Chemistry subject report

2023 cohort

February 2024

Queensland Government

Queensland Curriculum & Assessment Authority

240034

For all Queensland schools

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Introduction

Throughout 2023, schools and the Queensland Curriculum and Assessment Authority (QCAA) continued to improve outcomes for students in the Queensland Certificate of Education (QCE) system. These efforts were consolidated by the cumulative experience in teaching, learning and assessment of the current General and General (Extension) senior syllabuses, and school engagement in QCAA endorsement and confirmation processes and external assessment marking. The current evaluation of the QCE system will further enhance understanding of the summative assessment cycle and will inform future QCAA subject reports.

The annual subject reports seek to identify strengths and opportunities for improvement of internal and external assessment processes for all Queensland schools. The 2023 subject report is the culmination of the partnership between schools and the QCAA. It addresses school-based assessment design and judgments, and student responses to external assessment for this subject. In acknowledging effective practices and areas for refinement, it offers schools timely and evidence-based guidance to further develop student learning and assessment experiences for 2024.

The report also includes information about:

- how schools have applied syllabus objectives in the design and marking of internal assessments
- how syllabus objectives have been applied in the marking of 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 that demonstrate best practice.

Schools are encouraged to reflect on the effective practices identified for each assessment, consider the recommendations to strengthen assessment design and explore the authentic student work samples provided.

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 internal and external assessment.

The report is publicly available to promote transparency and accountability. Students, parents, community members and other education stakeholders can use it to learn about the assessment practices and outcomes for senior 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 highlights

416
schools offered Chemistry

81.64%
of students completed 4 units

99.52%
of students received a C or higher

Subject data summary

Subject completion

The following data includes students who completed the General subject.

Note: All data is correct as at January 2024. Where percentages are provided, these are rounded to two decimal places and, therefore, may not add up to 100%.

Number of schools that offered Chemistry: 416.

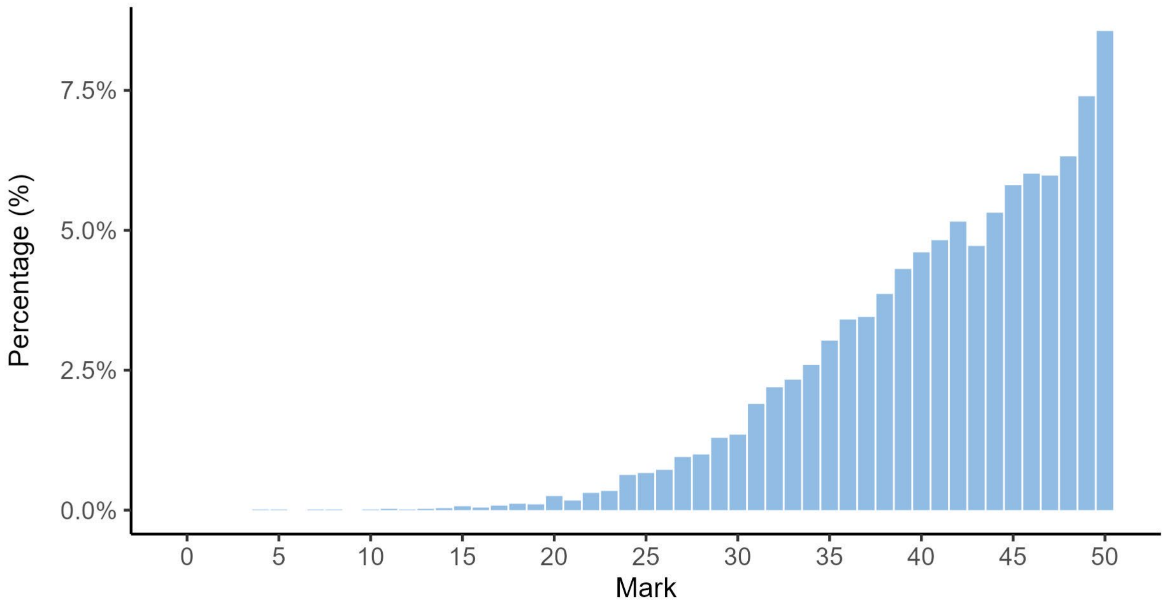
Completion of units	Unit 1	Unit 2	Units 3 and 4
Number of students completed	10,666	9,806	8,708

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory
Unit 1	10,040	626
Unit 2	9,028	778

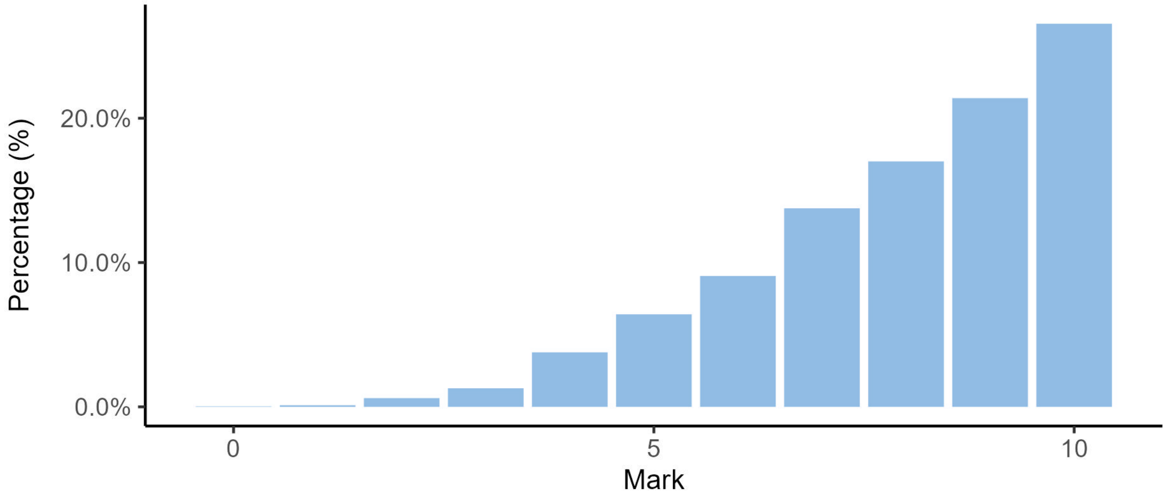
Units 3 and 4 internal assessment (IA) results

Total marks for IA

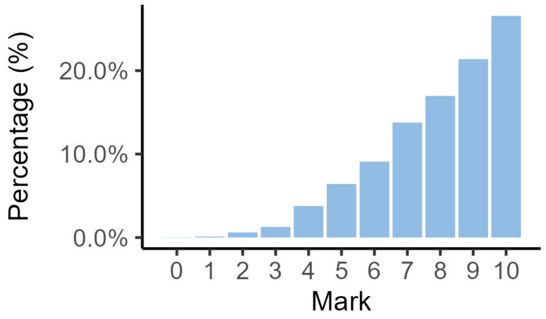


IA1 marks

IA1 total

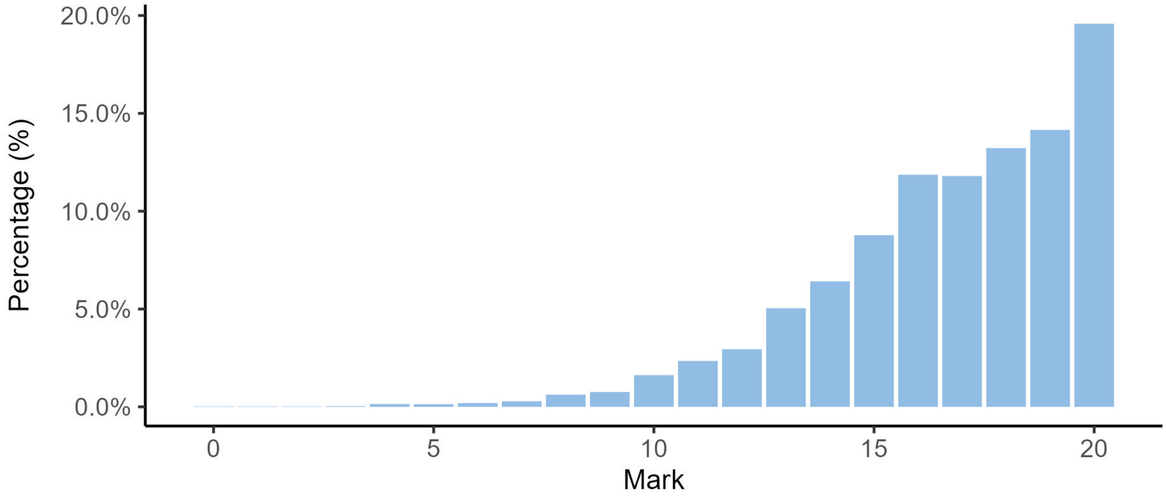


IA1 Criterion: Data test

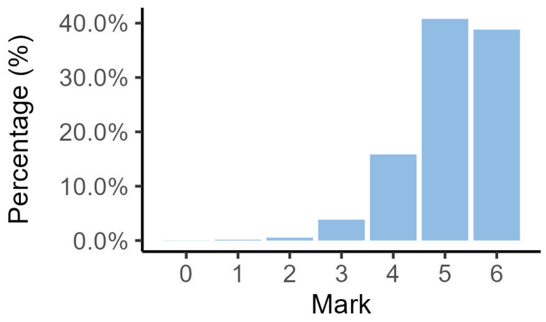


IA2 marks

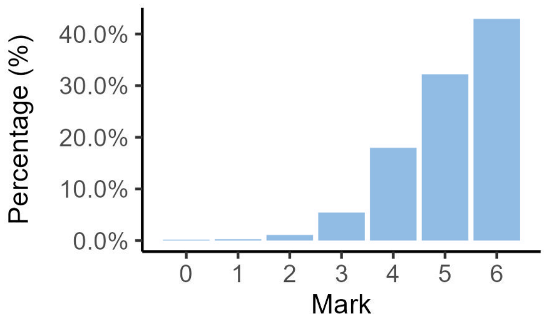
IA2 total



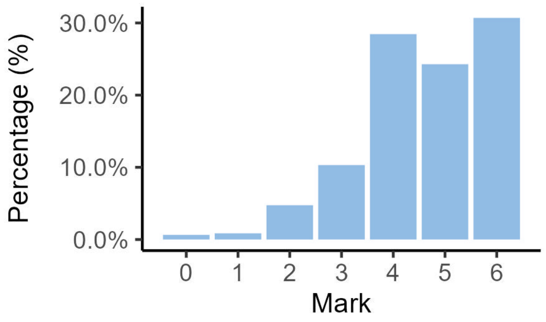
IA2 Criterion: Research and planning



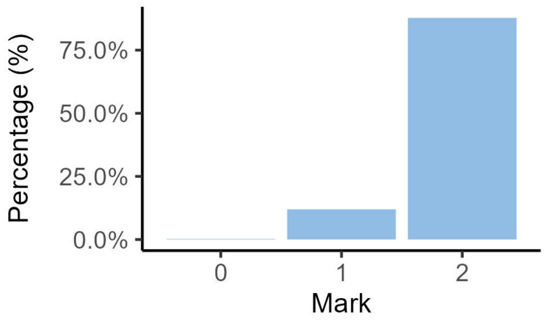
IA2 Criterion: Analysis of evidence



IA2 Criterion: Interpretation and evaluation

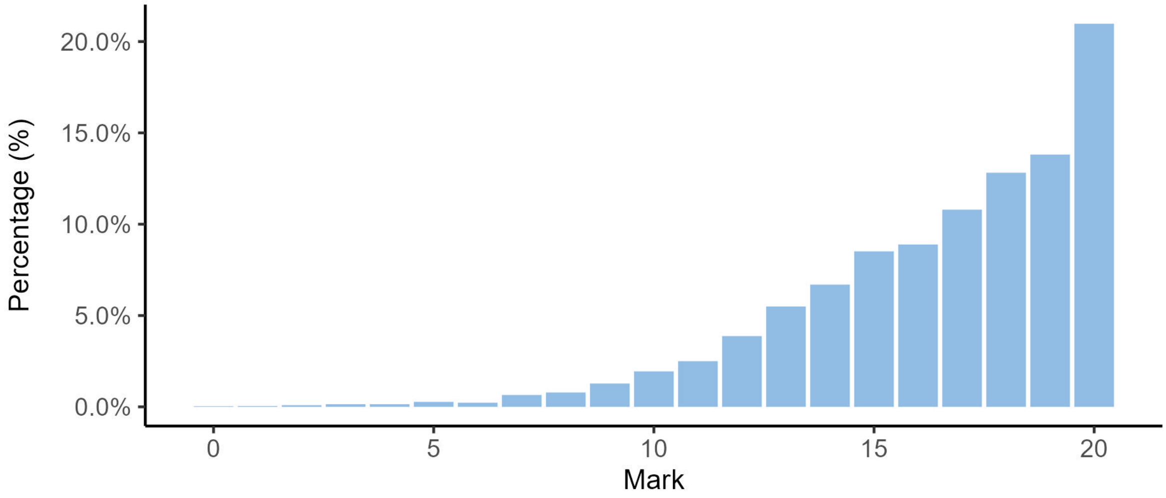


IA2 Criterion: Communication

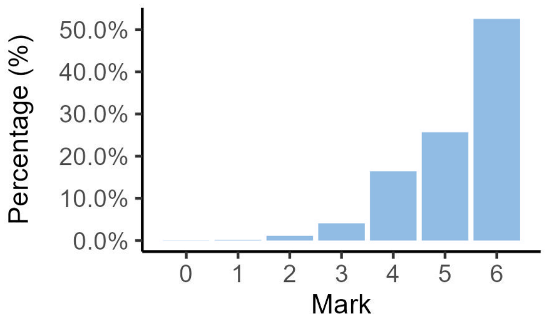


IA3 marks

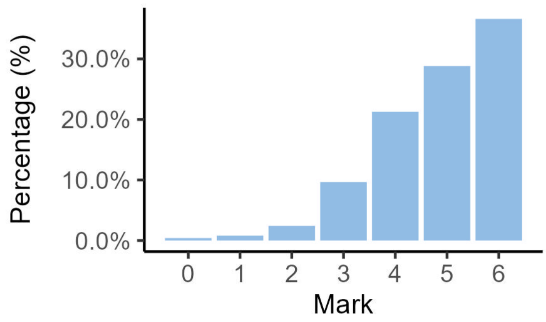
IA3 total



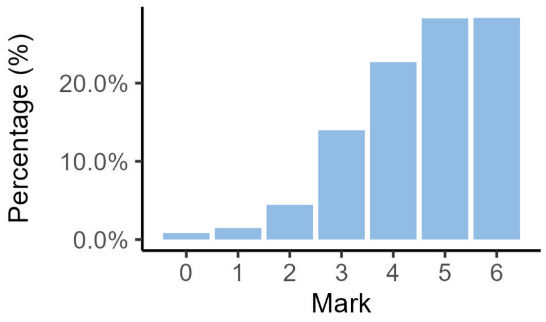
IA3 Criterion: Research and planning



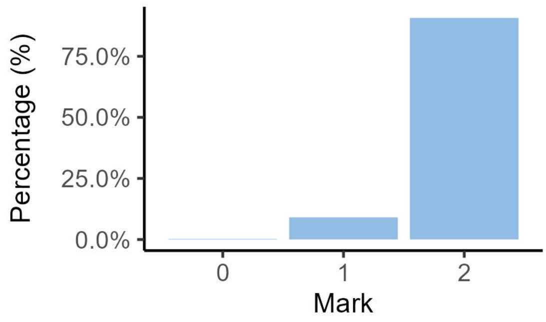
IA3 Criterion: Analysis and interpretation



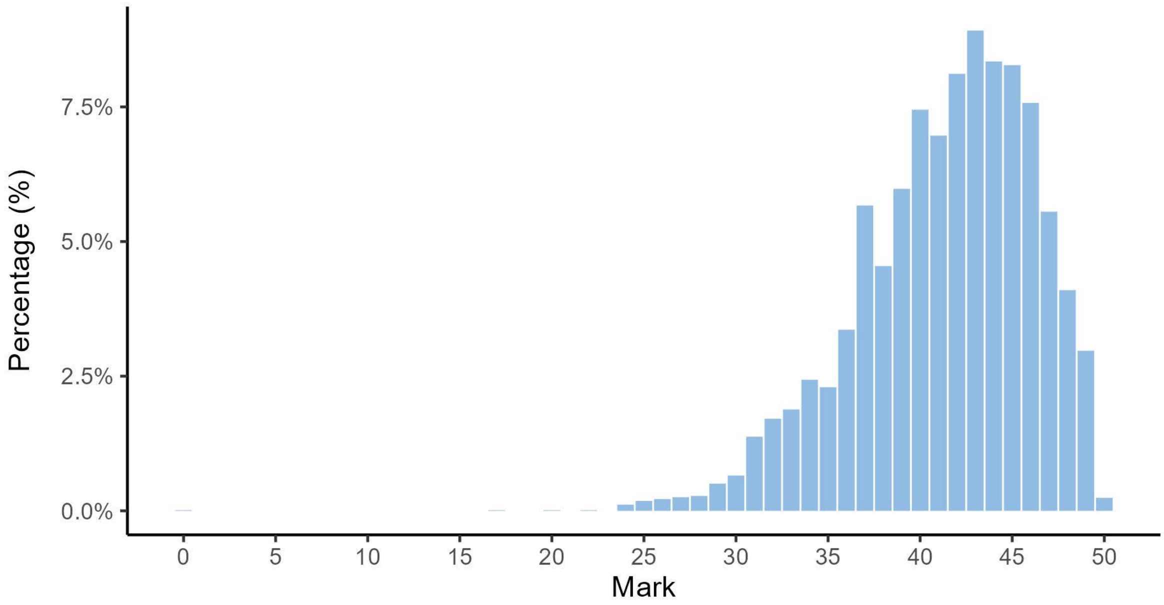
IA3 Criterion: Conclusion and evaluation



IA3 Criterion: Communication

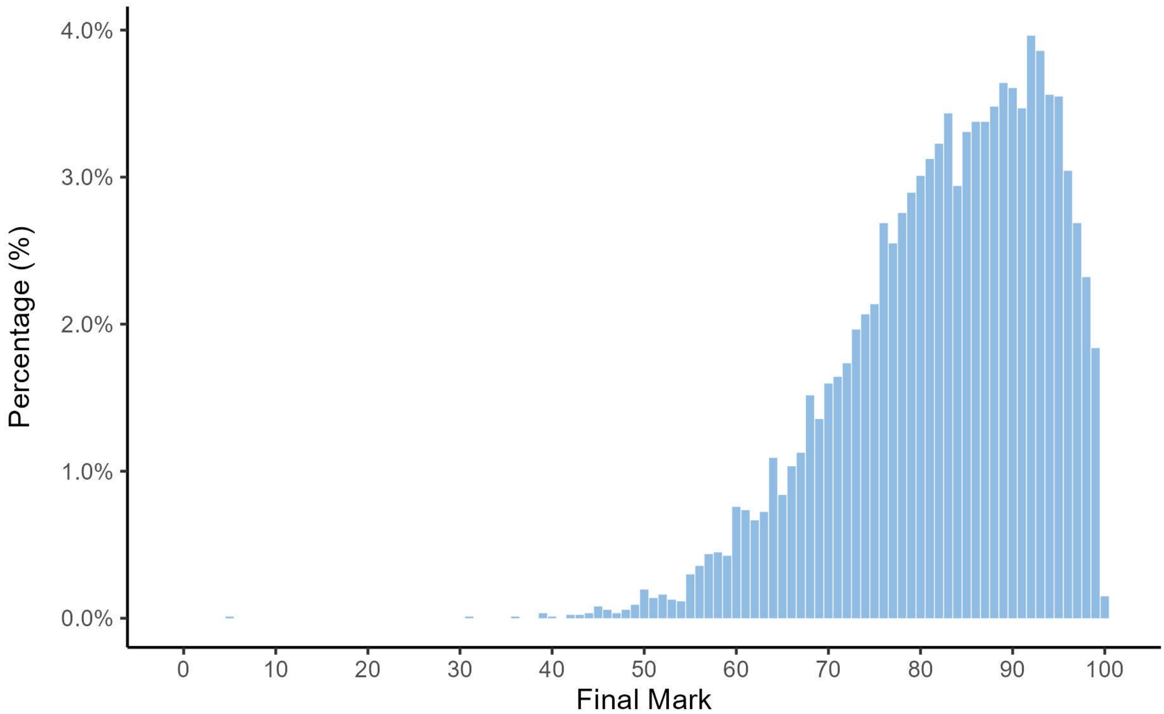


External assessment (EA) marks



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	100–87	86–72	71–50	49–19	18–0

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	3,704	3,588	1,374	41	1

Internal assessment

The following information and advice relate 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 *QCE and QCIA policy and procedures handbook v5.0*, Section 9.6.

Percentage of instruments endorsed in Application 1

Number of instruments submitted	IA1	IA2	IA3
Total number of instruments	416	416	414
Percentage endorsed in Application 1	39%	93%	94%

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 instrument-specific marking guide (ISMG), and are used to make decisions about the cohort's results.

Refer to *QCE and QCIA policy and procedures handbook v5.0*, Section 9.7.

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	409	2,225	0	98.29%
2	408	2,853	71	80.88%
3	408	2,842	34	81.62%

Internal assessment 1 (IA1)

Data test (10%)

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 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	160
Authentication	0
Authenticity	10
Item construction	56
Scope and scale	39

*Each priority might contain up to four assessment practices.

Total number of submissions: 416.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included all the information required for students to respond to the given items
- contained datasets that were of suitable scope and scale, e.g. were clearly based on data adapted from the mandatory or suggested practicals
- featured a variety of cognitions to enable students to demonstrate a range of skills across the task.

Practices to strengthen

It is recommended that assessment instruments:

- match the cognitive verb to the nature of the expected response and the relevant syllabus objective (see the Mark allocations table, Syllabus section 4.5.1)
- avoid repetition of specific question types, e.g. calculations
- include a marking scheme that shows how the number of marks assigned can be identified as distinct cognitions or steps in the expected student response.

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	39
Language	100
Layout	43
Transparency	66

*Each priority might contain up to four assessment practices.

Total number of submissions: 416.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- included images, diagrams and other visual elements that were clear, well-formatted and large enough to be easily legible to students
- contained datasets relevant to the task with minimal distractors
- provided clear instructions that avoided unnecessary complexity or details, ensuring students could address the task effectively.

Practices to strengthen

It is recommended that assessment instruments:

- are checked for spelling, grammar and consistent textual features within questions and datasets, e.g. if a table in a dataset is labelled as ‘Table 1’, then the question should not refer to it as a ‘figure’
- use clear language that cues students to produce important features of the expected response, e.g. ‘justify your conclusion’
- model correct scientific conventions when writing chemical formulas and equations, e.g. NH_3 instead of NH3. Use the ‘Print preview’ function to check the accuracy of scientific conventions before submitting for endorsement.

Additional advice

- Questions that assess Objective 3 (analyse evidence) must relate to the evidence in the data provided, not the methods of data collection or knowledge of the experimental method.
- Schools should ensure internal quality assurance processes are carried out before submission for endorsement, e.g. using the *IA1 quality assurance tool* under Resources in the Syllabuses application (app) on the QCAA Portal to check that all elements have been addressed (*QCE and QCIA policy and procedures handbook v5.0*, Section 9.6.1).

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	98.29%	1.22%	0.24%	0.24%

Effective practices

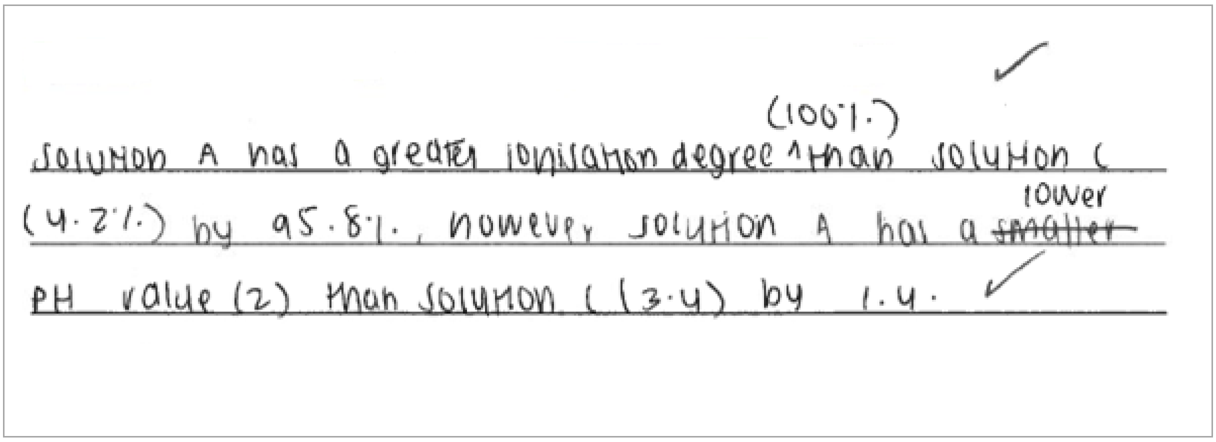
Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- the marking scheme was clearly aligned to the endorsed instrument, and any comparable assessments were clearly identified
- marking schemes were correct and showed the full breakdown of mark allocations awarded to each question to support consistent and accurate intra- and inter-marker decision-making
- student responses were clearly annotated to indicate how they were marked against the marking scheme (*QCE and QCIA policy and procedures handbook v5.0,* Section 9.7.1).

Samples of effective practices

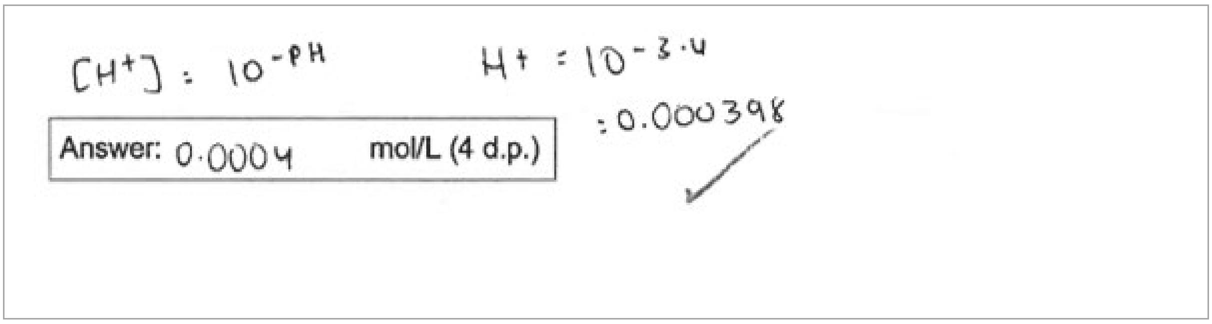
The following excerpt demonstrates clear annotations on a student response to an Objective 3 item. According to the marking scheme, students were required to contrast the degree of ionisation and pH of two solutions for two marks.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.


Solution A has a greater ionisation degree (100%) than solution C (4.2%) by 95.8%, however solution A has a ~~smaller~~ lower pH value (2) than solution C (3.4) by 1.4.

The following excerpt demonstrates a suitable annotation indicating the allocation of one mark to an Objective 2 item that required students to calculate the concentration of hydronium ions.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.


[H+] : 10-PH   H+ = 10-3.4
= 0.000398 ✓
Answer: 0.0004 mol/L (4 d.p.)

Practices to strengthen

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

- marks are correctly totalled, percentages are accurately determined, and cut-offs from the ISMG are correctly applied to determine provisional marks, e.g. 12/20 is 60%, not > 60%, therefore 6 should be awarded
- marking schemes are updated prior to confirmation to ensure errors are corrected and alternative student responses are accounted for.

Additional advice

- Internal quality assurance processes (e.g. cross-marking) should be implemented to ensure intra- and inter-marker reliability.
- Comparable assessments should allow students to demonstrate the same knowledge and skills required for the endorsed instrument and require a separate marking scheme to be provided.

Internal assessment 2 (IA2)

Student experiment (20%)

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 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	9
Authentication	8
Authenticity	4
Item construction	8
Scope and scale	0

*Each priority might contain up to four assessment practices.

Total number of submissions: 416.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- clearly identified the required task specifications within the task description, particularly those aspects that were to be completed as individuals or as a group
- included suitable authentication strategies to check the authenticity of student work produced during the groupwork components of the task, e.g. comparing the responses of students who have worked together.

Practices to strengthen

It is recommended that assessment instruments:

- include information directing students to address all aspects of the task listed in the syllabus specifications (Syllabus section 4.5.2)
- provide practicals that are clearly related to the topics of Unit 3 (i.e. Topic 1: Chemical equilibrium systems and Topic 2: Oxidation and reduction), e.g. single displacement reactions in aqueous solutions.

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	0
Layout	0
Transparency	0

*Each priority might contain up to four assessment practices.

Total number of submissions: 416.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- featured checkpoints that provided clear directions for students to complete the task
- used internal quality assurance processes to ensure the task was free from clerical errors
- were checked for errors in spelling, grammar or other textual features, e.g. using 'rational' instead of 'rationale'
- used correct chemical formulation for species symbols throughout the task, e.g. CO_2 instead of CO2.

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	86.27%	13.48%	0.25%	0%
2	Analysis of evidence	89.46%	10.29%	0.25%	0%
3	Interpretation and evaluation	90.44%	9.07%	0.25%	0.25%
4	Communication	98.28%	1.23%	0.25%	0.25%

Effective practices

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

- for the Analysis of evidence criterion,
  - *correct* and *relevant* processing of raw data was conducted using appropriate algorithms and graphical representation, e.g. mean cell potential, percentage uncertainties and percentage error were calculated and scatter graphs with appropriate lines of best fit and error bars were presented
  - uncertainty and limitations were
    - *appropriate* for the data and correctly applied to enable systematic and effective analysis of the data, e.g. absolute uncertainties, percentage uncertainties and percentage error for mean cell potentials and error bars, gradients and R^2 values for graphical relationships
    - *thoroughly* identified through systematic and effective analysis of the evidence rather than discussing problems relating to methodology, e.g.
      - precision, reliability and random error in the data
      - validity, accuracy and systematic error of the experimental results
- for the Interpretation and evaluation criterion,
  - *justified* conclusions referred to the trends, patterns or relationships identified in the analysis of evidence to indicate how the evidence matched the theoretical concepts identified in the rationale
  - *justified* discussions of the reliability and validity of the experiment referred to the uncertainty and limitations identified in the analysis of evidence
  - logically derived improvements and extensions to the experiment identified how
    - random error can be reduced to improve the reliability of the data, e.g. repeating measurements
    - measurement uncertainty can be reduced by using more precise measuring equipment, e.g. an instrument with a finer-grained scale
    - modifying the methodology improved the accuracy of the data and the validity of the conclusions drawn, e.g. by identifying and rectifying any systematic error in the measurement process.

Samples of effective practices

The following excerpt demonstrates justified modifications to the methodology and explains how modifications to the original experiment improve the reliability and validity of the data collected to address the research question.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

The original experiment conducted in class was aiming to record the E_{Cell} between different electrodes (Cu, Fe, Zn, C, I_2). This experiment contained many errors and limitations that impacted its reliability and accuracy. A significant limitation of the experiment was not identifying any factors contributing to the cell potential except for identifying the electrodes. Furthermore, using filter-paper salt bridges introduced many random errors. The filter-paper would vary in size and the amount of salt solution it soaked in varies too, decreasing the reliability.

The modified experiment aims to identify the quantitative relationship between the electrolyte concentration and the cell potential under a non-standard lab condition. The experiment will examine the effects of 5 different concentrations (0.01M, 0.1M, 0.25M, 0.5M, 1M) on $E_{Cell,}$ with three trials for each treatment. When one electrolyte concentration is fixed at 1M, a logarithmic relationship can be expected between the E_{Cell} and the varying concentration. Other variables will be held constant. Temperature and the other electrolyte concentration must be kept constant (25°C at 1M) to minimise the uncertainty and increase the reliability.

1.1 Research Question:
What is the relationship between the cell potential and the electrolyte concentration in a Daniell cell when one concentration varies between 0.01M, 0.1M, 0.25M, 0.5M and 1M when another electrolyte concentration keeps constant at 1M under 25 °C?

2.0 Modifications:

Table 1 Experiment Modifications

Modification	Justification
Redirection **Change the independent variable from identity of the electrodes to electrolyte concentration**	To identify a quantitative relationship between electrolyte concentration and E_{Cell}.
Refinement **Increase to three trials per treatment.**	Using 3 repetitions minimized the random errors, thus eliminating uncertainties and improve precision
Refinement **Change from filter paper to glass U-shaped salt bridge (KNO_3 +agar)**	Using a glass U-tube salt bridge minimised random errors between trials to improve reliability.
Refinement **Change analogue voltmeter to digital multi-meter**	Improve measurement accuracy
Refinement **Change measuring cylinder to a pipette to measure the volume of electrolyte solutions.**	Improve the accuracy of electrolyte volume
Refinement **Using an electrical water bath to control the electrolyte temperature to 25 degrees. Doors and windows will be closed, and the AC will be set to 25°C in the lab.**	To better control the electrolyte temperature to 25°C, ensure accuracy for the Nerst equation.

The following excerpt demonstrates a methodology that enables the collection of *sufficient*, *relevant* data so that trends, patterns or relationships and the uncertainty and limitations of the evidence can be thoroughly and appropriately identified.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Raw Data:

Table 1 Experimental Cell Potential Vs [Cu^{2+}]

Cu^{2+} Concentration	Cell Potential (V) Trial 1 (±0.01V)	Cell Potential (V) Trial 2 (±0.01V)	Cell Potential (V) Trial 3 (±0.01V)	Mean Cell Potential (V) (±0.01V)
0.01M	1.06	1.06	1.06	1.06
0.1M	1.07	1.08	1.07	1.07
0.25M	1.07	1.08	1.08	1.08
0.5M	1.08	1.09	1.08	1.08
1M	1.08	1.09	1.09	1.09

Table 2 Experimental Cell Potential Vs [Zn^{2+}]

Zn^{2+} Concentration	Cell Potential (V) Trial 1 (±0.01V)	Cell Potential (V) Trial 2 (±0.01V)	Cell Potential (V) Trial 3 (±0.01V)	Mean Cell Potential (V) (±0.01V)
0.01M	1.09	1.09	1.08	1.09
0.1M	1.08	1.07	1.08	1.08
0.25M	1.07	1.07	1.08	1.07
0.5M	1.07	1.07	1.07	1.07
1M	1.06	1.06	1.07	1.06

The following excerpt demonstrates thorough and appropriate identification of the uncertainty and limitations of the evidence to analyse the precision and accuracy of experimental data.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Processed Data:

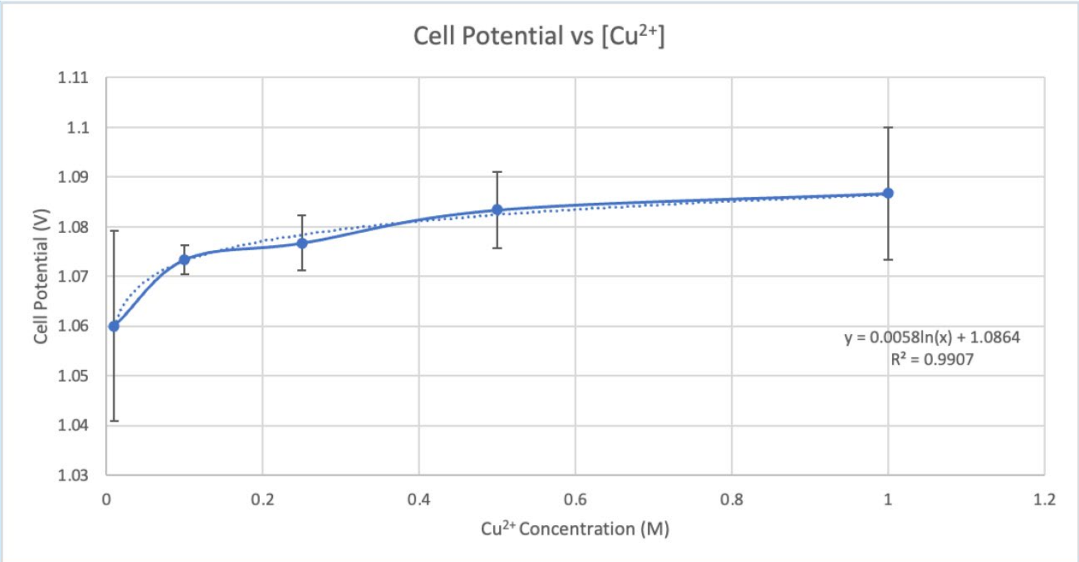


Figure 2 The effect of $CuSO_4$ concentration (when [Zn^{2+}]=1M)on Cell Potential (V)

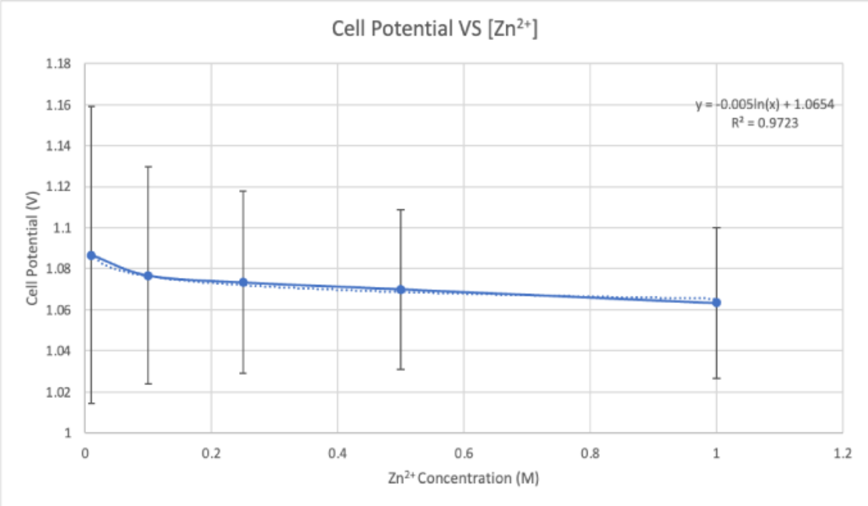


Figure 3 The effect of $ZnSO_4$ concentration (when $[Cu^{2+}]$=1M) on Cell Potential (V)

In Figures 2 and 3, two opposite logarithmic relationships can be identified and R^2 value were obtained respectively. The absolute uncertainty value indicated minimal variance and good precision. In Figure 2, a positive logistic pattern is observed; as the concentration of $CuSO_4$ increases, cell potential (V) increases. This is consistent with the hypothesis using Nernst equation. Two variables are highly correlated as $R^2 = 0.9907$, very close to $R^2 = 1$. However, the error bars overlap for all mean voltages, suggesting the difference is statistically insignificant and due to random errors. Figure 3 shows a negative logistic pattern, displaying as concentration of $ZnSO_4$ increases, cell potential (V) decreases, which is also consistent with the Nernst equation. The data is highly correlated as $R^2 = 0.9723$ (close to $R^2 = 1$). Moreover, the error bars overlap for all data points, meaning the relationship is statistically insignificant, and the cell potential difference is due to random error. This means both observed trends are insignificant and might not reflecting the true voltage at different concentrations. Despite the insignificant trends for both experiments, the precision of Figures 2 and 3 is high, as percentage uncertainties all below 0.5%, indicating high reliability.

Table 4 Processed Data for Experiment 1

$CuSO_4$ Conc.(M)	Mean Cell Potential (V)	Absolute Uncertainty (V)	Percentage Uncertainty (%)	Theoretical E_{Cell} (V)	Absolute Error(E)	Percentage Error (%)
0.01	1.06	±0	±0	1.040	±0.019	±1.835
0.10	1.073	±0.005	±0.465	1.070	±0.003	±0.269
0.25	1.076	±0.005	±0.464	1.082	±0.005	±0.512
0.50	1.083	±0.005	±0.462	1.091	±0.007	±0.711
1.00	1.086	±0.005	±0.460	1.1	±0.013	±1.212

Table 5 Processed Data for Experiment 2

$ZnSO_4$ Conc. (M)	Mean Cell Potential (V)	Absolute Uncertainty (V)	Percentage Uncertainty (%)	Theoretical E_{Cell} (V)	Absolute Error(E)	Percentage Error (%)
0.01	1.087	±0.005	±0.460	1.159	±0.072	±6.249
0.10	1.077	±0.005	±0.464	1.129	±0.053	±4.681
0.25	1.073	±0.005	±0.465	1.117	±0.044	±3.977
0.50	1.070	±0	±0	1.108	±0.039	±3.506
1.00	1.063	±0.005	±0.470	1.100	±0.037	±3.333

Tables 4 and 5 show the processed data of the experiments. The percentage error across both experiments is below 7%, indicating high experimental validity. The average experimental error for experiment 1 (0.0094) is smaller than experiment 2 (0.049), suggesting experimental 1 is more accurate. The significant difference between the theoretical and experimental data in experimental 2 suggested multi-meter errors. The overall accuracy of the results is reasonably high, demonstrated by the low error values (all experimental errors<0.072). An outlier in experiment 1 at 0.01M is identified as outlier as its experimental error is 1.5 times greater than the next highest E. The may due to systematic error.

Practices to strengthen

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

- for the Research and planning criterion
  - a *specific* research question be developed to enable a response that is achievable within the required response length, e.g. ‘What is the relationship between the cell potential and the electrolyte concentration in a Daniell cell when one concentration varies between 0.01M, 0.1M, 0.25M, 0.5M and 1M when another electrolyte concentration keeps constant at 1M and 25° C?’
  - a *considered* rationale demonstrates why the dependent and independent variables are chosen and how the research question is developed and linked to Unit 3 subject matter
  - modifications to the methodology are *justified* and explain how modifications to the original experiment improve the reliability and validity of the data collected, e.g. change filter paper to glass u-shaped salt bridge to improve reliability
  - the methodology enables the collection of *relevant* data that measures variables (e.g. pH, concentration, temperature, time) rather than comparing products, and *sufficient* data for appropriate trends, patterns or relationships and uncertainty and limitations of the evidence to be thoroughly identified (e.g. cell potential (V) at five different concentrations (M) of electrolyte measured)
  - the impacts of risks associated with the experiment and their subsequent management are *considered* with regard to how the methodology was carried out.

Additional advice

- ISMGs must be clearly annotated to indicate the characteristics evident in the student response and the mark awarded for each criterion *(QCE and QCIA policies and procedures handbook v5.0*, Section 9.7.1).
- When applying best-fit judgments on an ISMG, the higher of the two possible marks for that performance level is awarded when all characteristics in the performance level are identified (see *Using ISMGs For General Science syllabuses* under Resources in the Syllabuses app on the QCAA Portal and the *QCE and QCIA policy and procedures handbook v5.0*, Section 9.7.1).
- Schools must use appropriate strategies to promote academic integrity and manage response length in student responses (*QCE and QCIA policy and procedures handbook v5.0*, Sections 8.1.1 and 8.2.6).

Internal assessment 3 (IA3)

Research investigation (20%)

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 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	7
Authentication	3
Authenticity	1
Item construction	3
Scope and scale	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 414.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- directed students to address all aspects of the task, as outlined in the syllabus specifications (Syllabus section 5.5.1)
- ensured the topics identified in the task conditions matched the subject matter addressed in the claims
- contained claims that would allow students to generate multiple research questions, e.g. 'synthetic proteins will revolutionise industries'.

Practices to strengthen

It is recommended that assessment instruments:

- include information that directs students to address all aspects of the task listed in the syllabus specifications (Syllabus section 5.5.1).

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	2
Language	5
Layout	0
Transparency	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 414.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- ensured examples provided in the scaffolding could not be used by students as a basis for their inquiry.

Practices to strengthen

It is recommended that assessment instruments:

- are free from formatting, spelling and/or other clerical errors.

Additional advice

- Only one complete or near-complete draft for feedback is permitted (*QCE and QCIA policy and procedures handbook v5.0,* Section 8.2.5).

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	89.95%	9.56%	0.49%	0%
2	Analysis and interpretation	90.93%	8.82%	0.25%	0%
3	Conclusion and evaluation	89.71%	9.56%	0.74%	0%
4	Communication	99.51%	0.49%	0%	0%

Effective practices

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

- for the Analysis and interpretation criterion,
  - *justified* scientific arguments used concepts related to Unit 4 subject matter and were linked to insightful interpretation of the research evidence, e.g. atom economy and comparative graphical analysis of green synthesis pathways
  - *sufficient* and *relevant* evidence was drawn from more than one credible source and drew upon enough qualitative and/or quantitative data, directly related to the research question, to ensure *relevant* trends, patterns and relationships were *thoroughly* identified, e.g. atom economy data, reaction and waste products
  - *thorough* and *appropriate* limitations of evidence were identified with respect to the validity and reliability of the evidence (e.g. weak points of the data) or methodological limitations of the evidence (e.g. the principles of green chemistry were partially considered)
- for the Conclusion and evaluation criterion,
  - *justified* conclusions directly addressed the research question and were supported by justified scientific arguments that clearly linked to the analysis and interpretation of credible evidence
  - *insightful* discussions about the quality of the evidence addressed the identified limitations and the reliability and validity of the evidence used in response to the research question
  - *considered* and *relevant* improvements and extensions addressed the limitations of the evidence and focused on ways to refine or extend the research investigation to obtain more valid and/or reliable evidence applicable to the claim.

The following excerpt demonstrates a considered rationale showing the development of a specific and relevant research question from the claim.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Claim:

Chemical industries are becoming fully sustainable

Rationale:

Numerous chemical industries produce and release waste, which contradicts the principles of green chemistry. Roche, the 5th largest pharmacy globally, discharges 50,000 tonnes of waste annually, including active pharmaceutical ingredients that can be environmentally toxic and contaminate soil (374 Water, 2022), (Statista, 2023).

Ibuprofen is the 26th most-produced drug worldwide and a widely used anti-inflammatory medication with an annual production of over 20,000 tonnes (National Health Service, 2022), (ClinCal, 2018). This will be the specific drug investigated due to its extensive production and common usage for pain relief among families (BBC, 2015).

The evaluation of the pharmaceutical industry's sustainability will be based on the principles of green chemistry. Green chemistry is a specialised field focusing on creating products and processes that minimise or eliminate the use and generation of harmful substances (United States Environmental Protection Agency, 2023).

There are 12 principles of green chemistry however the three that are most relevant to this investigation will be: Atom economy, Catalysis and Design less hazardous chemical syntheses.

Atom economy is the measure of the efficiency of a reaction. This can be done in many ways but the most common is by using the formula:

$$Atom\ Economy = \frac{Molecular\ weight\ of\ desired\ product}{Molecular\ weight\ of\ all\ reactants} \times 100$$

This determines how much useful product is formed from reactants in a chemical reaction (Manahan, n.d.). The higher the percentage, the more efficient the reaction is.

The second principle, Catalysis, involves the use of catalysts to increase reaction rates without being consumed. Catalysts may also lower the reaction temperature, making the process more economical. Some catalysts enable fewer synthesis steps, thus improving atom economy (United States Environmental Protection Agency, 2023).

The third principle, Design less hazardous chemical syntheses, states that the method used in generating a product or completing a reaction should not release anything that could potentially negatively impact the environment or human health (United States Environmental Protection Agency, 2023).

To find out if the industry is becoming sustainable, a comparative study between two ibuprofen syntheses is required. The original route of ibuprofen production, developed by the Boots Pure Drug Company in the United Kingdom (the discoverers of Ibuprofen) in 1961, will be compared to the green route, the current synthesis used in industry, developed by the Boots Hoechst-Celanese (BHC) Company in the United States of America in 1984. By examining whether the green route/synthesis integrates more green chemistry principles than the original route/synthesis, the claim can be addressed.

Research Question:

Considering all of the above, the research question for this investigation is:

Does the improved synthesis from Ibuprofen’s original route to its new green route result in less wasted reactants and more useful products?

The following excerpt demonstrates *sufficient* and *relevant* evidence to address the research question and enable the thorough identification of relevant trends, patterns or relationships.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Analysis and Interpretation:

Paper 1:

Table 1: The atom economy (%) for Original route of ibuprofen synthesis

Reactions steps	Reagents chemical formula	Relative molecular mass of used reagents	Relative molecular mass of used products	Relative molecular mass of by-products or waste	Atom economy, %
Step 1	$C_{10}H_{14}$	134.0	176.0	60.0	74.58
	$C_4H_6O_3$	102.0			
Step 2	$C_{12}H_{16}O$	176.0	366.5	104.5	71.49
	$C_4H_7O_2Cl$	122.5			
	C_2H_5ONa	68.0			
Step 3	$C_{16}H_{22}O_3$	262.0	281.0	91.0	67.61
	H_3O	19.0			
Step 4	$C_{13}H_{18}O$	190.0	223.0	18.0	91.93
	NH_3O	33.0			
Step 5	$C_{13}H_{19}NO$	205.0	187.0	18.0	91.22
Step 6	$C_{13}H_{17}N$	187.0	182.0	17.0	92.38
	H_4O_2	36.0			

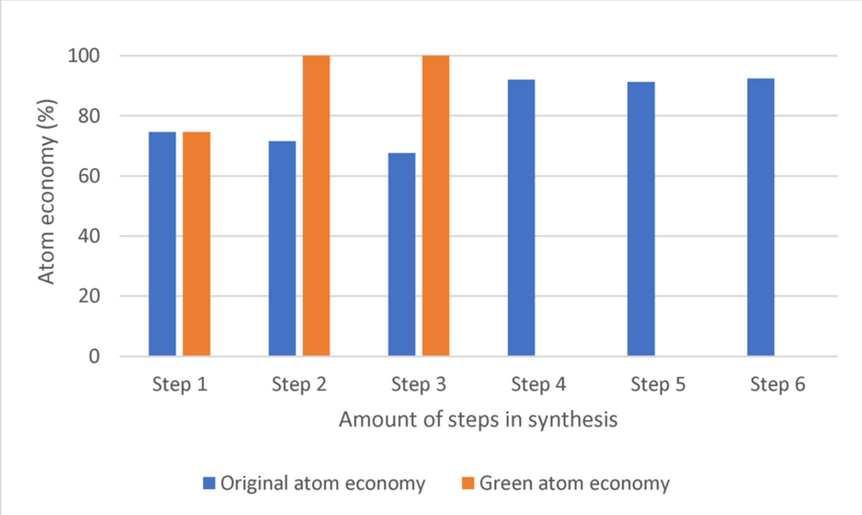
Table 2: The atom economy (%) for Green route of ibuprofen synthesis

Reactions steps	Reagents chemical formula	Relative molecular mass of used reagents	Relative molecular mass of used products	Relative molecular mass of by-products or waste	Atom economy, %
Step 1	$C_{10}H_{14}$	134.0	176.0	60.0	74.58
	$C_4H_6O_3$	102.0			
Step 2	$C_{12}H_{16}O$	176.0	178.0	0.0	100.00
	H_2	2.0			
Step 3	$C_{12}H_{18}O$	178.0	206.0	0.0	100.00
	CO	28.0			

Mureşan, A. C. (2018). Ibuprofen: Original versus green synthesis. Vol. 41, no. 3, p. 70. https://doi.org/10.35219/mms.2018.3.05. CC BY-NC

Hei, F. K., Ching, K. K., & Chi, T. Y. (2020). Production of Ibuprofen. Project on Green Chemistry, pp. 82–86. Retrieved from Education University of Hong Kong: http://aerodrive.ccchwc.edu.hk/

Using these two tables the graph below has been produced



(MUREŞAN, 2018)

Figure 3: Comparing Atom economy of Ibuprofen's original and green route.

Figure 3 illustrates the atom economy of the original synthesis of ibuprofen compared to the green route. It can be observed that both syntheses have the same first step but differ from each other in the remaining steps. It was observed that the 2nd and 3rd steps of the green synthesis have an atom economy of 28.51% and 32.39% greater than the original route respectively. The original synthesis steps 4-6 have relatively high atom economies of 91.22-92.38% however the green synthesis has 3 steps fewer than the original. The original synthesis has a much lower atom economy overall, with an atom efficiency of only 40.04% and the green synthesis consisting of a total atom efficiency of 70.44%.

Paper 3:

	Catalyst and auxiliary substances	Dangerous Reactions	Re-usability
Original Synthesis	1. Hydroxylamine 2. Sodium ethoxide 3. Aluminium Trichloride	1. $4\ NH_2OH + O_2 + heat \rightarrow 2\ N_2 + 6\ H_2O$ 2. $CH_3CH_2O^- + H_2O \rightarrow CH_3CH_2OH + OH^-$ 3. $AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$	1. Can be re-used 2. Can be re-used 3. Goes to Landfill
Green synthesis	1. Hydrogen Fluoride 2. Raney Nickel 3. Palladium	1. $HF + H_2O \rightarrow F + H_3O$ 2. No dangerous reactions 3. No dangerous reactions	1. Re-used to 99.9% efficiency 2. Can be re-used 3. Can be re-used

(Hei, Ching, & Chi, 2020)

Figure 5: Catalysts and toxicity of the reactants used

It can be observed in Figure 5 that Hydroxylamine is an unstable reactant as it only needs to gain heat to combust. Sodium ethoxide, Aluminium Trichloride and Hydrogen fluoride all react with water to form toxic products, H_2O is used in the original route thereby increasing the risk of the synthesis. Furthermore, all of the formerly mentioned reactants are common reactants or substances that can easily come into contact with each other during the synthesis, thereby making these reactions extremely dangerous. For the original synthesis, 3 catalysts/auxiliary substances can produce dangerous reactions when in contact with common reactants whereas only hydrogen fluoride does the same for the green synthesis. Therefore, the green synthesis has a less hazardous chemical synthesis than the original synthesis where no dangerous reactions can occur.

It can be observed in Figure 5 that in the original synthesis hydroxylamine and sodium ethoxide can be re-used as catalysts and auxiliary substances however Aluminium Trichloride cannot, it is hydrated into a substance that must be disposed into landfill. However, the green synthesis re-uses all of them and Hydrogen fluoride in particular can be re-used to 99.9% efficiency and generates no waste. Therefore, the green synthesis has better uses of catalysis than the original synthesis.

Mureşan, A. C. (2018). Ibuprofen: Original versus green synthesis. Vol. 41, no. 3, p. 70. https://doi.org/10.35219/mms.2018.3.05. CC BY-NC

Hei, F. K., Ching, K. K., & Chi, T. Y. (2020). Production of Ibuprofen. Project on Green Chemistry, pp. 82–86. Retrieved from Education University of Hong Kong: http://aerodrive.ccchwc.edu.hk/

The following excerpt demonstrates insightful discussion of the quality of the evidence to evaluate the research process and the conclusions drawn.

Note: The characteristic/s identified may not be the only time the characteristic/s has occurred throughout a response.

Evaluation:

A limitation of these papers is the fact that they did not perform the original synthesis themselves but used the documented findings of each synthesis to analyse it. Therefore, it is not known if the routes will retain their green principles in large industrial-scale settings. This impacts the reliability of the data collected.

Furthermore, no other independently conducted synthesis on the green route can be found online. The only company that uses this synthesis for ibuprofen is the BASF as they purchased the rights to this synthesis (Richard, Peggy, David, & Lindsey, 2011). This process is what all of the papers analysed in this investigation. Therefore, it is not known if this data can be trusted as the results may be biased, as the company may have manipulated them.

Not all green chemistry principles have been considered. The only techniques that have been used to analyse the original and green route of ibuprofen are atom economy, catalysis, and Design less hazardous chemical syntheses than the original synthesis. There are still 9 other principles that can be analysed, possibly affecting the sustainability of the green route as it may lack in the other principles. This reduces the answer's validity

The processes used to create the reactants in the synthesis of ibuprofen are not validated. If the processes used to produce the reactants in the green route are lacking in green chemistry principles, then this route would be invalidated and can't be considered as the more sustainable route.

Practices to strengthen

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

- for the Research and planning criterion,
  - a *considered* rationale clearly connects the research question to Unit 4 subject matter and demonstrates how the research question was developed from the claim. The rationale should clearly articulate why the dependent and independent variables were chosen to be investigated and how these variables linked the research question to the claim and Unit 4 subject matter
  - a specific research question clearly identifies an explicit link to Unit 4 subject matter and allows a justified conclusion to the research question to be reached within the response length conditions of the syllabus, e.g. 'does the improved synthesis from ibuprofen's original route to its new green route result in less waste reactants and more useful products?'.

Additional advice

- Students should be supported through the research investigation process to develop a suitable research question related to the properties and structure of organic materials or chemical synthesis and design to ensure successful completion of the task within the scope of Unit 4 (see the *IA3 effective processes and practices* resources in the Syllabuses app on the QCAA Portal).
- When applying best-fit judgments on an ISMG, the higher of the two possible marks for a performance level is awarded when all the characteristics in the performance level are identified (see *Using ISMGs For General Science syllabuses* under Resources in the Syllabuses app on the QCAA Portal and the *QCE and QCIA policy and procedures handbook v5.0*, Section 9.7.1).
- Schools must use appropriate strategies to promote academic integrity and manage response length in student responses (*QCE and QCIA policy and procedures handbook v5.0*, Sections 8.1.1 and 8.2.6).
- Marked ISMGs must clearly indicate the characteristics evident in the student response and the mark awarded for each criterion (*QCE and QCIA policies and procedures handbook v5.0*, Section 9.7.1).

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.

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 (54 marks).

The examination assessed subject matter from Units 3 and 4. Questions were derived from the contexts 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 questions.

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 question responses

There were 20 multiple choice questions 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	24.3	12.84	2.53	**59.98**
2	**89.15**	4.12	4.95	1.6
3	24.31	10.7	14.04	**50.24**
4	**64.62**	7.07	20.28	7.71
5	5.39	**90**	1.43	3.05
6	12.59	6.7	**72.82**	7.57
7	11.75	9.71	2.41	**75.83**

Question	A	B	C	D
8	**73.24**	6.86	16.28	3.41
9	11.58	**40.74**	13.8	33.62
10	**38.16**	31.25	19.07	10.8
11	**61.54**	4.87	19.14	14.06
12	6.1	**76.83**	4.41	12.42
13	10.88	13.03	24.16	**51.42**
14	8.62	12.52	2.7	**75.97**
15	27.43	11.92	**43.99**	16
16	7.8	28.19	**58.9**	4.8
17	**79.35**	9.77	2.14	8.49
18	7.23	5.45	**78.27**	8.77
19	14.67	7.87	**66.84**	10.2
20	10.29	**61.78**	15.78	11.72

Effective practices

Overall, students responded well to:

- Objective 1 (describe and explain) items that required them to
  - explain dynamic equilibrium
  - describe qualitative observation for oxidation of alcohols
  - explain structural differences between primary and secondary alcohols
  - describe chemical reactions by writing balanced equations and redox half-equations
- Objective 2 (apply understanding) items that required them to
  - calculate cell potential (V), pH and equilibrium constants (K_c and K_a)
  - identify dynamic equilibrium and apply Le Châtelier's principle
  - determine oxidation state and identify oxidating/reducing agents
- Objective 3 (analyse evidence) items that required them to
  - contrast the structure of saturated and unsaturated organic compounds
  - use experimental data to justify the identity of unknown organic compounds and metals
  - identify features of polymers, esters, galvanic cells and equilibrium concentrations
- Objective 4 (interpret evidence) items that required them to
  - deduce an organic compound from infrared data
  - determine the relative strength of acids by contrasting K_a values
  - predict pH and volume of titrant from an acid-base titration curve
  - deduce structural formula for isomers and distinguish between structural and geometric isomers.

Samples of effective practices

The following excerpt is from Question 21 in Paper 1. It required students to apply collision theory to explain a shift in equilibrium.

Effective student responses:

- identified that increasing the concentration of O_2 increased the number of O_2 molecules
- explained that increasing the concentration of O_2 increased collisions between O_2 and CO molecules
- explained that the rate of forward reaction increased
- identified that equilibrium shifted to the right and the concentration of CO_2 increased.

This excerpt has been included:

- to demonstrate the alignment between the number of marks and the number of aspects required in the response
- to demonstrate a response that specifically addresses the question. Students often incorrectly applied Le Châtelier's principle, rather than collision theory, to explain how increasing the concentration of O_2 would affect the concentration of CO_2.

Increasing the concentration of O_2 increases the concentration of reactant particles. This increases the rate of the forward reaction since successful collisions between reactant particles are more frequent. The rate of the reverse reaction does not initially change since the concentration of products remains the same. Therefore, the equilibrium position shifts to the right since the forward reaction will occur at a greater rate. This will increase the concentration of CO_2, until the rates of both reactions become equal, and equilibrium is re-established.

The following excerpt is from Question 26 in Paper 1. It required students to interpret reaction pathways to determine unknown organic compounds, apply IUPAC rules of nomenclature and draw a structural formula.

Effective student responses:

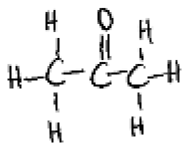
- determined compound A was propene and correctly applied IUPAC naming conventions
- identified compound B was a secondary alcohol
- explained that the OH group in propanol is attached to a terminal carbon while the OH group in Compound B is attached to a carbon, which is attached to two other carbon atoms
- deduced the structural formula for compound C as propanone.

This excerpt has been included:

- to demonstrate that students should
  - understand the difference between reagents and reactants in reaction pathways
  - distinguish between organic and inorganic acids in reaction pathways
  - apply their understanding of organic reactions when deducing the identity of organic compounds, rather than applying rote-learnt pathways that are not supported by the evidence provided.

IUPAC name: propene

Compound B is propan-2-ol. The difference between propanol and propan-2-ol is the position of the hydroxy group. For propan-2-ol, the OH group is on the second carbon but for propanol the OH is on the first carbon. Thus they are structural isomers (have a different spatial arrangement of atoms) Propanol is a primary alcohol and propan-2-ol is secondary.



The following excerpt is from Question 2 in Paper 2. It required students to compare the structure of α-helix and β-pleated sheets in secondary structure proteins.

Effective student responses:

- identified that both α-helix and β-pleated sheets contained hydrogen bonds between peptide bonds in the polypeptide chain
- identified that α-helix structure contains intra-chain H-bonds while β-pleated sheets contain inter-chain H-bonds
- explained that due to the structural difference, α-helix forms coils and β-pleated forms sheets.

This excerpt has been included:

- to demonstrate a response to the cognitive verb *compare* by
  - identifying a structural similarity rather than restating that α-helix and β-pleated sheets are both secondary proteins
  - identifying a structural difference rather than stating the name or the shape (e.g. α-helix are coiled and β-pleated are sheets) of the secondary structures as a difference
  - explaining the significance of the structural difference or structural similarity rather than restating the difference identified
- to demonstrate that students should read the question carefully to ensure that they do not confuse α-helix and β-pleated secondary protein structures with α-glucose and β-glucose.

Similarity: Both form as a result of hydrogen bonding between the functional groups in amino acids.

Difference: α-helix is formed through intra-chain hydrogen bonding, while β-pleated sheets are formed through inter-chain hydrogen bonding.

Significance: Due to the less rigid nature of intra-chain hydrogen bonding, as opposed to inter-chain hydrogen bonding, α-helixes are elastic, whereas, β-pleated sheets are not.

The following excerpt is from Question 5 in Paper 2. It required students to analyse data to determine the strength of acids, identify amphiprotic species and calculate pH.

Effective student responses:

- contrasted K_a values to determine the relative strength of acids
- identified the characteristics of amphiprotic species
- calculated K_a values, dilution factors and pH

This excerpt has been included:

- to demonstrate a response to the cognitive verb *determine* by
  - calculating the K_a value from given data and then contrasting K_a values to decide the relative strength of acids
  - explaining the relationship between hydrogen ion concentration and pH to calculate a dilution volume
- to demonstrate a response to the cognitive verb *identify* by
  - explaining the properties of an amphiprotic species in relation to a conjugate base
  - writing the reversible, balanced equation for the dissociation of a weak acid
- to demonstrate a response to the cognitive verb *calculate* by
  - performing multi-stepped calculations, supported by logical working which supports the response
- to demonstrate that students should attempt all parts of a question to maximise their marks when answering questions rather than focusing on the total mark for the question.

$K_{a_1} = \frac{[H^+][\text{conjugate base}]}{[\text{acid}]}$ Assume $[H^+] = [\text{conjugate base}]$ because equal dissociation

$= \frac{[H^+]^2}{[\text{acid}]} = 3.1205 \times 10^{-8}$

Acid 2 is a stronger acid than acid 1 because its K_a of 1.8×10^{-4} is greater than the K_a of 3.12×10^{-8} of acid 1 indicating more ionisation and thus more strength

$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$

The conjugate base of ethanoic is $CH_3COO^-_{(aq)}$, which is not amphiprotic because it cannot donate more H^+ ions to another base, meaning it cannot act as an acid, and thus not be an amphiprotic species, despite being able to accept H^+ ions.

$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$ Assume $[H_3O^+] = [CH_3COO^-]$ because it is a weak acid so approximate equal dissociation.

$K_a = \frac{[H_3O^+]^2}{[CH_3COOH]}$

$[H_3O^+] = \sqrt{K_a \times [CH_3COOH]} = \sqrt{1.78 \times 10^{-5} \times 0.1} = 1.334 \times 10^{-3} M$

$pH = -\log[H_3O^+] = -\log[1.334 \times 10^{-3}] = 2.87$ Therefore pH is 2.87

$n(HCl) = c \times V = 0.01 \times \frac{100}{1000} = 1 \times 10^{-3}$ moles of HCl originally

At pH 3, $[H^+] = 10^{-pH} = 10^{-3} = 1 \times 10^{-3}$ ← number of mol is constant.

$V = \frac{n}{c} = \frac{1 \times 10^{-3}}{1 \times 10^{-3}} = 1L$ at 1 litre total the volume, the pH = 3 ∴ 1L − 100mL = 900mL of water

Therefore 900mL of water must be added

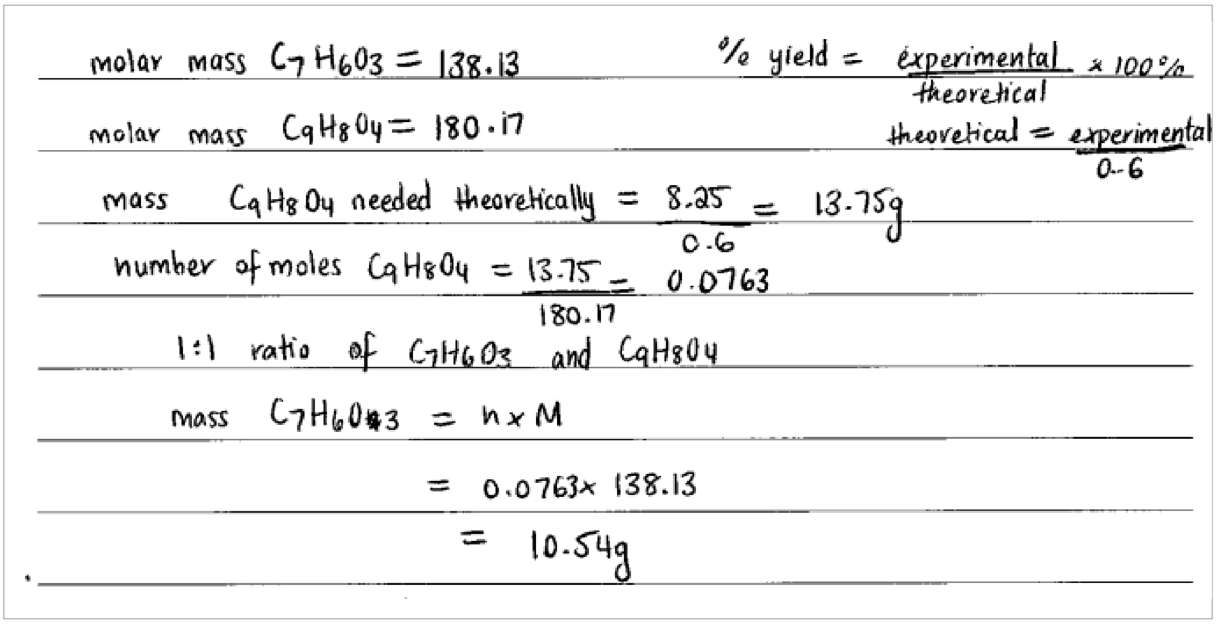
The following excerpt is from Question 9 in Paper 2. It required students to perform multi-stepped calculations.

Effective student responses:

- determined the molar mass and moles of aspirin
- determined the moles of salicylic acid
- calculated the mass of salicylic acid

This excerpt has been included:

- to demonstrate a response to the cognitive verb *calculate* by
  - determining the molar mass of aspirin and salicylic acid
  - determining the theoretical mass of aspirin produced for 100% yield
  - applying mole ratio to determine moles of salicylic acid required
  - calculating mass of salicylic acid
- to demonstrate that students should use a logical approach that clearly sets out their working when responding to multi-stepped calculations.
- to demonstrate that different mathematical approaches can be used to determine a valid response.



molar mass $C_7H_6O_3 = 138.13$

% yield = $\frac{\text{experimental}}{\text{theoretical}} \times 100\%$

molar mass $C_9H_8O_4 = 180.17$

theoretical = $\frac{\text{experimental}}{0.6}$

mass $C_9H_8O_4$ needed theoretically $= \frac{8.25}{0.6} = 13.75g$

number of moles $C_9H_8O_4 = \frac{13.75}{180.17} = 0.0763$

1:1 ratio of $C_7H_6O_3$ and $C_9H_8O_4$

mass $C_7H_6O_3 = n \times M$

$= 0.0763 \times 138.13$

$= 10.54g$

Practices to strengthen

When preparing students for external assessment, it is recommended that teachers consider:

- the cognitive verb and the nature of the response required when responding to questions. For instance, when responding to questions that use the verb 'compare' students should ensure they explain the significance of the similarities and differences identified, e.g. Question 23 in Paper 1 and Question 2 in Paper 2
- teaching and learning opportunities for students to apply their understanding to an appropriate depth across the breadth of the subject matter. For instance, consider reviewing multiple choice questions and short response questions that require application of understanding from

two or more areas of the subject matter or across two or more steps, e.g. Questions 21, 25 and 27 in Paper 1, and Question 9 in Paper 2

- problem-solving activities that require students to critically analyse and interpret evidence, deduce outcomes and provide justified reasoning for responses. For instance, consider applying understanding of organic compounds and reactions to critically evaluate reaction pathways, e.g. Question 26 in Paper 1 and Questions 4 and 5 in Paper 2
- teaching and learning opportunities for students to practise drawing structural formulas and correctly applying the IUPAC nomenclature system to name organic compounds, e.g. Question 26 in Paper 1 and Question 4 in Paper 2.

Additional advice

- Schools should review their sequences of teaching and learning to ensure that they help students to understand the connections between the subject matter across syllabus topics and units.
- Teachers should review their use of the guidance information provided in the syllabus to ensure that students understand this information can be used to clarify the scope of the subject matter but is not a summary of, nor a substitute for, the subject matter.

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.

Assessment design

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: 13.

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

Assessment decisions

Effective practices

Overall, students responded well to:

- opportunities to demonstrate their understanding of titration curves to identify an appropriate indicator and the concentration and identity of an unknown weak acid
- opportunities to analyse equilibrium graphs to identify general trends, patterns and relationships, and calculate K_a values
- opportunities to interpret evidence by writing conclusions in response to a research question and to evaluate a claim.

Practices to strengthen

This subject will no longer be offered after 2023.