differentiated; characterised by subtle shades of meaning or expression; a subtle distinction, variation or quality; sensibility to, awareness of, or ability to express delicate shadings, as of meaning, feeling, or value
O	
objectives	see 'syllabus objectives', 'unit objectives', 'assessment objectives'
obvious	clearly perceptible or evident; easily seen, recognised or understood
optimal	best, most favourable, under a particular set of circumstances
organise	arrange, order; form as or into a whole consisting of interdependent or coordinated parts, especially for harmonious or united action
organised	systematically ordered and arranged; having a formal organisational structure to arrange, coordinate and carry out activities
outcome	result of something; a consequence
outlier	a value that 'lies outside' (is much smaller or larger than) most of the other values in a set of data
outstanding	exceptionally good; clearly noticeable; prominent; conspicuous; striking
P	
partial	not total or general; existing only in part; attempted, but incomplete
particular	distinguished or different from others or from the ordinary; noteworthy
pattern	a repeated occurrence or sequence (ACARA 2015c)
percentage error	a mathematical indication of how accurate the measurements were with respect to the accepted value of a quantity $Percentage\ error\ (\%) = \left\lvert \frac{measured\ value - true\ value}{true\ value} \right\rvert \times 100$ (Taylor 1982)
perceptive	having or showing insight and the ability to perceive or understand; discerning (see also 'discriminating')

Term	Explanation
performance	an assessment technique that requires students to demonstrate a range of cognitive, technical, creative and/or expressive skills and to apply theoretical and conceptual understandings, through the psychomotor domain; it involves student application of identified skills when responding to a task that involves solving a problem, providing a solution or conveying meaning or intent; a performance is developed over an extended and defined period of time
persuasive	capable of changing someone's ideas, opinions or beliefs; appearing worthy of approval or acceptance; (of an argument or statement) communicating reasonably or credibly (see also 'convincing')
perusal time	time allocated in an assessment to reading items and tasks and associated assessment materials; no writing is allowed; students may not make notes and may not commence responding to the assessment in the response space/book
phenomena	events that are not artificial and can be observed through the senses or can be scientifically described or explained
planning time	time allocated in an assessment to planning how to respond to items and tasks and associated assessment materials; students may make notes but may not commence responding to the assessment in the response space/book; notes made during planning are not collected, nor are they graded or used as evidence of achievement
polished	flawless or excellent; performed with skilful ease
practical	in science, an activity that produces primary data
precise	definite or exact; definitely or strictly stated, defined or fixed; characterised by definite or exact expression or execution
precision	accuracy; exactness; exact observance of forms in conduct or actions in science, exactness; how close two or more measurements of the same object or phenomena are to each other
predict	give an expected result of an upcoming action or event; suggest what may happen based on available information
primary data	data collected directly by a person or group (ACARA 2015c)
primary source	information created by the person or persons directly involved in a study, investigation or experiment or observing an event (ACARA 2015c)
process	in science, to collect and manipulate data to produce meaningful information; operate on a set of data to extract the required information in an appropriate form such as tables or graphs
product	an assessment technique that focuses on the output or result of a process requiring the application of a range of cognitive, physical, technical, creative and/or expressive skills, and theoretical and conceptual understandings; a product is developed over an extended and defined period of time
proficient	well advanced or expert in any art, science or subject; competent, skilled or adept in doing or using something

Term	Explanation
project	an assessment technique that focuses on a problem-solving process requiring the application of a range of cognitive, technical and creative skills and theoretical understandings; the response is a coherent work that documents the iterative process undertaken to develop a solution and includes written paragraphs and annotations, diagrams, sketches, drawings, photographs, video, spoken presentations, physical prototypes and/or models; a project is developed over an extended and defined period of time
propose	put forward (e.g. a point of view, idea, argument, suggestion) for consideration or action
prove	use a sequence of steps to obtain the required result in a formal way
purposeful	having an intended or desired result; having a useful purpose; determined; resolute; full of meaning; significant; intentional
psychomotor procedures	a domain of knowledge in Marzano's taxonomy, and acted upon by the cognitive, metacognitive and self-systems; these are physical procedures used to negotiate daily life and to engage in complex physical activities; the two categories of psychomotor procedures are skills (foundational procedures and simple combination procedures) and processes (complex combination procedures)
Q	
QCE	Queensland Certificate of Education
qualitative data	information that is not numerical in nature
quality of evidence	the standard of evidence, as measured against relevant criteria
quantitative data	numerical information (Taylor 1982)
quantity	in science, having magnitude, size, extent, amount or the like
R	
random error	uncontrollable effects of the measurement equipment, procedure and environment on a measurement result; the magnitude of random error for a measurement result can be estimated by finding the spread of values around the average of independent, repeated measurements of the quantity (ACARA 2015c)
rationale	a set of reasons, or logical basis for a course of action or decision
raw data	unprocessed and/or unanalysed data; data that has been collected without any additional processing (Taylor 1982)
realise	create or make (e.g. a musical, artistic or dramatic work); actualise; make real or concrete; give reality or substance to
reasonable	endowed with reason; having sound judgment; fair and sensible; based on good sense; average; appropriate, moderate
reasoned	logical and sound; based on logic or good sense; logically thought out and presented with justification; guided by reason; well-grounded; considered

Term	Explanation
recall	remember; present remembered ideas, facts or experiences; bring something back into thought, attention or into one's mind
recognise	identify or recall particular features of information from knowledge; identify that an item, characteristic or quality exists; perceive as existing or true; be aware of or acknowledge
redirect	in science, to redirect an experiment is to modify the methodology to gain further insight into the phenomena observed in the original experiment
referencing conventions	agreed, consistent ways of referencing a source of information
refine	in science, to refine an experiment is to modify the methodology to obtain more accurate or precise data
refined	developed or improved so as to be precise, exact or subtle
reflect on	think about deeply and carefully
rehearsed	practised; previously experienced; practised extensively
related	associated with or linked to
relationship	scientific relationships are a connection or association between ideas or between components of systems and structures (ACARA 2015c)
relevance	being related to the matter at hand
relevant	bearing upon or connected with the matter in hand; to the purpose; applicable and pertinent; having a direct bearing on
reliability	in science, the likelihood that another experimenter will obtain the same results (or very similar results) if they perform exactly the same experiment under the same conditions (ACARA 2015c, Taylor 1982)
reliable	constant and dependable or consistent and repeatable
repetitive	containing or characterised by repetition, especially when unnecessary or tiresome
reporting	providing information that succinctly describes student performance at different junctures throughout a course of study
representation/s	in science, verbal, physical or mathematical demonstration of understanding of a science concept or concepts; a concept can be represented in a range of ways and using multiple models (ACARA 2015c)
research	to locate, gather, record, and analyse information in order to develop understanding (ACARA 2015c)
research ethics	norms of conduct that determine ethical research behaviour; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics (ACARA 2015c)

Term	Explanation
research question	a question that directs the scientific inquiry activity; it focuses the research investigation or student experiment, informing the direction of the research, and guiding all stages of inquiry, analysis, interpretation and evaluation
resolve	in the Arts, consolidate and communicate intent through a synthesis of ideas and application of media to express meaning
risk assessment	evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities; requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate (ACARA 2015c)
routine	often encountered, previously experienced; commonplace; customary and regular; well-practised; performed as part of a regular procedure, rather than for a special reason
rudimentary	relating to rudiments or first principles; elementary; undeveloped; involving or limited to basic principles; relating to an immature, undeveloped or basic form
S	
safe	secure; not risky
scientific language	terminology that has specific meaning in a scientific context
scrutinise	to examine closely or critically
secondary data	data collected by a person or group other than the person or group using the data (ACARA 2015c, Macquarie 1981)
secure	sure; certain; able to be counted on; self-confident; poised; dependable; confident; assured; not liable to fail
select	choose in preference to another or others; pick out
sensitive	capable of perceiving with a sense or senses; aware of the attitudes, feelings or circumstances of others; having acute mental or emotional sensibility; relating to or connected with the senses or sensation
sequence	place in a continuous or connected series; arrange in a particular order
show	provide the relevant reasoning to support a response
significant	important; of consequence; expressing a meaning; indicative; includes all that is important; sufficiently great or important to be worthy of attention; noteworthy; having a particular meaning; indicative of something
significant figures	the use of place value to represent a measurement result accurately and precisely (ACARA 2015c)
simple	easy to understand, deal with and use; not complex or complicated; plain; not elaborate or artificial; may concern a single or basic aspect; involving few elements, components or steps

Term	Explanation
simplistic	characterised by extreme simplification, especially if misleading; oversimplified
simulation	a representation of a process, event or system which imitates a real or idealised situation (ACARA 2015c)
sketch	execute a drawing or painting in simple form, giving essential features but not necessarily with detail or accuracy; in mathematics, represent by means of a diagram or graph; the sketch should give a general idea of the required shape or relationship and should include features
skilful	having technical facility or practical ability; possessing, showing, involving or requiring skill; expert, dexterous; demonstrating the knowledge, ability or training to perform a certain activity or task well; trained, practised or experienced
skilled	having or showing the knowledge, ability or training to perform a certain activity or task well; having skill; trained or experienced; showing, involving or requiring skill
solve	find an answer to, explanation for, or means of dealing with (e.g. a problem); work out the answer or solution to (e.g. a mathematical problem); obtain the answer/s using algebraic, numerical and/or graphical methods
sophisticated	of intellectual complexity; reflecting a high degree of skill, intelligence, etc.; employing advanced or refined methods or concepts; highly developed or complicated
source	any piece of scientific literature or text from which scientific evidence is drawn
specific	clearly defined or identified; precise and clear in making statements or issuing instructions; having a special application or reference; explicit, or definite; peculiar or proper to something, as qualities, characteristics, effects, etc.
sporadic	happening now and again or at intervals; irregular or occasional; appearing in scattered or isolated instances
statement	a communication or declaration setting forth facts, particulars; an expression
straightforward	without difficulty; uncomplicated; direct; easy to do or understand
structure	*verb* give a pattern, organisation or arrangement to; construct or arrange according to a plan; *noun* in languages, arrangement of words into larger units, e.g. phrases, clauses, sentences, paragraphs and whole texts, in line with cultural, intercultural and textual conventions
structured	organised or arranged so as to produce a desired result
subject	a branch or area of knowledge or learning defined by a syllabus; school subjects are usually based in a discipline or field of study (see also ‘course’)

Term	Explanation
subject matter	the subject-specific body of information, mental procedures and psychomotor procedures that are necessary for students' learning and engagement within that subject
substantial	of ample or considerable amount, quantity, size, etc.; of real worth or value; firmly or solidly established; of real significance; reliable; important, worthwhile
substantiated	established by proof or competent evidence
subtle	fine or delicate in meaning or intent; making use of indirect methods; not straightforward or obvious
successful	achieving or having achieved success; accomplishing a desired aim or result
succinct	expressed in few words; concise; terse; characterised by conciseness or brevity; brief and clear
sufficient	enough or adequate for the purpose
suitable	appropriate; fitting; conforming or agreeing in nature, condition, or action
summarise	give a brief statement of a general theme or major point/s; present ideas and information in fewer words and in sequence
summative assessment	assessment whose major purpose is to indicate student achievement; summative assessments contribute towards a student's subject result
superficial	concerned with or comprehending only what is on the surface or obvious; shallow; not profound, thorough, deep or complete; existing or occurring at or on the surface; cursory; lacking depth of character or understanding; apparent and sometimes trivial
supported	corroborated; given greater credibility by providing evidence
sustained	carried on continuously, without interruption, or without any diminishing of intensity or extent
syllabus	a document that prescribes the curriculum for a course of study
syllabus objectives	outline what the school is required to teach and what students have the opportunity to learn; described in terms of actions that operate on the subject matter; the overarching objectives for a course of study (see also 'unit objectives', 'assessment objectives')
symbolise	represent or identify by a symbol or symbols
synthesise	combine different parts or elements (e.g. information, ideas, components) into a whole, in order to create new understanding
system	a group of interacting objects, materials or processes that form an integrated whole; systems can be open or closed (ACARA 2015c)

Term	Explanation
systematic	done or acting according to a fixed plan or system; methodical; organised and logical; having, showing, or involving a system, method, or plan; characterised by system or method; methodical; arranged in, or comprising an ordered system
systematic errors	an error that is affected by the accuracy of a measurement process that causes readings to deviate from the accepted value by a consistent amount each time a measurement is made (Taylor 1982)
T	
test	take measures to check the quality, performance or reliability of something
theory	in science, a set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena; theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power (ACARA 2015c)
thorough	carried out through, or applied to the whole of something; carried out completely and carefully; including all that is required; complete with attention to every detail; not superficial or partial; performed or written with care and completeness; taking pains to do something carefully and completely
thoughtful	occupied with, or given to thought; contemplative; meditative; reflective; characterised by or manifesting thought
topic	a division of, or sub-section within a unit; all topics/sub-topics within a unit are interrelated
trend	general direction in which something is changing (ACARA 2015c)
U	
uncertainty	range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment (ACARA 2015c); indicators of uncertainty may include percentage, and/or absolute measurement uncertainty, confidence intervals, inferential statistics, statistical measure of spread, e.g. range, standard deviation
unclear	not clear or distinct; not easy to understand; obscure
understand	perceive what is meant by something; grasp; be familiar with (e.g. an idea); construct meaning from messages, including oral, written and graphic communication
understanding	perception of what is meant by something
uneven	unequal; not properly corresponding or agreeing; irregular; varying; not uniform; not equally balanced
unfamiliar	not previously encountered; situations or materials that have not been the focus of prior learning experiences or activities

Term	Explanation
unit	a defined amount of subject matter delivered in a specific context or with a particular focus; it includes unit objectives particular to the unit, subject matter and assessment direction
unit objectives	drawn from the syllabus objectives and contextualised for the subject matter and requirements of a particular unit; they are assessed at least once in the unit (see also 'syllabus objectives', 'assessment objectives')
unrelated	having no relationship; unconnected
use	operate or put into effect; apply knowledge or rules to put theory into practice
V	
vague	not definite in statement or meaning; not explicit or precise; not definitely fixed, determined or known; of uncertain, indefinite or unclear character or meaning; not clear in thought or understanding; couched in general or indefinite terms; not definitely or precisely expressed; deficient in details or particulars; thinking or communicating in an unfocused or imprecise way
valid	sound, just or well-founded; authoritative; having a sound basis in logic or fact (of an argument or point); reasonable or cogent; able to be supported; legitimate and defensible; applicable
validity	in science, the extent to which tests measure what was intended; the extent to which data, inferences and actions produced from tests and other processes are accurate (ACARA 2015c)
variable	*adjective* apt or liable to vary or change; changeable; inconsistent; (readily) susceptible or capable of variation; fluctuating, uncertain; *noun* in mathematics, a symbol, or the quantity it signifies, that may represent any one of a given set of number and other objects in science, a factor that can be changed, kept the same or measured in an investigation, e.g. time, distance, light, temperature
variety	a number or range of things of different kinds, or the same general class, that are distinct in character or quality; (of sources) a number of different modes or references
visual representations	in science, an image that shows relationships within scientific evidence
W	
wide	of great range or scope; embracing a great number or variety of subjects, cases, etc.; of full extent
with expression	in words, art, music or movement, conveying or indicating feeling, spirit, character, etc.; a way of expressing or representing something; vivid, effective or persuasive communication

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8 Version history

Version	Date of change	Update
1.1	June 2017	Minor editorial changes
1.2	December 2017	Editorial changes
		Syllabus objective 2: Amendment to explanatory paragraph
		Subject matter • Unit 3: Topic 1 Dissociation constants — ‘evaluate’ changed to ‘compare’ the relative strengths of acids and bases • Unit 4: Topic 2 Green chemistry — ‘evaluate’ changed to ‘draw conclusions about’ the economic and environmental impact of chemical synthesis processes
		IA1: Data test • Minor amendments to Assessment objectives 2,3 & 4 • Percentage of marks modified – objective 3 — 40% changed to 30% – objective 4 — 30% changed to 40% • Condition amendment (Length) — 400 words changed to ‘up to 500 words’
		IA2: Student experiment • Minor amendment to Assessment objective 5
		IA3: Research investigation • Minor amendment to Assessment objective 5
		Amendments to ISMGs to reflect modifications to objectives
		Glossary update
1.3	June 2018	Editorial changes
		Minor amendments to formulas in Unit 1 and Unit 2
		IA1: Data test • Minor amendments to Assessment objective 2 • Minor amendments to description and conditions • Addition of information about cognition and nature of response for each objective
		IA2: Student experiment • Minor editorial changes to ISMG
		IA3: Research investigation • Minor editorial changes to ISMG
		EA: Examination • Minor amendments to Assessment objectives 3 and 4 • Minor amendments to description and conditions
		Glossary updates
1.4	July 2022	Amendments to Unit 1 and Unit 2 Assessment guidance

ISBN: 978-1-921802-91-1

Chemistry General Senior Syllabus 2019

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