

Enthalpy Changes and Calorimetry

Using temperature data to calculate the heat and molar enthalpy change of a chemical reaction.



Figure 1: A polystyrene-cup calorimeter setup on a lab bench, showing a nested pair of foam cups inside a beaker for stability, a thermometer probe

Learning intentions

We are learning to:

- Define enthalpy and molar enthalpy for a chemical reaction.
- Apply $Q = mc\Delta T$ to calculate the heat transferred during a reaction.
- Use calorimetry data to calculate the molar enthalpy change of a reaction and express it using correct sign and units.

Success criteria

I can:

- State what enthalpy and molar enthalpy mean in the context of a chemical reaction.
- Calculate Q using $Q = mc\Delta T$, from given mass, specific heat capacity and temperature change.
- Convert a heat value into a molar enthalpy change (kJ/mol) using moles of limiting reactant.
- Write the enthalpy change using ΔH , ΔH_{r} or ΔH_{f}

Curriculum alignment

- 30-A1.3k: define enthalpy and molar enthalpy for chemical reactions ([Outcome](#), [Outcome](#))
- 30-A1.1k: recall the application of $Q = mc\Delta T$ to calculate energy changes ([Outcome](#))
- 30-A1.8k: use calorimetry data to determine the enthalpy changes in chemical reactions ([Outcome](#))
- 30-A1.5k: use and interpret ΔH , ΔH_{r} or ΔH_{f} to communicate and calculate energy changes in chemical reactions ([Outcome](#))
- 30-A1.2s: perform calorimetry experiments and use temperature probes appropriately when measuring temperature changes ([Outcome](#))
- 30-A1.3s: analyze data and apply mathematical models to determine energy changes ([Outcome](#))

Materials

- Whiteboard or projector for worked examples
- Student handout with the calorimetry problem set (create from examples below)
- Scientific calculators
- One demonstration calorimeter set-up: polystyrene cups, thermometer or temperature probe, graduated cylinder, hot plate or kettle, balance (for a quick live demo or to reference photographs from [Resource](#))
- Sticky notes or mini whiteboards for the exit check

Lesson sequence

1. Hook (5 minutes)

Ask the class: "If I dissolve 5.0 g of solid sodium hydroxide in 100 mL of water in a foam cup, and the temperature rises from 21.0°C to 33.5°C, where did that energy come from, and where did it go?"

Take two or three verbal answers. Push for the idea that the chemical reaction released energy and the water absorbed it. Write on the board: "Today we calculate exactly how much energy, and express it per mole of reactant."

2. Direct instruction (10 minutes)

Define terms on the board:

- Enthalpy (H): the heat content of a system at constant pressure. Enthalpy change (ΔH), ΔH_{r} or ΔH_{f} absorbed or released by a reaction ([Outcome](#), [Outcome](#)).
- Molar enthalpy (ΔH_{m}): the enthalpy change per mole of a specified reactant or product, in kJ/mol ([Outcome](#), [Outcome](#)).
- ΔH , ΔH_{r} or ΔH_{f} are negative for exothermic reactions and positive for endothermic reactions ([Outcome](#)).

Write the calorimetry equation: $Q = mc\Delta T$ transferred (J), m is mass of the calorimeter fluid (g), c is specific heat capacity ($\text{J}/(\text{g}\cdot^\circ\text{C})$, usually 4.19 for water), and ΔT is temperature change ($^\circ\text{C}$) ([Outcome](#), [Outcome](#)).

Work through this example on the board:

"25.0 g of water absorbs heat as a reaction proceeds. The water temperature rises from 20.0°C to 27.4°C . Calculate Q ."

$$Q = mc\Delta T$$

$$Q = (25.0 \text{ g})(4.19 \text{ J}/(\text{g}\cdot^\circ\text{C}))(7.4^\circ\text{C})$$

$$Q = 775 \text{ J}$$

$$Q = 0.775 \text{ kJ}$$

Then extend it to molar enthalpy: "This heat was released by 0.010 mol of reactant. Calculate the molar enthalpy change and write it with correct notation."

$$\Delta H = \frac{Q}{n} = \frac{-0.775 \text{ kJ}}{0.010 \text{ mol}} = -77.5 \text{ kJ/mol}$$

Since the water gained heat, the reaction released heat, so the reaction itself is exothermic: $\Delta H = -77.5 \text{ kJ/mol}$ ([Outcome](#), [Outcome](#)).

Point out the sign convention explicitly: heat gained by the water is heat lost by the reacting system, so the sign flips when you assign ΔH , $Q_{\text{water}} = -Q_{\text{reaction}}$.

3. Guided practice (10 minutes)

Put this problem on the board and work it with the class, calling on different students for each step:

"In a calorimetry experiment, 50.0 g of water is heated by the combustion of a small sample of fuel. The water temperature increases from 22.0°C to 46.0°C . The fuel sample used has a mass corresponding to 0.0050 mol.

a) Calculate Q .

b) Calculate the molar enthalpy change of combustion.

c) Write the value using ΔH , $\Delta H_{\text{comb}} = -60 \text{ kJ/mol}$.

Guide students to:

$$a) Q = mc\Delta T = (50.0 \text{ g})(4.19 \text{ J}/(\text{g}\cdot^\circ\text{C}))(24^\circ\text{C}) = 5027 \text{ J}$$

$$b) \Delta H = \frac{Q}{n} = \frac{-5027 \text{ J}}{0.0050 \text{ mol}} = -1.0 \times 10^6 \text{ J/mol}$$

c) $\Delta H_{\text{comb}} = -1.0 \times 10^6 \text{ J/mol}$ exothermic, since the water gained heat

Pause here for a checkpoint (see Assessment section) before moving to independent work.

Reference [Resource](#) briefly: "This is the same reasoning used in the nut-combustion calorimetry lab, where burning a food sample heats a known mass of water."

4. Independent practice (10 minutes)

Students work individually or in pairs on two problems, written on the handout:

Problem 1: "75.0 g of water in a calorimeter increases in temperature from 19.5°C to 28.0°C when 0.0125 mol of a salt dissolves. Calculate Q , calculate the molar enthalpy of dissolution, and write ΔH , with the correct sign."

Problem 2: "A student burns 0.80 g of ethanol (molar mass 46.0 g/mol) under 100.0 g of water. The water temperature rises by 32.0°C . Calculate the moles of ethanol burned, calculate Q , calculate the molar enthalpy of combustion, and write ΔH_{comb} , $\Delta H_{\text{comb}} = -1.3 \times 10^6 \text{ J/mol}$ "

Circulate while students work. Prompt students who get stuck on Problem 2 with: "What do you need before you can calculate ΔH_{comb} how many moles of ethanol actually reacted?"

5. Consolidation (5 minutes)

Cold-call for answers to Problem 1 and Problem 2, and correct any sign errors on the board.

Ask: "Why does calorimetry only give us an experimental value for ΔH rather than the true value?" Draw out ideas such as heat loss to the surroundings, the calorimeter absorbing some heat, and incomplete reactions. Note this connects to [Resource](#), where students test calorimeter precision directly.

Close with a one-sentence exit prompt written on the board: "In your own words, what is the difference between enthalpy and molar enthalpy?"

Differentiation

Extension: Ask early finishers to research why the value of ΔH_{comb} for a reaction obtained experimentally often differs from the accepted literature value, and to list two sources of experimental error specific to a polystyrene-cup calorimeter (reference [Resource](#)). Extend Problem 2 by asking students to compare their experimental ΔH_{comb} for ethanol to a published value and calculate a percent difference.

Support: Provide a written step-by-step template for Problems 1 and 2 that separates the Q calculation from the 9D†ÖöÂ 6 Æ7VÆ F—öâ—çFò Gpo labelled boxes. Provide a reference card with Q = mc9GBÂ 9D†ÖöÂ Ò r âÂ æB F†R 6—vâ ule (system loses heat ! 9D, æVv F—`e; system gains heat ! 9D, ÷6—F—`e) for students to keep at their desks. Allow calculators with stored formulas and pair support students with a stronger peer for the independent practice.

Assessment

Formative check: During the guided practice checkpoint, ask students to hold up mini whiteboards or sticky notes showing only their calculated Q value for the combustion problem before revealing the class answer.

Look for:

- Correct substitution into $Q = mc\Delta T$ (F6†-æ Væ—G2 †Ö 72 -â prams, c in J/(g·°C), ΔT -â 2'â
- Correct handling of ΔT (Ö-àus initial, always positive when temperature rises).
- Whether students convert J to kJ correctly before the next step.

Use the spread of answers to decide whether to slow down before independent practice or move ahead as planned.