

3.2.2 Calorimetry and evaluation

Name: _____ Class: _____ Date: _____

Total: 21 marks

KEY WORDS heat loss • extrapolation • insulated container

Objective

Master the calorimetry calculation and its evaluation: prove the excess, convert a temperature change to an enthalpy change per mole of the limiting reagent, diagnose heat loss, and know which improvements the scheme credits – and which it ignores. Original practice for WCH13 Q5 (Summer 2025) and CP2.

1 Key knowledge and worked examples

■ The four-step enthalpy calculation

1. Which reagent limits? Compare amounts: $n = cV$ for solution, $n = m/A_r$ for solid.
2. Energy: $q = mc\Delta T$ with the **solution's** mass (g), $c = 4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$, ΔT in $^\circ\text{C}$.
3. Per mole: $\Delta H = -q/n$ using the **limiting reagent's** moles.
4. Sign and unit: exothermic reaction, negative, kJ mol^{-1} .

Worked check (2025 paper). 50.0 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ ZnSO}_4$ ($n = 0.0500 \text{ mol}$) + 2.20 g Mg (0.0905 mol – excess). T : $19.4 \rightarrow 55.2 \text{ }^\circ\text{C}$.

$$\Delta T = 55.2 - 19.4 = 35.8 \text{ }^\circ\text{C}$$

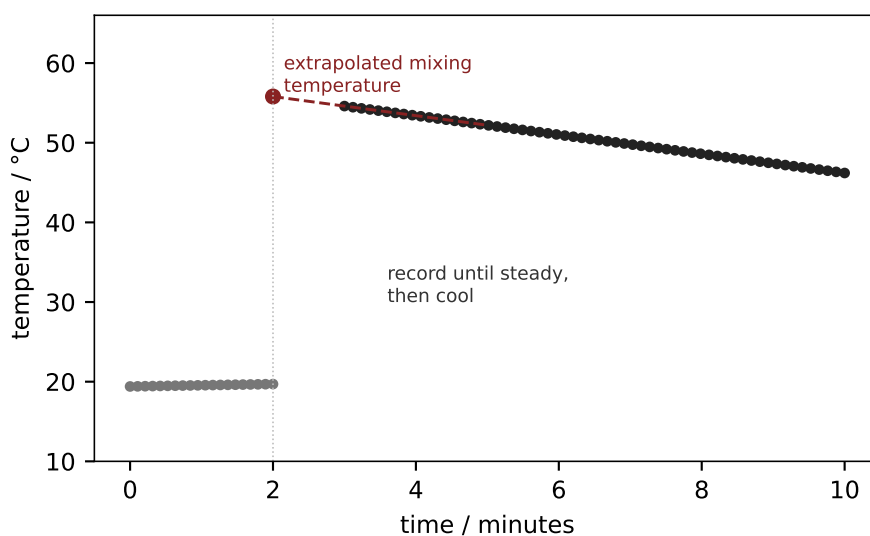
$$q = 50.0 \times 4.18 \times 35.8 = 7482 \text{ J}$$

$$\Delta H = -7.482 \text{ kJ} \div 0.0500 \text{ mol} = -150 \text{ kJ mol}^{-1}$$

■ Why values come out low, and what fixes them

An experimental value well below the data book means **heat loss to the surroundings** – the standard one-mark answer. Credited improvements: an insulated container (polystyrene cup); a lid; temperature every 30 s or a data logger; a **lower concentration** (slower, less intense heating, less loss); a temperature–time graph with the

cooling extrapolated back to mixing (below). The scheme *ignores* more accurate glassware (pipette/burette), a better balance, and repeats.



2 Practice

2.1 25.0 cm³ of 0.800 mol dm⁻³ copper(II) sulfate is mixed with 1.50 g of zinc powder. Show which reagent is in excess. (*A_r* Zn = 65.4.) [3]

2.2 For that mixture, the temperature rises from 21.5 °C to 34.3 °C. Calculate *q*. [2]

2.3 Using your answers, calculate ΔH with sign and unit. [2]

2.4 State the most likely reason an experimental value is much less exothermic than the data-book value. [1]

3 Exam-style questions

3.1 A student measures the enthalpy of displacement between magnesium and 50.0 cm³ of 1.00 mol dm⁻³ zinc sulfate using a glass beaker, a thermometer read at the start and once after stirring, and 2.20 g of magnesium powder. The temperatures were 19.4 °C and 55.2 °C. Calculate the enthalpy change (mass of solution 50.0 g; c = 4.18 J g⁻¹ °C⁻¹), and justify four improvements to equipment or procedure. [8]

3.2 A second student's value is considerably less exothermic than the data book's. Give the most likely reason, and explain why repeating and averaging would not close the gap. [3]

3.3 Explain why the enthalpy change is divided by the moles of zinc ions rather than the moles of magnesium added, in the 2025 calculation. [2]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 $n(\text{Cu}^{2+}) = 0.0250 \times 0.800 = 0.0200 \text{ mol}$; $n(\text{Zn}) = 1.50/65.4 = 0.0229 \text{ mol}$; zinc is in excess – copper(II) ions limit.

2.2 $\Delta T = 34.3 - 21.5 = 12.8 \text{ }^\circ\text{C}$; $q = 25.0 \times 4.18 \times 12.8 = 1338 \text{ J}$.

2.3 $\Delta H = -1.338/0.0200 = -66.9 \text{ kJ mol}^{-1}$ (exothermic, per mole of Cu^{2+} displaced).

2.4 Heat loss to the surroundings.

3.1 $n(\text{Zn}^{2+}) = 0.0500 \text{ mol}$ (zinc ions limit; $\text{Mg} = 0.0905 \text{ mol}$ excess). $\Delta T = 35.8 \text{ }^\circ\text{C}$; $q = 50.0 \times 4.18 \times 35.8 = 7482 \text{ J}$; $\Delta H = -7.482/0.0500 = -150 \text{ kJ mol}^{-1}$. Improvements (any four): use an insulated container / polystyrene cup; fit a lid; record temperature every 30 s or use a data logger; use a lower concentration so heat is lost more slowly; plot temperature–time and extrapolate the cooling curve back to mixing.

3.2 Heat loss – energy leaves the beaker before the thermometer reads the true maximum. Repeats reduce random error and improve reliability, but heat loss is systematic: every repeat loses heat the same way, so the mean stays low.

3.3 Magnesium was added in excess, so only 0.0500 mol of it reacted; the measured heat belongs to the reaction of the limiting zinc ions, so per-mole values must use the limiting reagent's amount.