

Enthalpy Changes and Calorimetry

Calculate the heat released in a chemical reaction using calorimetry data and express the result as molar enthalpy.

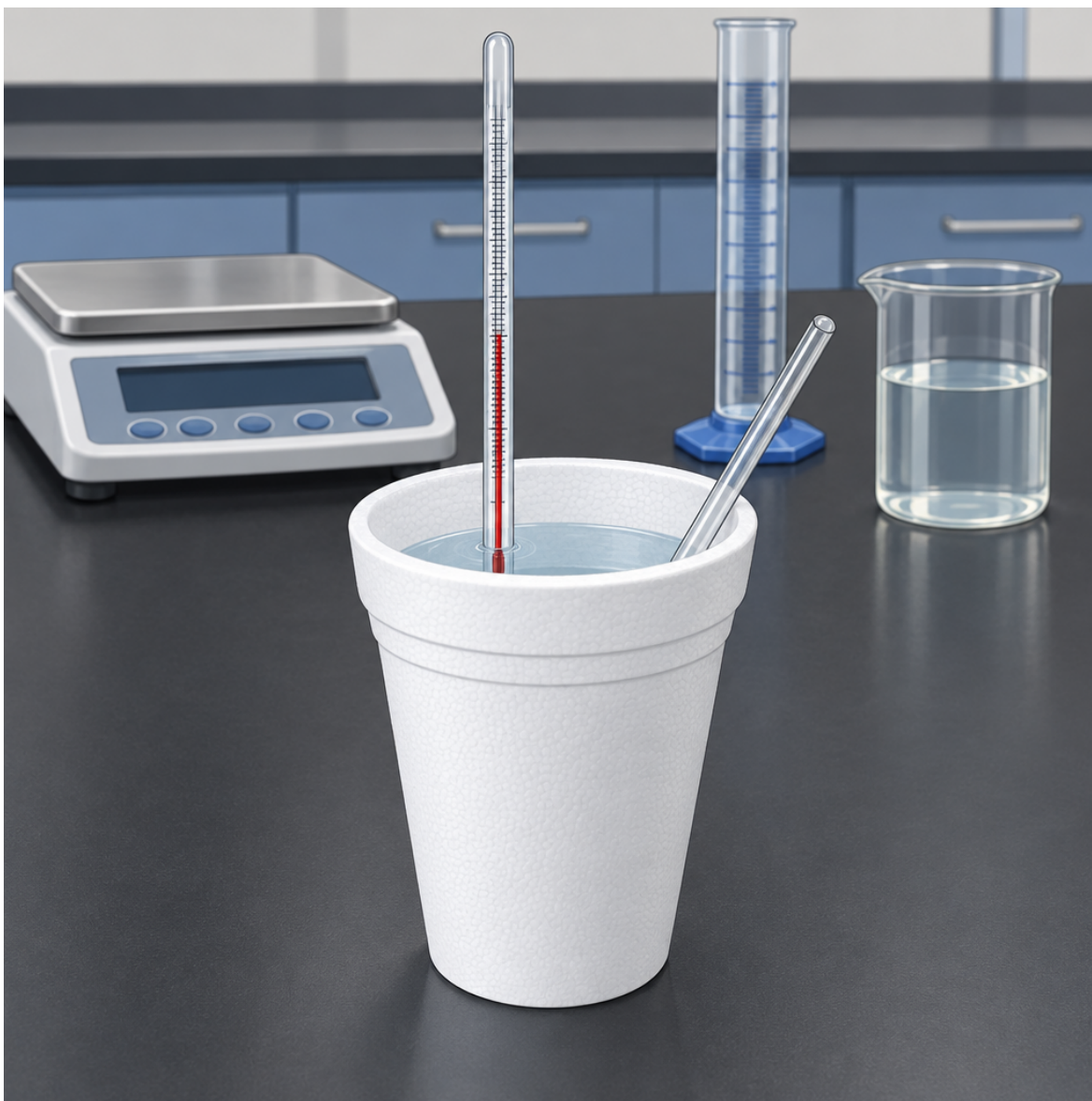


Figure 1: A polystyrene cup calorimeter sits on a lab bench

Learning intentions

We are learning to:

- apply the equation $Q = mc\Delta T$ transferred in a chemical reaction
- define enthalpy and molar enthalpy
- use calorimetry data to calculate enthalpy changes for chemical reactions
- express enthalpy changes using ΔH

Success criteria

I can:

- calculate the heat absorbed or released by a substance using $Q = mc\Delta T$
- distinguish between enthalpy and molar enthalpy
- use calorimetry experimental data to determine ΔH for a reaction
- interpret and write ΔH values with correct signs and units

Curriculum alignment

- Students determine and interpret energy changes in chemical reactions ([Topic](#))
- Students recall the application of $Q = mc\Delta T$ to calculate heat transfer ([Outcome](#))
- Students define enthalpy and molar enthalpy for chemical reactions ([Outcome](#))
- Students use and interpret ΔH to communicate and calculate energy changes in chemical reactions ([Outcome](#))
- Students use calorimetry data to determine the enthalpy changes in chemical reactions ([Outcome](#))
- Students analyze data and apply mathematical and conceptual models to develop and assess possible solutions ([Outcome](#))

Materials

Per pair of students:

- polystyrene cup calorimeter (or two nested foam cups with a lid)
- thermometer (0 to 110°C, graduated to 0.1°C)
- stirring rod
- graduated cylinder (100 mL)
- digital balance (± 0.01 g)
- water
- calcium chloride (anhydrous, 5 to 10 g) or ammonium nitrate (5 to 10 g)
- small beaker or weighing boat
- paper towels

Per class:

- periodic table
- calculator (scientific or graphing)
- reference sheet with $Q = mc\Delta T$ and ΔH values

Lesson sequence

1. Hook: Observing an exothermic reaction (5 minutes)

Demonstrate a quick exothermic reaction. Use calorimetry data to determine enthalpy changes in chemical reactions. Ask students to observe and describe what they see: the mixture becomes hot, steam may rise, the beaker is warm to touch. **Ensure all students wear safety goggles and work in a well-ventilated area during this demonstration.** Ask: Where does the energy come from? What happens to the temperature of the water? How could we measure the energy released?

Write on the board: "The reaction released energy. How much?"

2. Direct instruction: Heat transfer and the Q equation (8 minutes)

Explain that when a chemical reaction occurs, energy is transferred to or from the surroundings. We measure this energy transfer by observing temperature change in a known mass of water or solution.

Write the equation on the board:

$$Q = mc\Delta T$$

Define each term clearly:

- Q is the heat absorbed or released, measured in joules (J)
- m is the mass of the substance (usually water), in grams (g)
- c is the specific heat capacity. For water, $c = 4.18 \text{ J/(g}\cdot^{\circ}\text{C)}$
- ΔT is the change in temperature, in $^{\circ}\text{C}$. Calculate as: $\Delta T = T_{\text{final}} - T_{\text{initial}}$

Work through a sample calculation on the board:

A reaction causes 100 g of water to heat from 20°C to 28°C . Calculate the heat released.

$$Q = mc\Delta T$$

$$Q = mc\Delta T$$

$$Q = (100 \text{ g})(4.18 \text{ J/(g}\cdot^{\circ}\text{C)})(8^{\circ}\text{C})$$

$$Q = 3344 \text{ J} = 3.3 \text{ kJ}$$

If ΔT is negative, the temperature of the water decreased, indicating heat was absorbed from the water by the reaction (endothermic).

3. Direct instruction: Enthalpy and molar enthalpy (7 minutes)

Define enthalpy: Enthalpy is the heat energy released or absorbed during a chemical reaction at constant pressure. We use the symbol ΔH for enthalpy change.

Explain the sign convention ([Outcome](#)):

- ΔH is negative for exothermic reactions (heat is released)
- ΔH is positive for endothermic reactions (heat is absorbed)

Introduce molar enthalpy: Molar enthalpy is the enthalpy change per mole of a reactant or product. It tells us how much energy is released or absorbed when one mole of a substance reacts.

Write an example on the board:

If 5.0 g of calcium chloride dissolves in water and releases 1670 J of heat, what is the molar enthalpy of dissolution?

$$\text{Molar mass of CaCl}_2 = 111 \text{ g/mol}$$

$$\text{Moles of CaCl}_2 = 5.0 \text{ g} \div 111 \text{ g/mol} = 0.045 \text{ mol}$$

$$\text{Molar enthalpy} = 1670 \text{ J} \div 0.045 \text{ mol} = 37,100 \text{ J/mol} = 37.1 \text{ kJ/mol}$$

Since heat was released, ΔH is negative.

4. Guided practice: Calculation with calorimetry data (10 minutes)

Provide students with a worked calorimetry problem. Project or distribute:

A student burns 0.50 g of a nut in a calorimeter containing 100 g of water. The water temperature rises from 22°C to 35°C . Calculate the heat released and the molar enthalpy of combustion. (Assume the

molar mass of the fuel is 180 g/mol.)

Work through the problem step by step with the class:

Step 1: Calculate q

$$q = mc\Delta T = 100 \text{ g} \times 4.18 \text{ J/(g}\cdot^\circ\text{C)} \times 13^\circ\text{C} = 5434 \text{ J} \approx 5.4 \text{ kJ}$$

Step 2: Calculate Q using $Q = mc\Delta T$

$$Q = (100 \text{ g})(4.18 \text{ J/(g}\cdot^\circ\text{C)})(13^\circ\text{C}) = 5434 \text{ J} \approx 5.4 \text{ kJ}$$

Step 3: Calculate moles of fuel burned.

$$\text{Moles} = 0.50 \text{ g} \div 180 \text{ g/mol} = 0.00278 \text{ mol}$$

Step 4: Calculate molar enthalpy.

$$\text{Molar enthalpy} = 5434 \text{ J} \div 0.00278 \text{ mol} = 1,954,000 \text{ J/mol} \approx 2.0 \times 10^3 \text{ kJ/mol}$$

Step 5: Write the result with sign and units.

$$\Delta H_{\text{comb}} = -1.95 \times 10^3 \text{ kJ/mol} \quad \text{(negative because heat was released)}$$

Ask students: Why is ΔH negative? What would happen if we used an endothermic reaction instead?

5. Independent practice: Student calculations (7 minutes)

Distribute a problem set with three calorimetry scenarios. Students work individually or in pairs:

Problem A: A reaction heats 50 g of water from 18°C to 26°C. Calculate Q in joules.

Problem B: Dissolving 2.0 g of ammonium nitrate in 100 g of water causes the temperature to drop from 20°C to 12°C. Calculate the heat absorbed (Q) and identify whether the reaction is exothermic or endothermic.

Problem C: A combustion reaction releases 8500 J of heat. The mass of fuel burned and its molar mass can be used to determine the enthalpy changes in chemical reactions. Calculate the molar enthalpy (ΔH_{comb}).

Circulate and check student work. Ask: What does the sign of ΔH tell you? How would you know if your answer is reasonable?

6. Consolidation: Summary and preview (3 minutes)

Summarize the key ideas:

- $Q = mc\Delta T$ tells us the heat transferred in a reaction
- Enthalpy (ΔH) is the heat transferred at constant pressure
- Molar enthalpy tells us the energy change per mole of reactant
- Negative ΔH , exothermic; positive ΔH , endothermic

Preview the next lesson: "Next class, you will perform a calorimetry experiment to measure the enthalpy of a real chemical reaction using the methods we practiced today."

Differentiation

Extension:

- Introduce the concept of heat capacity of the calorimeter itself. Ask: Does the polystyrene cup absorb any heat, or does all the heat go into the water? Have students estimate the heat capacity of the calorimeter using a hot water mixing experiment ([Resource](#)) and recalculate Q with a correction factor.
- Present a problem where students must account for the mass of the solution, not just the water. For example, if 100 g of water and 5 g of solid reactant are mixed, what is the total mass used in Q =

mc9GCđ

- Ask students to predict the sign of ΔH , or common reactions (combustion, neutralization, dissolution of salts) before calculating, then verify their predictions.

Support:

- Provide a calculation template with blanks for $q = mc\Delta T$, ΔH_{rxn} , and ΔH_{f} . Include unit labels for every number.
- Use only exothermic reactions in the first round of problems. Introduce endothermic reactions after students are confident with the sign convention.
- Pair students with a stronger partner during independent practice. Have the partner talk through each step aloud before writing.
- Reduce the number of significant figures required in answers. Accept answers rounded to two significant figures.
- Provide a reference card with the equation $q = mc\Delta T$, ΔH_{rxn} , and ΔH_{f} (4.18 J/(g·°C)), and the formula for molar enthalpy (ΔH_{m})

Assessment

Formative checkpoint (during independent practice):

Collect Problem C from each student. Look for:

- Correct calculation of $q = mc\Delta T$
- Correct application of $q = mc\Delta T$, ΔH_{rxn} , ΔH_{f}
- Correct conversion of grams to moles using molar mass
- Correct division of q by moles to find molar enthalpy
- Correct sign on ΔH , (negative for exothermic)
- Proper units on the final answer (kJ/mol or J/mol)

If a student has made an error in sign or units, ask: "What does a negative ΔH , or ΔH_{f} mean in terms of molar enthalpy?" to prompt self-correction. If the student has confused the calculation order, work through the steps aloud together and have them redo the problem on a fresh sheet.

Use the results to decide whether the class is ready for the hands-on calorimetry lab ([Resource](#)) or whether a second practice round is needed before the experiment.