Chemistry subject report

2021 cohort

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Introduction

Despite the challenges brought about by the COVID-19 pandemic, Queensland's education community can look back on 2021 with satisfaction at having implemented the first full assessment cycle in the new Queensland Certificate of Education (QCE) system. That meant delivering three internal assessments and one external assessment in each General subject.

This report analyses that cycle — from endorsing summative internal assessment instruments to confirming internal assessment marks, and designing and marking external assessment. It also gives readers information about:

- applying syllabus objectives in the design and marking of internal and external assessments
- patterns of student achievement.

The report promotes continuous improvement by:

- identifying effective practices in the design and marking of valid, accessible and reliable assessments
- recommending where and how to enhance the design and marking of valid, accessible and reliable assessment instruments
- providing examples of best practice where relevant, possible and appropriate.

Audience and use

This report should be read by school leaders, subject leaders and teachers to:

- inform teaching and learning and assessment preparation
- assist in assessment design practice
- assist in making assessment decisions
- help prepare students for external assessment.

The report is publicly available to promote transparency and accountability. Students, parents, community members and other education stakeholders can learn about the assessment practices and outcomes for General subjects (including alternative sequences (AS) and Senior External Examination (SEE) subjects, where relevant) and General (Extension) subjects.

Report preparation

The report includes analyses of data and other information from endorsement, confirmation and external assessment processes. It also includes advice from the chief confirmer, chief endorser and chief marker, developed in consultation with and support from QCAA subject matter experts.

Subject data summary

Subject completion

The following data includes students who completed the General subject.

Note: All data is correct as at 17 December 2021. Where percentages are provided, these are rounded to two decimal places and, therefore, may not add up to 100%.

Number of schools that offered the subject: 413.

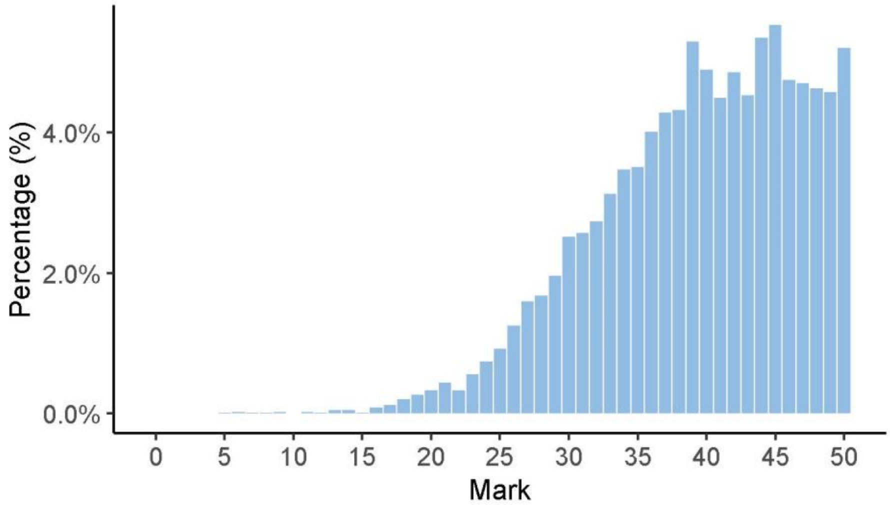
Completion of units	Unit 1	Unit 2	Units 3 and 4
Number of students completed	10300	9459	8207

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory
Unit 1	9663	637
Unit 2	8707	752

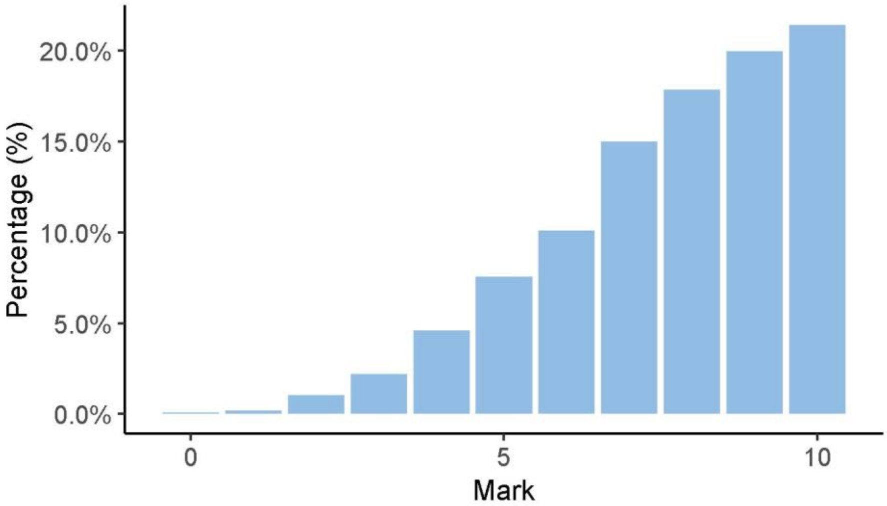
Units 3 and 4 internal assessment (IA) results

Total marks for IA

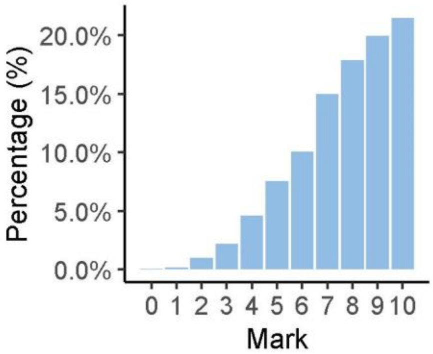


IA1 marks

IA1 total

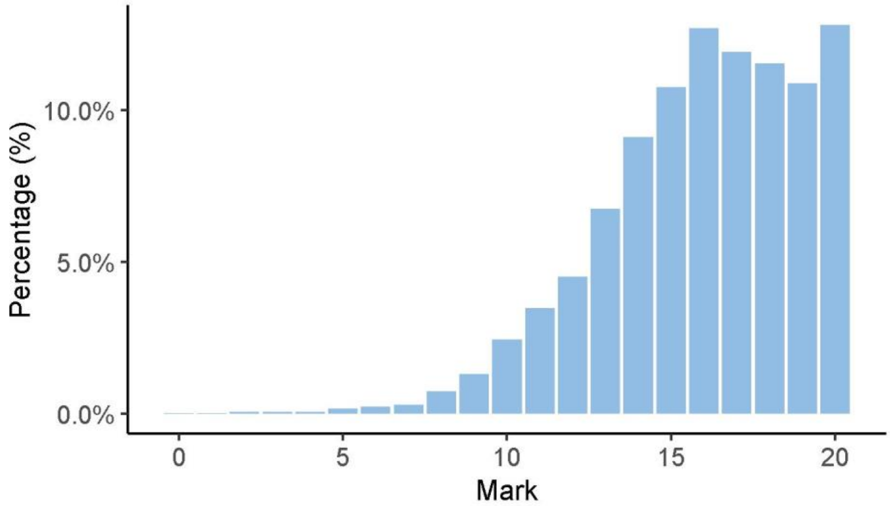


IA1 Criterion: Data test

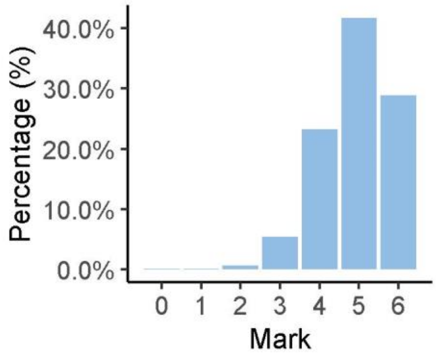


IA2 marks

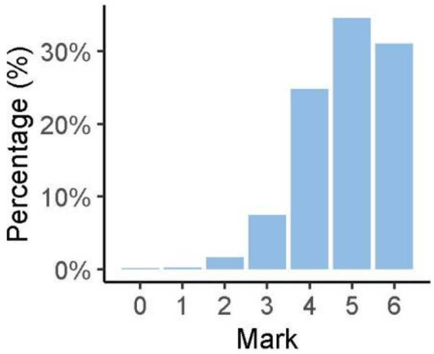
IA2 total



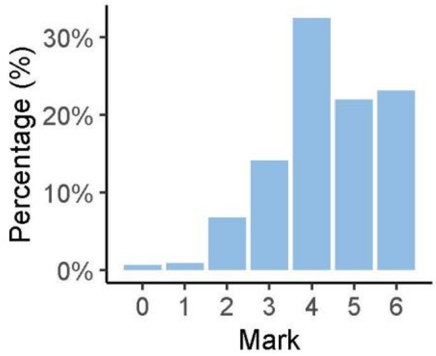
IA2 Criterion: Research and planning



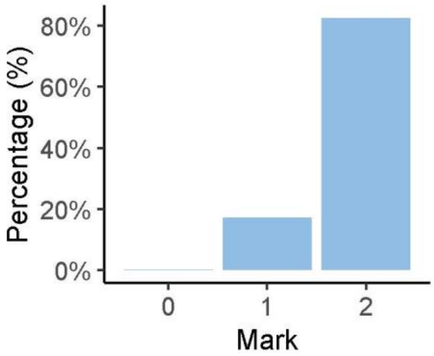
IA2 Criterion: Analysis of evidence



IA2 Criterion: Interpretation and evaluation

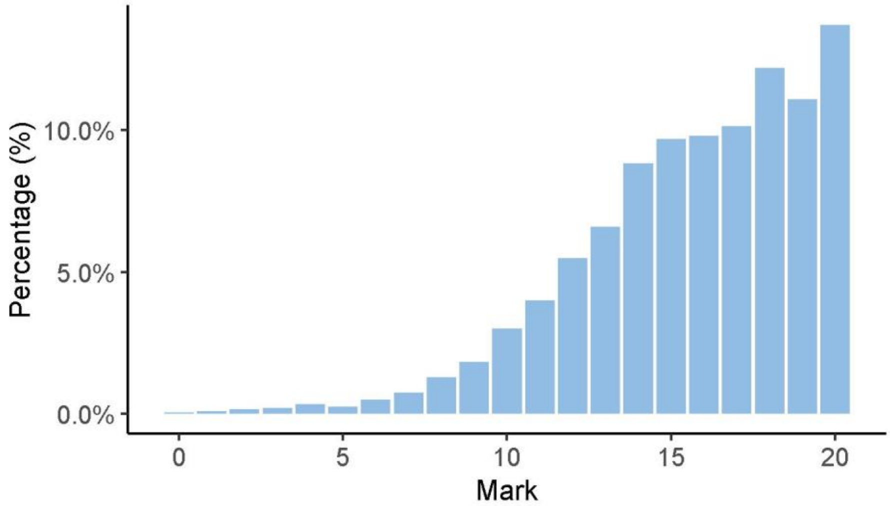


IA2 Criterion: Communication

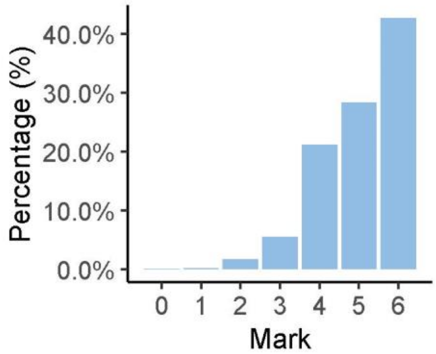


IA3 marks

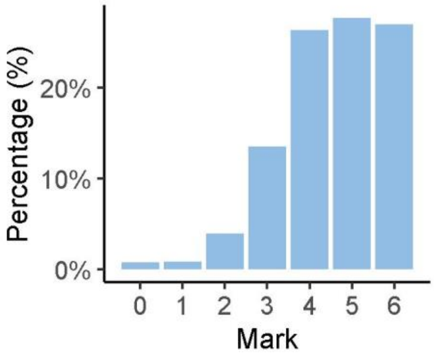
IA3 total



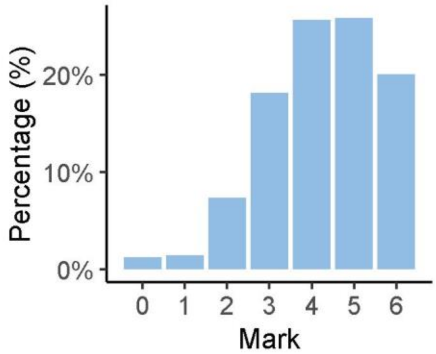
IA3 Criterion: Research and planning



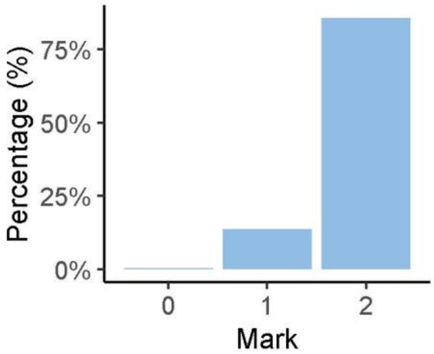
IA3 Criterion: Analysis and interpretation



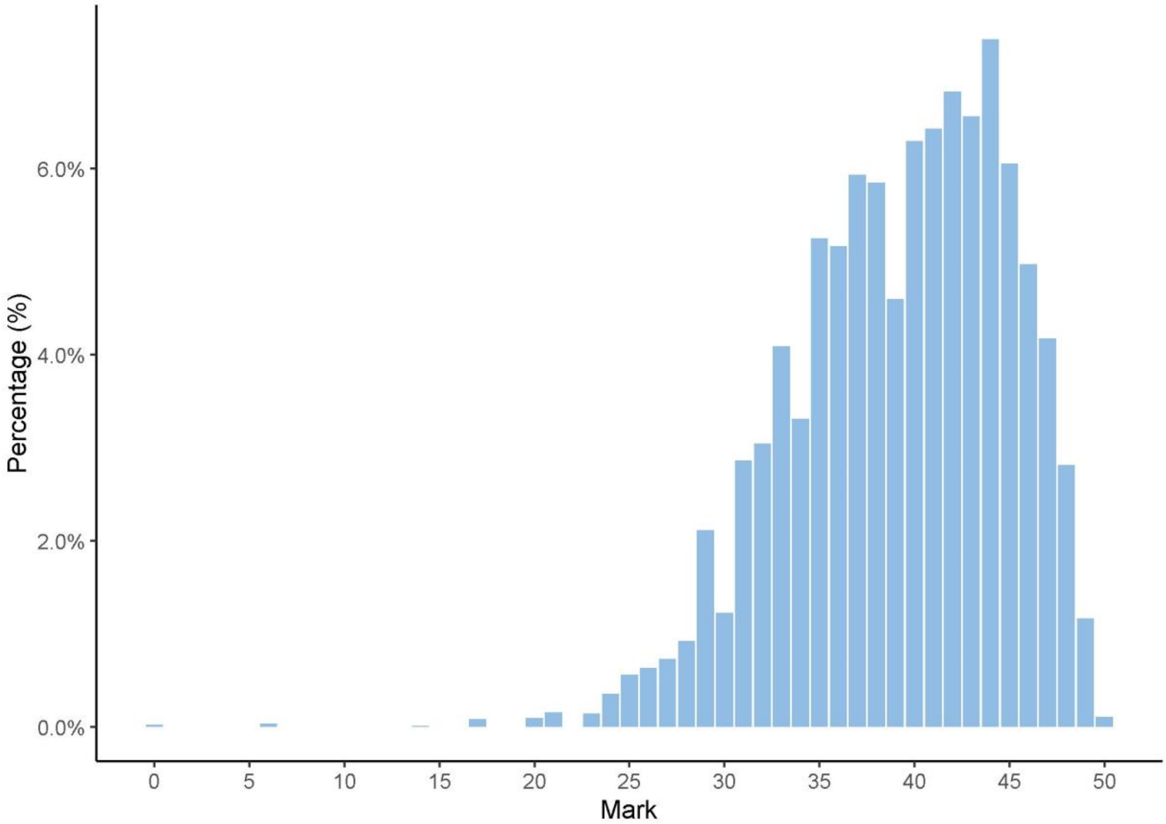
IA3 Criterion: Conclusion and evaluation



IA3 Criterion: Communication

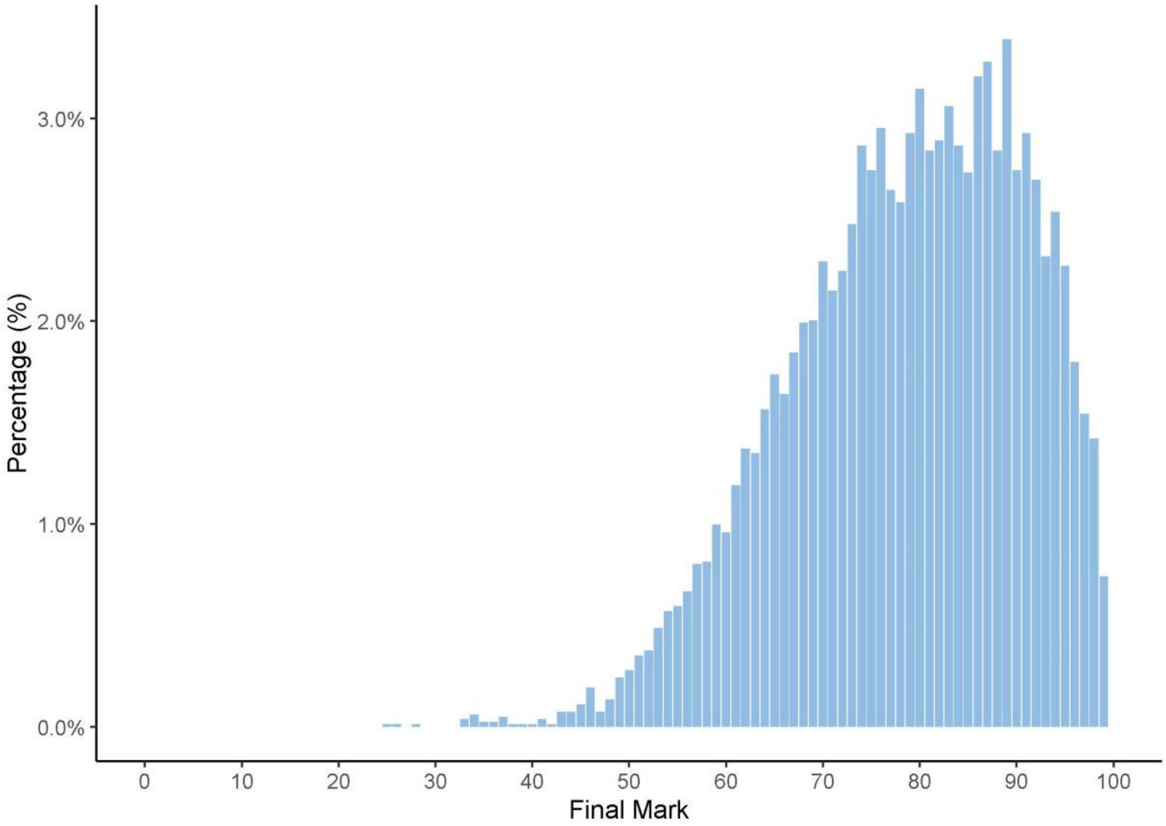


External assessment (EA) marks



Final subject results

Final marks for IA and EA



Grade boundaries

The grade boundaries are determined using a process to compare results on a numeric scale to the reporting standards.

Standard	A	B	C	D	E
Marks achieved	100–85	84–70	69–49	48–17	16–0

Distribution of standards

The number of students who achieved each standard across the state is as follows.

Standard	A	B	C	D	E
Number of students	3002	3339	1790	79	0

Internal assessment

The following information and advice pertain to the assessment design and assessment decisions for each IA in Units 3 and 4. These instruments have undergone quality assurance processes informed by the attributes of quality assessment (validity, accessibility and reliability).

Endorsement

Endorsement is the quality assurance process based on the attributes of validity and accessibility. These attributes are categorised further as priorities for assessment, and each priority can be further broken down into assessment practices.

Data presented in the Assessment design section identifies the reasons why IA instruments were not endorsed at Application 1, by the priority for assessments. An IA may have been identified more than once for a priority for assessment, e.g. it may have demonstrated a misalignment to both the subject matter and the assessment objective/s.

Refer to the quality assurance tools for detailed information about the assessment practices for each assessment instrument.

Percentage of instruments endorsed in Application 1

Number of instruments submitted	IA1	IA2	IA3
Total number of instruments	413	413	412
Percentage endorsed in Application 1	39%	86%	89%

Confirmation

Confirmation is the quality assurance process based on the attribute of reliability. The QCAA uses provisional criterion marks determined by teachers to identify the samples of student responses that schools are required to submit for confirmation.

Confirmation samples are representative of the school's decisions about the quality of student work in relation to the ISMG and are used to make decisions about the cohort's results. If further information is required about the school's application of the ISMG to finalise a confirmation decision, the QCAA requests additional samples.

Schools may request a review where an individual student's confirmed result is different from the school's provisional mark in one or more criteria and the school considers this result to be an anomaly or exception.

The following table includes the percentage agreement between the provisional marks and confirmed marks by assessment instrument. The Assessment decisions section of this report for each assessment instrument identifies the agreement trends between provisional and confirmed marks by criterion.

Number of samples reviewed and percentage agreement

IA	Number of schools	Number of samples requested	Number of additional samples requested	Percentage agreement with provisional marks
1	410	2197	0	99.27%
2	409	2317	287	84.39%
3	409	2292	292	86.8%

Internal assessment 1 (IA1)

Data test (10%)

The IA1 data test requires students to apply a range of cognitions to multiple provided items. Students respond to items using qualitative and/or quantitative data derived from practicals, activities or case studies on chemical equilibrium systems or oxidation and reduction. The task requires students to identify unknown scientific quantities or features; identify trends, patterns, relationships, limitations or uncertainty in datasets; and draw conclusions based on the analysis of data.

Assessment design

Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	182
Authentication	2
Authenticity	20
Item construction	56
Scope and scale	29

*Each priority might contain up to four assessment practices.

Total number of submissions: 413.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- provided stimulus and datasets that were relevant to the topics of Unit 3, i.e. Chemical equilibrium systems and Oxidation and reduction
- featured items that were clearly aligned with the corresponding objective by considering both the cognitive verb and the nature of the response and assessed only one cognitive process, e.g. calculate an average
- contained stimulus items that were of suitable scope and scale, e.g. datasets clearly based on data adapted from the mandatory or suggested practicals
- followed a consistent approach to mark value (i.e. one mark per cognition) as opposed to occasionally using half marks.

Practices to strengthen

It is recommended that assessment instruments:

- contain items that are clearly aligned with the corresponding objective by using an appropriate cognitive verb and requiring an appropriate nature of response, e.g. in an objective 3 item, '*identify* a trend in the dataset'. Teachers should refer to the Mark allocations table in Syllabus section 4.5.1 for guidance on the appropriate cognitive verbs and responses associated with each objective
- match the conventions of item construction required for the data test, e.g. not including multiple choice questions
- ensure the mark allocation for each item matches the scale of work required to respond to the item, e.g. avoid the inconsistent use of part marks for items
- assess each cognitive process (e.g. calculating an average) once only.

Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

Reasons for non-endorsement by priority of assessment

Accessibility priority	Number of times priority was identified in decisions*
Bias avoidance	60
Language	94
Layout	29
Transparency	60

*Each priority might contain up to four assessment practices.

Total number of submissions: 413.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- avoided gender or cultural bias and inappropriate content
- used appropriate language and avoided jargon, specialist language and colloquial language that did not contribute understanding of subject matter
- provided response spaces that were adequate and reflected the expected length of the response.

Practices to strengthen

It is recommended that assessment instruments:

- provide clear instructions using cues that align to the specifications, objectives and marking scheme
- contain images, diagrams and other visual elements that are legible, clear, relevant and accessible
- use bolding and italics in a consistent and appropriate manner
- model accurate spelling and scientific conventions.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and confirmed marks

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional	Percentage both less and greater than provisional
1	Data test	99.27%	0.73%	0%	0%

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- clear and accurate marking schemes were provided, showing the breakdown and allocation of marks for each question
- comparable tasks had corresponding marking schemes that showed the breakdown and allocation of marks for each question
- the marking scheme was consistently and accurately applied across all samples for the cohort
- the correct percentage cut-off was applied when determining the final marks on the ISMG.

Samples of effective practices

There are no student response excerpts because either the student/s did not provide permission or there were third-party copyright issues in the response/s.

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG for this IA, it is recommended that:

- partial credit (i.e. half marks) should not be awarded for responses that demonstrate incomplete cognition, e.g. working that would not lead to a correct response, two contradictory responses to the same item
- marks are correctly totalled to ensure cut-offs and final marks are correct
- percentage cut-offs from the ISMG are correctly applied.

Additional advice

- Schools should ensure that uploaded student responses are complete and include any additional pages where responses may be found.
- If a comparable task is developed, schools should ensure it is clearly marked as a comparable task. Schools should ensure a marking guide for the comparable task is developed and uploaded with the task.

Internal assessment 2 (IA2)

Student experiment (20%)

The IA2 student experiment requires students to modify (i.e. refine, extend or redirect) an experiment to address their own hypothesis or question related to chemical equilibrium systems or oxidation and reduction. Students may use a practical performed in class as the basis for their methodology. They develop a research question, collect and process primary data, analyse and interpret evidence, and evaluate the reliability and validity of their experimental process.

Assessment design

Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	14
Authentication	19
Authenticity	0
Item construction	22
Scope and scale	0

*Each priority might contain up to four assessment practices.

Total number of submissions: 413.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- provided practicals that were more closely related to the topics of Unit 3 (i.e. Chemical equilibrium systems and Oxidation and reduction) than topics from Units 1 or 2 or from other subjects
- used authentication strategies to identify how individual students would be assessed during group work
- used scaffolding that did not repeat or redefine information already provided in the assessment instrument.

Practices to strengthen

It is recommended that assessment instruments:

- provide task specifications that match all the specifications in Syllabus section 4.5.2
- provide scaffolding with clear instructions that inform students about the processes they could use to complete the response or the presentation requirements for their response, e.g. steps taken to develop a research question
- provide checkpoints that are suitable for the task and align with authentication strategies and confirmation deadlines.

Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

Reasons for non-endorsement by priority of assessment

Accessibility priority	Number of times priority was identified in decisions*
Bias avoidance	0
Language	6
Layout	1
Transparency	3

*Each priority might contain up to four assessment practices.

Total number of submissions: 413.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- provided clear instructions using cues that aligned with the specifications, objectives and ISMGs
- used appropriate language and avoided jargon, specialist language and colloquial language that did not contribute to the understanding of subject matter
- were free of errors and modelled accurate spelling, grammar, punctuation and other textual features
- used bold, italics and other formatting features only where relevant.

Practices to strengthen

There were no significant issues identified for improvement.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and confirmed marks

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional	Percentage both less and greater than provisional
1	Research and planning	88.29%	10.98%	0.73%	0%
2	Analysis of evidence	90.49%	7.80%	1.46%	0.24%
3	Interpretation and evaluation	90.73%	8.78%	0.49%	0%
4	Communication	98.54%	0.73%	0.73%	0%

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- in the Research and planning criterion
  - a *considered* rationale clearly connected the research question to subject matter from Unit 3
  - a *specific* research question was explicit enough to be answered within the required response length, e.g. the relationship between the dependent and independent variable was evident
  - modifications to the methodology were *justified* using concepts from Unit 3 subject matter
  - the methodology enabled collection of *sufficient and relevant* data to draw valid conclusions, e.g. at least five data points to establish a trend
- in the Interpretation and evaluation criterion
  - conclusions were *justified* by referring to the trends/patterns/relationships and uncertainty/limitations identified in the analysis of evidence
  - *discussion* of the reliability and validity of the experimental process was *justified* by referring to the uncertainty and limitations identified in the analysis of the evidence
  - suggested improvements and extensions to the experiment were *logically derived* from the uncertainty and limitations of evidence identified in the analysis.

Samples of effective practices

The following are excerpts from responses that illustrate the characteristics for the criteria at the performance level indicated. The excerpts may provide evidence of more than one criterion. The characteristics identified may not be the only time the characteristics have occurred throughout the response.

This student response excerpt has been included:

- to demonstrate a considered rationale, the development of a suitable research question and justified modifications of the methodology.

Research and planning (5–6 marks)

- a considered rationale for the experiment
- a specific and relevant research question
- justified modifications to the methodology

Rationale

Electrochemistry studies chemical processes which cause electrons to move from one species to another. This movement of charged particles (electrons) is called electricity. These reactions which produce electricity, are called redox reactions (Libre Texts, 2020). An example of an electrochemical cell that uses spontaneous redox reactions to generate electricity is galvanic cells. Galvanic cells are important as it is the basis for batteries, such as lithium-ion batteries. In lithium-ion batteries, electrons flow from the anode to the cathode to form a single source of voltage (Lumen Candela, 2020). The half-reactions that occur at each electrode is given below:

$Li_{(s)} \rightarrow Li^{+} + e^{-}$ (anode half-cell)

$Li^{+}_{(aq)} + CoO_2 + e^{-} \rightarrow LiCoO_{2\,(s)}$ (cathode half-cell)

$Li^{+}_{(s)} + CoO_2 \rightarrow LiCoO_{2\,(s)}$ (overall reaction)

Galvanic cells consist of two separate half cells and a flow of electrons, which produces an electric current through an external circuit. Consequently, creating batteries that power engines or devices (Z. Ahmad, 2006). Thus, fuelling modern society. The power of the battery can be determined by the cell potential.

The cell potential of a battery, measured in voltage, is the difference in electrical potential between the two half-cells. Higher cell potentials have the potential to 'push' more electrons at a lower current. A higher voltage battery is more efficient and experiences less energy loss from resistance (Khan Academy, 2020). Hence, it's important to study what effects the cell potential by producing higher voltages. A study by John Newman which modelled these lithium-ion batteries, suggested that increasing the concentration of the electrolyte in the lithium half-cell would increase the cell potential (J. Newman, 2003). Altering the concentration of the electrolyte increases the number of anions or cations, so it puts the system further out of equilibrium. This causes a steeper concentration gradient across the half-cells, hence increasing the cell potential (N. Vassal, 2017). However, this hypothesis is under standard conditions, but this experiment is under non-standard conditions. To assess the effects of concentration on the cell potential, the Nernst Equation for non-standard conditions will be used:

$$E = E^{o} - \frac{RT}{nF} ln\,Q$$

The original experiment indicated that the metals constituting the electrodes also affects the cell potential. Consequently, zinc was modified to magnesium because magnesium metal would produce a higher theoretical cell potential (appendix 1) (J. Chandler 2015). As mentioned, a higher theoretical cell potential would be more efficient and have less resistance. Hence lowering error through larger and clearer results, thus increasing practicality in modern society. Figure 1 and equation below model the modifications:

$Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Cu_{(s)} + Mg^{2+}_{(aq)}$

A salt bridge consisting of chromatograph paper soaked in potassium sulphate was chosen as the salt solution completely dissociates due to its high solubility. This allows the exchanging of ions to take place between the half cells (K.A. Khan, 2018).

Research Question

Does increasing the concentration of an electrolyte (copper II sulphate) at the cathode affect the potential difference produced in three minutes of a galvanic cell with a magnesium metal electrode in a magnesium sulphate solution for the anode?

RQ - a specific and relevant research question

Original Experiment

The methodology has been adapted from *Pearson Chemistry 12 Queensland* (M. Brown et al., 2019). Mandatory Practical 3 investigated essential components of galvanic cells such as cell potentials. The aim of the original experiment was modified to qualitatively examine one galvanic cell and the effects of increasing the concentration of the electrolyte.

Methodology Modifications

To ensure relevant and specific data was collected, the original experiment was:

Refined by:

a) Introducing a DC voltmeter that indicates voltages to two decimal places to quantify the voltage passing through the external circuit between the two half cells. This allows applications of the Nernst equation with more accurate readings. Thus, increasing validity.
b) Using a timer to indicate 30 seconds increments. This increases the sample size to calculate more reliable averages.
c) Making the copper sulphate concentrations. This allows dilutions and measurement uncertainties and errors to be controlled. Consequently, managing the accuracy of the concentrations.
d) Increasing the independent variable range for concentrations to five variables (1.25M, 1M, 0.75M, 0.5M, 0.25M) with six trials. This will increase the quantity of the comparative data, thus increasing validity.

Extended by:

a) making comparisons with theoretical and experimental cell potentials allows conclusions to be drawn on how much concentration affects cell potential.

Redirected by:

a) Changing the half cells combinations. A copper electrode in a copper (II) sulphate solution for the cathode and a magnesium electrode in a magnesium sulphate solution. The theoretical cell potential was higher than that of the original method which makes the readers of the DC voltmeter easier to read. Hence, increasing accuracy.

This student response excerpt has been included:

- to demonstrate thorough and appropriate identification of uncertainties to support the thorough identification of trends, patterns and relationships relevant to the research question.

Analysis of evidence (5–6 marks)

- thorough and appropriate identification of uncertainties and limitations of evidence
- thorough identification of relevant trends, patterns or relationships

Graph 1: Mean voltage produced over 7mins with 10sec intervals, five different treatments (0.500, 0.250, 0.200, 0.150, 0.100M).

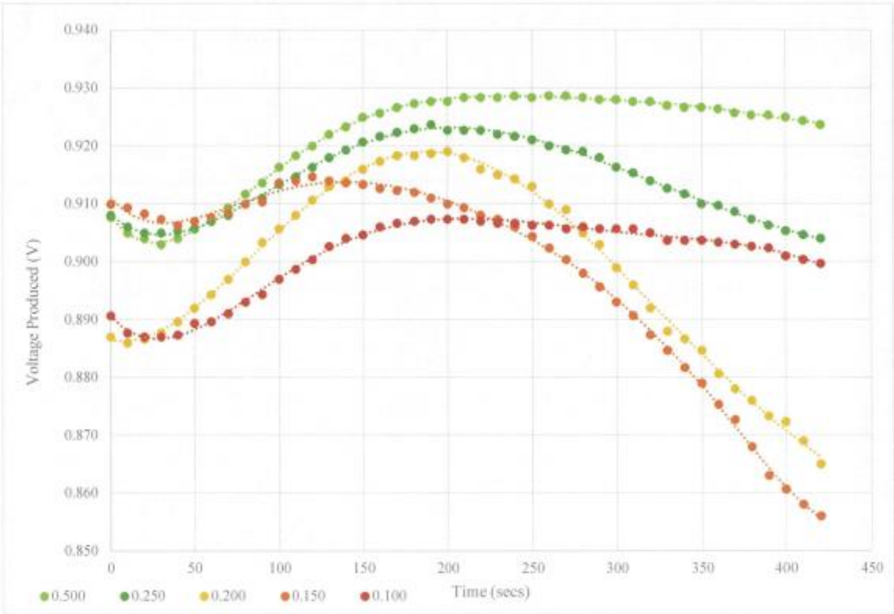


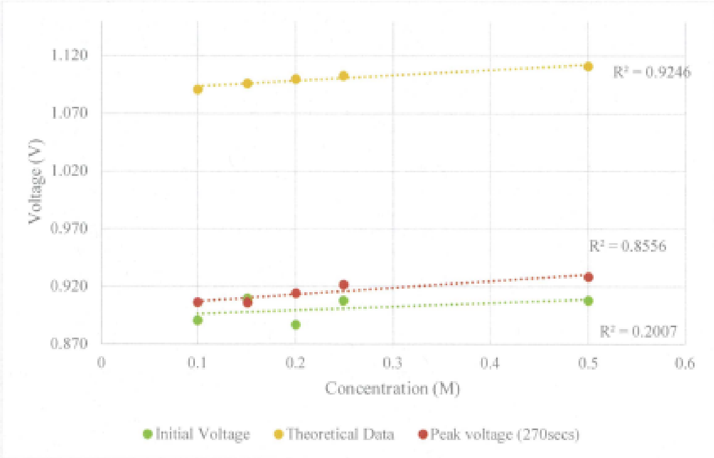
Table 6: Regressions and equations for graph1

Concentration(M)	Regression and Equation
0.500	y = 2E-16x^6 - 4E-13x^5 + 2E-10x^4 - 7E-08x^3 + 1E-05x^2 - 0.0004x + 0.9078 R^2 = 0.9994
0.250	y = 4E-17x6 - 1E-13x5 + 8E-11x4 - 3E-08x3 + 6E-06x2 - 0.0003x + 0.9081 R^2 = 0.998
0.200	y = -7E-17x6 + 5E-14x5 + 2E-11x4 - 2E-08x3 + 4E-06x2 - 6E-05x + 0.8865 R^2 = 0.9983
0.150	y = 3E-16x^6 - 5E-13x^5 + 2E-10x^4 - 6E-08x^3 + 8E-06x^2 - 0.0003x + 0.9111 R^2 = 0.9985
0.100	y = 1E-16x^6 - 2E-13x^5 + 2E-10x^4 - 5E-08x^3 + 8E-06x^2 - 0.0003x + 0.8906 R^2 = 0.9964

Analysis of evidence (5–6 marks)

- thorough and appropriate identification of uncertainties and limitations of evidence
- thorough identification of relevant trends, patterns or relationships

Graph 2: Theoretical (E_{cel}) vs Experimental (instantaneous with initial readings) voltage produced.



5 TRENDS, PATTERNS AND RELATIONSHIPS

Graph 1 indicates first-order reaction with slight decrease (due to electrodes not being inserted immediately together), general upward trend, back to decreasing again. Demonstrating relationship: as concentration increase, the voltage also increases, gaining peak quicker, seen with 0.500M reaching 0.929V and 0.150M reaching 0.906V. A pattern is higher concentrations begin initially higher (0.500/0.250M), ending high voltage (0.500M=0.924V), but lower start low, increase then steeply decrease (0.150M=0.856), rather than maintained. It's clear higher concentrations don't decrease significantly, but maintain voltage (electron current), little difference between treatments. 0.100M being an anomaly yielding greater voltage than 0.150/0.200M.

Graph 2 illustrates theoretical against experimental values gained by Nernst equation. There is a general pattern of increasing then decreasing seen across all concentrations in initial experimental, whereas theoretical values produced a constant, positive linear increase, rather than polynomial. However, strong positive correlation at peak reaction (270secs), supporting theory, only 0.150M outlying. Concentrations 0.500M and 0.250M are the same at 0.908V, which can be excused possibly because human error, however the major anomaly is in 0.150M in which yield 0.910V to begin, where theoretically it should be smaller than all proceeding concentrations.

This student response excerpt has been included:

- to demonstrate justified discussion of the experimental process and of improvements and extensions logically derived from the analysis.

Interpretation and evaluation (5–6 marks) • 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 the evidence	**Interpretation of Evidence** The oxidation of the magnesium metal releases electrons, which flow through the wire to the copper electrode. Electrons are accepted by copper ions in the solution when the ions collide with the copper electrode. These electrons are transferred via the external circuit and the magnesium electrode corrodes as the magnesium metal forms magnesium ions in the solution (Spark Notes LLC, 2021). Le Chatelier's Principle supports that increasing the concentration of the electrolyte at the cathode pushes the system further out of equilibrium. Consequently, the system shifts in forward direction, hence the reaction becomes more spontaneous and the cell potential increases. The concentration cells work to establish equilibrium by transferring electrons from the anode to the cathode. Hence, higher concentrations result in a higher cell potential, thus answering the research question (C. Harvard, 2021). The salt bridge provides a path for ions to maintain electrical neutrality in the cell. This ionic transport involves not only electroactive species but the nitrate ions, which will move from the copper side to the magnesium side to compensate for the decrease in copper ions and increase in magnesium ions (Libre Texts, 2020). The salt bridge must be concentrated enough to effectively separate the electrolyte solutions, but porous enough to allow ionic flow (K. Thomas, 2003). Hence without a sufficient salt bridge, the cathode and anode compartments become charged, and the repulsive forces will prohibit the flow of electrons within the cell. Since the salt bridge was not replaced after each trial, an ion build-up prevented efficient electron flow and decreased the cell potential (A. Kolesnikov, 2007). This may explain the large percentage errors. Trends and patterns - thorough identification of relevant trends , patterns or rel **Evaluation of Experimental Process** Limitations involving the Nernst Equation weren't considered. Throughout the reaction, the concentration of the products and reactants are changing as reactants become products, hence the Q value is constantly changing. This suggests an optimal time when the EMF peaks. The equation also doesn't consider internal resistance of the cell, which compromises voltage from small concentrations (N. Vassel, 2017). Additionally, it does not consider the increased resistance at the external circuit. When the concentration increases more electrons pass through the external circuit, which increase collisions. Thus, increasing the kinetic energy and thermal energy. Consequently, warming the circuit and increasing the resistance (P. Culmer, 2015). The equation is best suited for dilute electrolyte concentrations, hence suggesting the dilute concentrations will have higher accuracy and indicating a molar limitation (D. Jayde, 2015). These limitations cause inaccurate conclusions from the results. The salt bridge was not replaced each trial. This allowed ion build-ups which altered the electrical neutrality of the cell. Consequently, decreasing the cell potential as it prohibits flow of electrons (K. Thomas, 2003). This systematic error caused large percentage uncertainties ranging from ±38.89% to ±45.75%. To improve this, replacing the salt bridge after each trial will reduce systematic error and improve validity. Theoretical EMF values didn't align with the experimental findings due to experimental error. Anomalies, overlapping error bars and percentage uncertainties from 0.93%-4.69% indicates invalid results. The results exhibited the same pattern as theoretical values, suggesting reliability. This is from a large sample size (150) and small standard errors. Hence, results are reliable but invalid, so findings cannot respond to the research question.

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG in this IA, it is recommended that:

- for the Analysis of evidence criterion, the uncertainties and limitations considered be correct and appropriate for the data and graphs being analysed
- only experiments related to Unit 3 subject matter be provided for students to modify
- authentication strategies have been implemented to ensure unique student responses for group experiments
- the spread of data and number of trials be appropriate for the collection of sufficient, relevant data and enables the effective analysis of experimental results.

Additional advice

- Encouraging students to use mandatory or suggested practicals from Unit 3 as the basis for their methodology ensures the research question will be relevant to the syllabus subject matter.
- When students work as a group (as permitted by the syllabus), the authenticity of student work can be substantiated by comparing responses of students who have worked together.
- When students undertake experiments of an appropriate scope and scale (e.g. only one independent variable), they are able to demonstrate the assessment objectives to the highest performance level within the syllabus.
- Students should use realistic contexts related to subject matter from Unit 3 as the basis for their methodology and research question rather than a comparison of products, e.g. testing the effect of temperature on pH rather than determining the pH of different brands of vinegar.

Internal assessment 3 (IA3)

Research investigation (20%)

The IA3 research investigation requires students to gather secondary evidence related to a research question in order to evaluate a claim about properties and structure of organic materials or chemical synthesis and design. Students develop a research question, collect and analyse secondary data, interpret evidence to form a justified conclusion, discuss the quality of the evidence and extrapolate the findings of the research to the claim.

Assessment design

Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	22
Authentication	10
Authenticity	0
Item construction	14
Scope and scale	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 412.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- provided claims that were more closely related to the topics of Unit 4 (i.e. Properties and structure of organic materials and Chemical synthesis and design) than topics from Units 1 or 2 or from other subjects
- provided scaffolding with clear instructions that informed students about the processes they could use to complete the response or the presentation requirements for their response
- included claims that would allow students to develop research questions within the scope and scale of the task, e.g. Chemical structure determines properties.

Practices to strengthen

It is recommended that assessment instruments:

- address all assessment specifications

- follow the conventions of item construction
- provide checkpoints that are suitable for the task and align with authentication strategies.

Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

Reasons for non-endorsement by priority of assessment

Accessibility priority	Number of times priority was identified in decisions*
Bias avoidance	0
Language	11
Layout	1
Transparency	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 412.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- provided clear instructions using cues that aligned to the specifications, objectives and ISMG
- used appropriate language and avoided jargon, specialist language and colloquial language that did not contribute to understanding of the subject matter
- were free of errors and modelled accurate spelling, grammar, punctuation and other textual features
- used bold, italics and other formatting features only where relevant.

Practices to strengthen

There were no significant issues identified for improvement.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and confirmed marks

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional	Percentage both less and greater than provisional
1	Research and planning	92.18%	7.33%	0.24%	0.24%
2	Analysis and interpretation	91.44%	8.07%	0.24%	0.24%
3	Conclusion and evaluation	89.98%	9.29%	0.49%	0.24%
4	Communication	99.27%	0%	0.73%	0%

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- in the Research and planning criterion
  - a *considered* rationale clearly connected the research question to Unit 4 subject matter
  - the research question was *specific* to the claim and *relevant* to Unit 4 subject matter from the Chemistry syllabus, as opposed to other subjects with related subject matter
  - *sufficient and relevant* sources were selected from a variety of scientifically credible sources
- in the Analysis and interpretation criterion, evidence was visually represented in tables and graphs to allow for *thorough identification* of trends, patterns and relationships.

Samples of effective practices

The following are excerpts from responses that illustrate the characteristics for the criteria at the performance level indicated. The excerpts may provide evidence of more than one criterion. The characteristics identified may not be the only time the characteristics have occurred throughout a response.

This student response excerpt has been included:

- to demonstrate a considered rationale and the development of a specific and relevant research question from the claim using concepts from the Unit 4 subject matter.

<table>
<tr>
<td>

Research and planning (5–6 marks)

- considered rationale identifying clear development of the research question from the claim
- a specific and relevant research question

</td>
<td>

Claim

A molecule's shape and bonds determine properties of polymers.

Rationale

As Earth's climate has warmed, a new pattern of more frequent and more intense weather events has unfolded around the world (Claudio, 2007). This increased likelihood and severity has placed a strain on Australia's agricultural industry. The polyethylene used within hail netting is unable to endure the higher frequency and severity of storms, deteriorating at a rapid rate causing millions of dollars in damages to stone fruit due to the bruising caused by impact from hail (Nichols, 2019). Hail netting is a mesh net cross weaved with a filament designed to catch hail and prevent it from colliding with the fruit (Lyu, 2021). Hail netting must possess a high tensile strength to resist tearing and have a high Young's Modulus value. The modulus allows the hail netting to maintain its structure and properties (Lyu, 2021).

A material that shows promise in replacing polyethylene is spider dragline silk. Numerous studies have been conducted on spider dragline silk and determined it has far superior mechanical properties to current materials (Kiseleva, 2020). Spider dragline silk has already proved effective as a substitute for single use plastics and is currently being studied as a replacement for Kevlar in bullet resistant vest (Kiseleva, 2020). To conclude if spider silk will be more effective than polyethylene for manufacturing hail netting, the molecular structure of each material and the mechanical properties will be compared to determine their efficacy as hail netting. The mechanical properties compared will be tensile strength and Young's modulus as they determine the maximum force a material can endure before breakage (hail hitting the net) and the objects ability to stretch and return to its original shape with no adverse effect to properties (hail remaining on top of the netting before melting). This scenario directly relates to the claim as the shapes and bonds present within each polymer will determine their properties. This will be explored by the research question below.

Research Question

Does the molecular structure of spider dragline silk and its tensile strength and Young's Modulus make it a more effective material than polyethylene as the material used for hail netting?

</td>
</tr>
</table>

This student response excerpt has been included:

- to demonstrate justified conclusions that have been linked to the research question, considered improvements/extensions relevant to the claim and the extrapolation of credible findings of the research to the claim.

Conclusion and evaluation (5–6 marks) • suggested improvements and extensions to the investigation that are considered and relevant to the claim • extrapolation of credible findings of the research to the claim • justified conclusion/s linked to the research question	**Claim:** Hydrogen is the fuel of the future. **Research question:** Can hydrogen polymer electrolyte membrane PEM) fuel cells be a viable alternative to combustion engines within the transport industry when comparing greenhouse gas emissions on a well-to-wheel and tank-to-wheel basis? **Further Improvements and Extensions required** A larger sample size would be required to improve the reliability of the experiment, as the sources initiated small samples from 1 to 10 of each vehicle type. A sample size of 30 for each vehicle would be an appropriate sample size to obtain a precise average of the GHG emissions produced. Controlling or ensuring that variables such as temperature are controlled would improve the reliability and internal validity of the experiments as it would ensure running on the same conditions which, limiting the influence of extraneous variables. In order to effectively examine the use of hydrogen as a fuel and fuel cells, analysis of costs involved with WTW and TTW values g/km values would be needed to produce a ratio that could compare the cost and emissions at the same time. This would produce an over-arching analysis for hydrogen as the fuel of the future. Furthermore, investigating the possibility of the use of catalysts in the SMR process, especially in the water shift reaction as may affect the emissions produced. Additionally, it would be viable to investigate the costs of PEM FCEVs to see if they potentially could be distributed into the markets for consumers to use instead of combustion engines. Lastly, PEM fuel cells can be investigated in other industrial applications, such as material handling, stationary, portable, and emergency backup power applications. **Conclusion** The extrapolation of the results of the research question can effectively be applied to the claim "Hydrogen is the fuel of the future" as it suggests that PEM FCEVs utilizing hydrogen fuel are better than combustion engines in terms of GHG emissions; one of the significant aspects that are considered within transport in the future. The evidence gathered suggests that PEM fuel cells are a viable alternative to combustion engines within transport as they produce lower greenhouse gas emissions as evident in Tables 1 and 2 and Figure 5 where PEM vehicles utilizing hydrogen fuel via SMR produced at least 66% and via electrolysis 367% lower greenhouse gas emissions when considering production, delivery and use within vehicles (WTW). In terms of the GHG emissions produced within use only (TTW), the sources outlined that PEM FCEVs did not emit any emissions, while combustion engines running on diesel and petrol emitted an increased amount 97.8g/km and 141.7g/km respectively- making hydrogen a viable alternative in both TTW and WTW. It can be concluded that hydrogen is the fuel of the future, however more investigations are required to consider costs, and comparisons to a variety of vehicles such as electric vehicles should be made to evaluate hydrogen's overall performance.

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG for this IA, it is recommended that:

- in the Conclusion and evaluation criterion
  - conclusions are *linked to the research question,* rather than the claim
  - improvements and extensions are considered *relevant* when they are linked to the claim.

Additional advice

- When students use a claim that is different to the claims in the endorsed assessment instrument, they should ensure the new claim is linked closely to Unit 4 subject matter so that they can produce a *considered* rationale and a *relevant* research question.

- Strategies identified in the *QCE and QCIA policy and procedures handbook* are administered to
  - manage response length to ensure student responses meet the conditions of the syllabus
  - promote academic integrity to ensure student responses clearly demonstrate their own achievement.

External assessment

External assessment (EA) is developed and marked by the QCAA. The external assessment for a subject is common to all schools and administered under the same conditions, at the same time, on the same day.

Summative external assessment — Examination (50%)

Assessment design

The assessment instrument was designed using the specifications, conditions and assessment objectives described in the summative external assessment section of the syllabus. The examination consisted of two papers:

- Paper 1, Section 1 consisted of multiple choice questions (20 marks)
- Paper 1, Section 2 consisted of short response questions (37 marks)
- Paper 2, Section 1 consisted of short response questions (51 marks)

The examination assessed subject matter from Units 3 and 4. Questions were derived from the context of

- Chemical equilibrium systems
- Oxidation and reduction
- Properties and structure of organic materials
- Chemical synthesis and design.

The assessment required students to respond to multiple choice and short response items.

The stimulus included a range of data tables, chemical reactions, diagrams and graphs related to Units 3 and 4.

Assessment decisions

Assessment decisions are made by markers by matching student responses to the external assessment marking guide (EAMG). The external assessment papers and the EAMG are published in the year after they are administered.

Multiple choice item responses

There were 20 multiple choice items in Paper 1.

Percentage of student responses to each option

Note:

- The correct answer is **bold** and in a blue shaded table cell.
- Some students may not have responded to every question.

Question	A	B	C	D
1	**89.65**	5.2	4.14	0.9
2	11	**52.81**	28.88	7.02
3	41.06	11.27	**25.17**	22.08
4	**30.65**	21.47	23.12	24.43
5	3.47	3.58	**75.75**	17
6	**65.74**	9.56	17.57	6.89
7	6.24	25.34	12.56	**55.65**
8	5.48	6.32	**66.79**	21.1
9	6.97	19.61	13.69	**59.56**
10	9.13	9.39	**75.47**	5.59
11	6.69	**78.83**	8.7	5.54
12	**91.48**	5.71	2.11	0.54
13	9.33	11.98	7.37	**71.11**
14	5.55	**68.97**	13.94	11.29
15	7.1	15.62	15.37	**61.57**
16	24.85	36.95	**35.32**	2.03
17	13.37	**63.68**	12.85	9.68
18	11.07	**48.03**	31.52	8.76
19	**74.56**	3.22	17.73	4.28
20	7.93	**66.89**	11.83	13.09

Effective practices

Overall, students responded well to:

- the opportunity to describe and explain by
  - using reference amino acids to analyse TLC experimental data
  - writing balance chemical equations to explain the reaction of alkanes with bromine water and drawing structural formulas to describe simple organic compounds
  - using balanced chemical equations to describe chemical reactions from experimental data
- the opportunity to apply understanding by
  - drawing structural formulas of isomers of alkanes and applying IUPAC nomenclature to simple organic compounds
  - calculating an equilibrium constant (K_c) from graphical data and using the relationship between K_w and K_a to determine K_b values

- determining the type of polymerisation used to form polymers and identify the function group/s formed
- balancing simple redox reactions, using oxidation numbers to identify species being oxidised in redox reactions and determining the standard reduction potential (E^0) of electrochemical cells

- the opportunity to analyse and interpret evidence by
  - identifying the reactants and products of equilibrium reactions from graphical representation and identifying enthalpy changes associated with reversible reactions based on shifts in equilibrium
  - deriving the equilibrium law expression from a balanced chemical equation and predicting the effect of a catalyst on the position of the equilibrium and the K_c value
  - comparing the strength of oxidising agents and predicting the flow of electrons in voltaic cells
  - using experimental data and qualitative observations to justify the identity of unknown organic compounds.

The following excerpts have been selected to illustrate effective student responses in one or more of the syllabus assessment objectives. The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Samples of effective practices

Short response

Assessment objective: 2

Paper 1

Question 27b

This question required students to balance a redox equation.

Effective student responses:

- provided a balanced oxidation half-equation
- provided a balanced reduction half-equation
- used a multiplication factor to balance electrons
- determined the balanced redox equation.

This student response excerpt has been included:

- to demonstrate that an item with the cognitive verb *use* requires students to apply their understanding of the subject matter to respond to the question
- to illustrate that the marks allocated for a question indicate the number of aspects required in the response
- to indicate that students should read the question carefully to ensure that their response addresses the question. Students often incorrectly attempted to use oxidation numbers rather than half-equations, which resulted in incorrect or unbalanced oxidation and/or reduction half-equations.

Apply understanding (4 marks)	**QUESTION 27 (6 marks)** Arsenous acid, H_3AsO_3, reacts with nitrate ions to form arsenic acid, H_3AsO_4, and nitrogen dioxide. b) Use half-equations to balance the reaction. *[4 marks]* $H_3AsO_{3(aq)} + NO_3^-{}_{(aq)} \rightarrow H_3AsO_{4(aq)} + NO_{2(g)}$ reduction: $NO_3^-{}_{(aq)} + 2H^+_{(aq)} + e^- \rightarrow NO_{2(g)} + H_2O_{(l)}$ oxidation: $H_3AsO_{3(aq)} + H_2O_{(l)} \rightarrow H_3AsO_{4(aq)} + 2H^+_{(aq)} + 2e^-$ Balance charges for half equations: $2NO_3^-{}_{(aq)} + 4H^+_{(aq)} + 2e^- \rightarrow 2NO_{2(g)} + 2H_2O_{(l)}$ $H_3AsO_{3(aq)} + H_2O_{(l)} \rightarrow H_3AsO_{4(aq)} + 2H^+_{(aq)} + 2e^-$ Overall reaction: $2NO_3^-{}_{(aq)} + 2H^+_{(aq)} + H_3AsO_{3(aq)} \rightarrow 2NO_{2(g)} + H_2O_{(l)} + H_3AsO_{4(aq)}$

Assessment objectives: 3 and 4

Paper 2

Question 3c

This question required students to analyse and interpret experimental data to identify an unknown organic compound.

Effective student responses:

- identified compound C as butane
- identified that compound C cannot be oxidised
- concluded that compound C is unreactive and saturated.

This student response excerpt has been included:

- to demonstrate how experimental data from the stimulus can be used to explain the conclusion, rather than just being restated.

Analyse evidence and Interpret evidence (3 marks)	c) Identify Compound C. Explain your reasoning. *[3 marks]* Compound C is butane. This is because compounds A and B are oxidised by $KMnO_4$, showing A and B are alcohols (2-butanol and 1-propanol) as they decolourise. Compound C has no reaction with Br_2 or $KMnO_4$ so cannot be alcohol or unsaturated so is butane.

Assessment objective: 2

Paper 2

Question 4b

This question required students to calculate the equilibrium constant (K_c) of a reversible reaction from a given set of conditions.

Effective student responses:

- correctly determined change in $[H_2] = [I_2] = 4.65 \times 10^{-4}$
- determined $[H_2]_{eq} = 3.50 \times 10^{-5}$
- determined $[I_2]_{eq} = 5.35 \times 10^{-4}$
- showed substitution correctly performed
- determined K_c = 46.2.

This student response excerpt has been included:

- to show appropriate working for this calculation.

Apply understanding (5 marks)

QUESTION 4 (9 marks)

5.00×10^{-4} moles of hydrogen gas is mixed with 1.00×10^{-3} moles of iodine vapour in a sealed 1.00 L vessel at 455.0 °C. The concentration of hydrogen iodide gas formed at equilibrium is 9.30×10^{-4} M.

The balanced equation for the reaction is shown.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

b) Calculate the equilibrium constant (K_c) for the reaction at 455.0 °C.
Show your working. *[5 marks]*

Let x be change in concentration(M)

From ICE table

	H_2	I_2	HI
I	5×10^{-4}	10^{-3}	0
C	$-x$	$-x$	$+2x$
E	$5 \times 10^{-4} - x$	$10^{-3} - x$	9.3×10^{-4}

$2x = 9.3 \times 10^{-4}$

$x = 4.65 \times 10^{-4}$ M

$\therefore [HI]_{eq} = 9.3 \times 10^{-4}$ M

$[H_2]_{eq} = 5 \times 10^{-4} - 4.65 \times 10^{-4}$

$= 3.5 \times 10^{-5}$ M

$[I_2]_{eq} = 10^{-3} - 4.65 \times 10^{-4}$

$= 5.35 \times 10^{-4}$ M

$K_c = \frac{[HI]^2}{[I_2][H_2]}$

$K_c = \frac{(9.3 \times 10^{-4})^2}{5.35 \times 10^{-4} \times 3.5 \times 10^{-5}}$

$= 46.2$

K_c = 46.2 (to three significant figures)

Practices to strengthen

It is recommended that when preparing students for external assessment, teachers consider:

- using qualitative observations to explain shifts in equilibrium in reversible reactions
- using K_a values to determine the strength of a Brønsted-Lowry acid and to calculate the pH of weak acid and using changes in the concentration of reactant and products in equilibrium reactions to calculate the equilibrium constant (K_c)
- using structural formulas to describe esters, applying IUPAC nomenclature to esters and non-primary alcohols, identifying amino acids in dipeptides, and identifying amino acids from TLC experimental data
- identifying and drawing the structural formulas of monomers from their polymer; explaining how the position of the methyl group affects the properties of polypropene and determining the type of polymerisation reaction used to form polymers from their monomers
- using half-equations to balance redox reactions and experimental data from redox titrations to calculate the percentage of a species in a compound; performing multi-stepped calculations to solve redox, pH and equilibrium problems; sketching titrations curves for weak bases and analysing and interpreting experimental data to draw justified conclusions.

Senior External Examination

The Chemistry Senior External Examination (SEE) is a standalone examination offered to eligible Year 12 students and adult learners. It contributes 100% to a student's final subject result.

The assessment was designed using the specifications, conditions and assessment objectives described in the summative external assessment section of the Chemistry Senior External Examination syllabus.

The SEE consisted of two assessments:

- SEE 1 contributed 50% of the marks
- SEE 2 contributed 50% of the marks.

Note: The SEE information should be read in conjunction with the rest of the subject report.

Number of students who completed the Chemistry Senior External Examination: 14.

Distribution of standards

There were insufficient student enrolments in this subject to provide useful analytics.

Assessment decisions

Effective practices

Overall, students responded well to questions that required them to:

- analyse titration curves to calculate the molarity of a solution and identify the relationship between the concentration of hydroxide ions and pH
- analyse data to determine the solubility of organic compounds
- interpret data to compare how the chain length of organic compounds affect boiling point and solubility

Practices to strengthen

It is recommended that when preparing students for the Senior External Examination, teachers consider:

- providing opportunities for students to plan and conduct experimental and research activities as learning experiences so students can learn key inquiry skills such as
  - developing research questions from a claim
  - analysing and critically reflecting on evidence
  - applying evidence to a research question in order to draw justified conclusions.