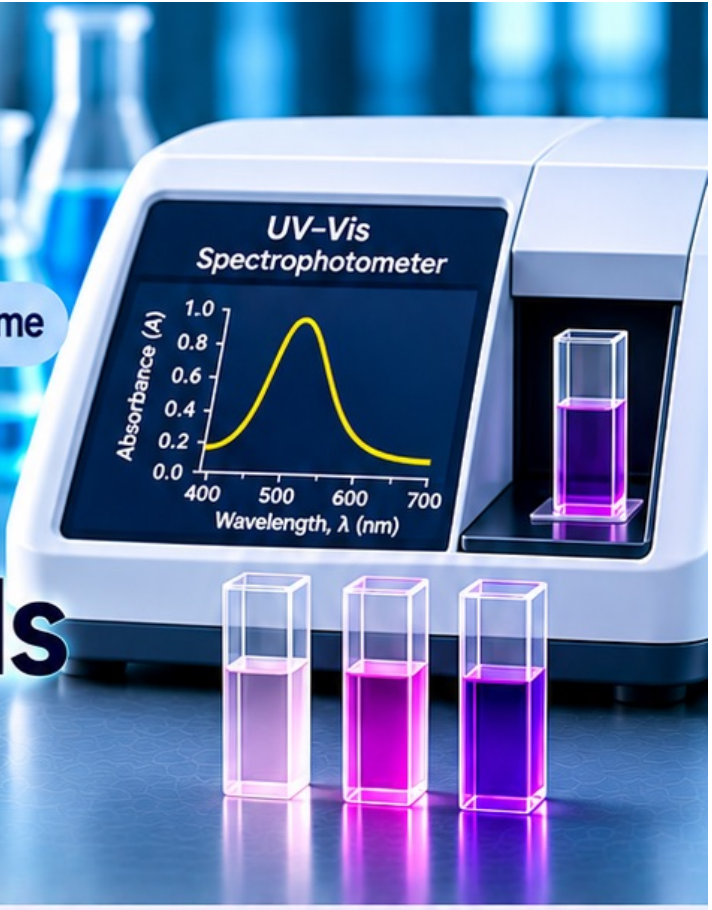
LearningSparks®
Education Services

Pre-IB Chemical Research Skills Programme



Chemical Research Skills

A Skills-Building Programme for Independent Chemical Investigation

Module 8 | Worksheets

Student Practice & Application

Module Focus

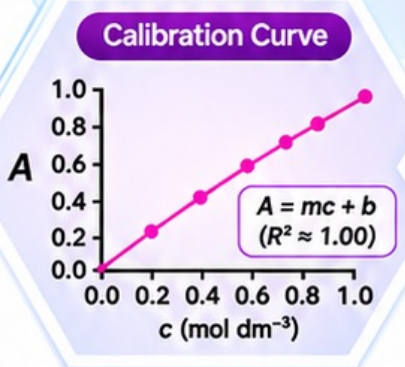
- Principles of UV-Vis spectrophotometry
- The Beer–Lambert Law ($A = \varepsilon lc$)
- Preparing standard solutions and serial dilutions
- Constructing a calibration curve
- Determining the concentration of an unknown solution
- Evaluating results and identifying sources of error

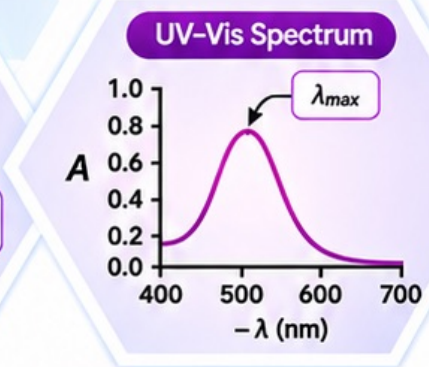


Key Equation

$$A = \varepsilon lc$$

- A = Absorbance (no unit)
- ε = Molar absorptivity (L mol^{-1} cm^{-1})
- l = Path length (cm)
- c = Concentration (mol dm^{-3})





Sunny Chiam

IB Chemistry Specialist & Examiner-Level Educator
Founder, LearningSparks Education Services
Creator of the CHIAM Framework™

Module 8 — Student Worksheets
Reliability, Accuracy & Data Quality
How Do We Know Whether Our Experimental Results Can Be Trusted?
Pre-IB Chemical Research Skills Programme
LearningSparks Education Services
Student: _____
Date: _____
Related 1-Minute Chemical Research Skills episodes:

- **Episode 19:** Why Do We Repeat Measurements?
- **Episode 20:** Accuracy vs Precision — What's the Difference?
- **Episode 21:** What Should We Do with Anomalous Results?

Module Learning Objectives

By completing these worksheets, students should be able to:

1. Explain why repeated measurements are important.
2. Distinguish repeated instrument readings from independent experimental repeats.
3. Calculate and interpret the mean, range, standard deviation and relative standard deviation.
4. Distinguish accuracy from precision.
5. Calculate percentage error and percentage difference.
6. Distinguish random errors from systematic errors.
7. Calculate absolute and percentage uncertainty.
8. Estimate uncertainty in quantities calculated from experimental measurements.
9. Recognise and investigate anomalous results.
10. Explain why anomalous results should not be removed without justification.
11. Evaluate the quality of calibration, extraction and titration data.
12. Identify whether numerical differences are meaningful relative to experimental uncertainty.
13. Recommend specific improvements to experimental methods.
14. Construct conclusions supported by quantitative evidence.

The worksheets progress from basic concepts to independent research judgement.

Measure → Repeat → Analyse → Evaluate → Conclude

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Section A — Why Do We Repeat Measurements?

Episode 19: Why Do We Repeat Measurements?

Worksheet 1 — Is One Measurement Enough?

A student measures the concentration of an unknown solution and obtains:

$$0.102\ \text{mol dm}^{-3}$$

Question 1

Can the student determine the repeatability of the method from this single measurement?

☐ Yes

☐ No

Explain.

_____

_____

Question 2

The student repeats the measurement and obtains:

$$0.101,\ 0.102,\ 0.103\ \text{mol dm}^{-3}$$

What additional information do these measurements provide?

_____

Question 3

Identify three reasons for repeating experimental measurements.

1. _____
2. _____
3. _____

Question 4

Complete:

Repeated measurements → Evidence about experimental _____

Research thinking

Does repeating an experiment automatically eliminate systematic error?

☐ Yes

☐ No

Explain.

_____

_____

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Worksheet 2 — Repeated Readings vs Independent Repeats

A student uses UV–Vis spectroscopy to measure the concentration of a coloured solution.

Method A

Prepare one solution and measure its absorbance five times using the same cuvette.

Method B

Prepare five independent solutions using the same procedure and measure the absorbance of each.

Question 1

Which method mainly evaluates the repeatability of the instrument measurement?

Method _____

Question 2

Which method provides more information about variation in the complete sample-preparation procedure?

Method _____

Question 3

Why are these methods not equivalent?

_____

_____

Question 4

Which method is more appropriate for evaluating the repeatability of an entire analytical procedure involving weighing, dilution and measurement?

_____

Complete

[Repeated readings] ≠ [independent experimental _____]

_____

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Worksheet 3 — What Counts as a Replicate?

For each investigation, describe an appropriate independent experimental replicate.

Investigation	Appropriate independent replicate
Acid–base titration	_____
Liquid–liquid extraction	_____
UV–Vis concentration determination	_____
Reaction-rate experiment	_____
Preparation of a standard solution	_____

Question 1

A student measures the absorbance of the same cuvette five times.

Has the student performed five independent solution preparations?

☐ Yes

☐ No

Question 2

Why should a research report explain exactly what was repeated?

_____

Question 3

Improve the following statement:

“The experiment was repeated three times.”

Your improved statement should specify what was repeated.

_____

_____

_____

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Worksheet 4 — Are Three Repeats Always Enough?

Student A says:

"Three repeats are always enough to prove that an experiment is reliable."

Student B says:

"The number of repeats should depend on the variation in the data, the purpose of the investigation and the required confidence."

Question 1

Which student demonstrates stronger scientific reasoning?

Student _____

Question 2

Explain why.

_____

_____

Question 3

Identify three factors that may influence the number of repeats required.

1. _____
2. _____
3. _____

Complete

automatic experimental _____

_____

Section B — Describing Variation in Experimental Data

Worksheet 5 — Calculating the Mean

A student obtains five concentration measurements:

$$0.101,\ 0.103,\ 0.102,\ 0.104,\ 0.100$$

All values are in:

$$\text{mol dm}^{-3}$$

Question 1

Write the formula for the arithmetic mean.

Question 2

Calculate the mean concentration.

Show your working.

Question 3

What does the mean represent?

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