International Baccalaureate · IB Diploma · Chemistry · HL

Practical Skills ·

The scientific investigation (the internal assessment, 20% of the grade) and the data-based questions of Paper 1B both mark the same habits: glassware read to its precision, uncertainties carried to the answer, and a conclusion that compares the result with a literature value and explains the gap. *1B*

The scientific investigation at a glance

About 10 hours of work, written up in at most 3,000 words, marked out of 24: four criteria of 6 marks each. Tables, graphs and calculations do not count towards the words, so spend the words on choices and their reasons.

Research design – a focused question naming the independent and dependent variables and the range, the chemistry behind it, and a method another student could repeat – concentrations, volumes, glassware, how each control is held

Data analysis – raw data with uncertainties, one full sample calculation, a graph where the data call for one, and the uncertainty carried to the final value

Conclusion – answers the question with numbers and compares the result with a literature value, giving the percentage error and the source

Evaluation – weaknesses that affected THIS data set, the direction each pushed the result, and improvements a school lab could carry out

A question that scores names what changes, what is measured and over what range: 'How does the temperature of 0.100 mol dm^{-3} hydrochloric acid, from 20 °C to 60 °C, affect the rate of its reaction with magnesium ribbon, measured as the time for the ribbon to disappear?'

Write a risk assessment into the method: the hazard, the concentration at which it applies, and the precaution. Note how waste is disposed of – heavy-metal solutions do not go down the sink.

Reading glassware and instruments

Use the tolerance printed on the glassware when there is one. Otherwise: an analogue scale is ± half its smallest division, a digital display ± one in its last digit.

Burette – read to 0.05 cm^3 at the bottom of the meniscus, at eye level; each reading ± 0.05 cm^3, so a titre (two readings) is ± 0.10 cm^3

Volumetric pipette – delivers one fixed volume – 25.00 cm^3 ± 0.06 cm^3 for a class B pipette. Fill with a pipette filler past the mark, then let the meniscus fall to it

Volumetric flask – makes up one fixed volume – 250.0 cm^3 ± 0.3 cm^3 class B. Add the last drops with a dropping pipette and invert to mix

Measuring cylinder – ± half a division – about 1% at best. Fine for a reagent in excess, not for the volume a calculation depends on

Balance – ± one in the last digit displayed; weigh by difference (container with solid, then empty container) so whatever stays in it does not matter

Thermometer – ± 0.5 °C for 1 °C divisions; a digital probe ± 0.1 °C. A temperature CHANGE is two readings, so double it

Record every reading to the precision of the instrument, including a trailing zero: 0.00 cm^3 and 25.00 cm^3 on a burette, never 0 and 25.

Propagating uncertainty

Adding or subtracting quantities: add the absolute uncertainties. Multiplying or dividing: add the percentage uncertainties. These give the maximum uncertainty, which the course uses.

Ignore the uncertainty of a value you were given without one (a molar mass, the 4.18 J g^{-1} K^{-1} of water), and of any reagent in excess.

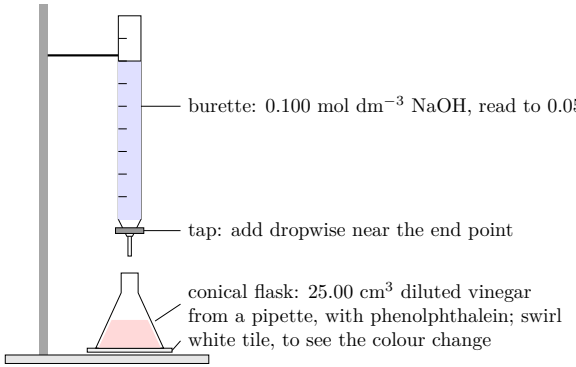
Compare the total uncertainty with the percentage error against the literature value. If the error is SMALLER, random error can explain it. If it is LARGER, the method has a systematic error – and you should say what it is and which way it pushed the result.

Round the final uncertainty to one significant figure and the value to match: 196.5 ± 8.1 kJ mol^{-1} becomes 196 ± 8 kJ mol^{-1}.

Worked example: ethanoic acid in vinegar by titration :

25.00 cm^3 of vinegar was diluted to 250.0 cm^3 in a volumetric flask. 25.00 cm^3 portions of the diluted solution were titrated with 0.100 mol dm^{-3} sodium hydroxide, using phenolphthalein, which turns from colourless to the first permanent pale pink at the end point.

Apparatus



Rinse the burette with the NaOH solution and the pipette with the vinegar solution first, so neither dilutes what it holds.

Results

	Rough	1	2	3
Final reading / cm^3 ± 0.05	22.10	22.10	21.85	22.55
Initial reading / cm^3 ± 0.05	0.00	0.50	0.20	1.00
Titre / cm^3 ± 0.10	22.10	21.60	21.65	21.55

Concordant titres agree within 0.10 cm^3. The rough titre only locates the end point and is left out of the mean.

Processing

1. Mean titre = (21.60 + 21.65 + 21.55) ÷ 3 = 21.60 cm^3.
2. n(NaOH) = 0.100 × 21.60 ÷ 1000 = 2.160 × 10^{-3} mol. $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$ is 1 : 1, so n(CH_3COOH) in 25.00 cm^3 = 2.160 × 10^{-3} mol.
3. Diluted concentration = 2.160 × 10^{-3} ÷ 0.02500 = 0.0864 mol dm^{-3}; the vinegar was diluted ten times, so it is 0.864 mol dm^{-3}.
4. Mass concentration = 0.864 × 60.06 = 51.9 g dm^{-3} (about 5.2 g per 100 cm^3).
5. Uncertainty: titre 0.10 ÷ 21.60 = 0.46%; two pipettings 2 × 0.06 ÷ 25.00 = 0.48%; flask 0.3 ÷ 250.0 = 0.12%. Total 1.1%, so 51.9 ± 0.6 g dm^{-3} – leaving out the uncertainty in the NaOH concentration, which should be stated if it is known.

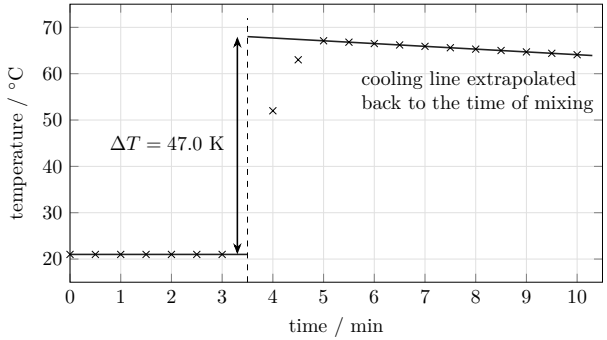
Evaluation

Sodium hydroxide absorbs carbon dioxide from the air, which lowers its concentration over time. Each titre then comes out larger and the calculated acid concentration HIGHER. Standardise the NaOH against potassium hydrogen phthalate on the day.

The end point is judged by eye. Titrate to the first PERMANENT pale pink, add the last drops one at a time, and compare against a flask already at the end point.

Worked example: an enthalpy change by calorimetry :

Excess zinc powder was added to 25.0 cm^3 of 1.00 mol dm^{-3} copper(II) sulfate in a polystyrene cup with a lid. The temperature was read every half minute for 3 minutes before mixing and for 7 minutes after; the zinc went in at 3.5 minutes.



Extrapolating the cooling line back to 3.5 min estimates the temperature the mixture would have reached with no heat lost while it reacted.

Processing

1. q = m c ΔT = 25.0 g × 4.18 J g^{-1} K^{-1} × 47.0 K = 4.91 × 10^3 J, taking the solution's mass and heat capacity as those of water.
2. n(Cu^{2+}) = 1.00 × 25.0 ÷ 1000 = 0.0250 mol; zinc is in excess, so this is the amount that reacted.
3. ΔH = −4.91 kJ ÷ 0.0250 mol = −196 kJ mol^{-1}, negative because the mixture warmed.
4. Uncertainty: ΔT (two readings at ± 0.5 °C) ± 1.0 K = 2.1%; measuring cylinder ± 0.5 cm^3 = 2.0%. Total 4.1%, so ΔH = −196 ± 8 kJ mol^{-1}.

Conclusion and evaluation

The literature value is −218 kJ mol^{-1}: the result is 10% low in magnitude, and that is more than the 4% uncertainty, so random error cannot explain it. The method has a systematic error that makes ΔT too small.

Heat lost through the cup and to the air is the main one, despite the extrapolation; the cup and thermometer also absorb heat that the calculation leaves out. Both make the magnitude smaller. Improvement: a lid with a hole only for the thermometer, the cup inside a beaker of cotton wool, and a calibration of the calorimeter's heat capacity with a reaction of known ΔH.

Measuring the 25.0 cm^3 with a pipette instead of a measuring cylinder cuts the volume uncertainty from 2.0% to 0.2%. It is worth doing, but it would not close the 10% gap – and saying that is the kind of judgement the evaluation marks.

Rates – reading a graph :

For a gas collected over time, the rate at any moment is the gradient of the volume–time curve. Draw the tangent at that time, make it long, and divide its rise by its run. The initial rate is the tangent at t = 0.

A '1/time' method (time for a cross to disappear, or for a fixed volume of gas) measures an AVERAGE rate to a fixed point. It is fair only if the same amount of reaction has happened at that point in every run.

For an order: plot initial rate against concentration. A horizontal line is zero order, a straight line through the origin first order, an upward curve second order – confirm with rate against concentration squared.

Temperature control: stand both reactants in the same water bath until they read the same temperature, then mix. 'At room temperature' is not a control.

Paper 1B – data-based questions 1B:

Paper 1B gives you someone else's experiment. Most marks are for reading the table or graph and processing it; the chemistry you need is usually in the question.

Check the units of every column before you calculate: cm^3 to dm^3 (÷ 1000), g to mol (÷ molar mass), °C differences are the same as K differences.

Give answers to the number of significant figures of the least precise data, and keep extra figures in the intermediate steps.

When asked why a result differs from the literature value, name a systematic error and its direction: 'heat lost to the surroundings makes ΔT, and so the magnitude of ΔH, too small'. 'Experimental error' alone scores nothing.

When asked for an improvement, match it to the error: heat loss → insulate and use a lid; a gas that dissolves in water, such as CO_2 → collect it in a gas syringe, not over water; an end point hard to see → a white tile, or a pH probe and a titration curve.

Evaluation – what scores and what does not :

Every weakness needs three parts: what it is, which way it pushed the result, and an improvement you could carry out. Missing any one loses the point.

'Use more accurate equipment' scores only when you name the equipment and its precision: 'a burette (± 0.05 cm^3) in place of the measuring cylinder (± 0.5 cm^3)'.

‘Repeat the experiment’ addresses random error only. Heat loss, impure reagents and a misjudged end point all repeat with the experiment.

Say what the uncertainty already explains before blaming anything: a result within its own uncertainty of the literature value needs no systematic error to explain it.