

Thermochemistry

Enthalpy, formation reactions, Hess's law, calorimetry, and bond energies.

01 Endothermic vs exothermic

CORE RULE

$\Delta H > 0$ = endothermic (system absorbs heat). $\Delta H < 0$ = exothermic (releases heat). Combustion is always exothermic; report ΔH negative, but report a magnitude when asked 'how much heat is released'.

02 Formation reactions

CORE RULE

Makes exactly 1 mol of compound from elements in their standard states (O_2 g, Br_2 l, C graphite, S rhombic, metals as solids). Fractional coefficients on the reactant side are allowed.

03 ΔH°_f of an element

CORE RULE

ΔH°_f of any element in its standard reference state = 0 kJ/mol by definition (the zero of the formation-enthalpy scale).

04 ΔH°_{rxn} from formation enthalpies

CORE RULE

$\Delta H^\circ_{rxn} = \sum n \cdot \Delta H^\circ_f(\text{products}) - \sum n \cdot \Delta H^\circ_f(\text{reactants})$, with n the balanced coefficients. Result is in kJ for the reaction as written; divide by a coefficient for a per-mole basis.

05 Heat for a given quantity

METHOD

mass $\rightarrow$ moles ($\div$ molar mass) $\rightarrow$ heat ($\times \Delta H \times$ the mole ratio from the balanced equation). Reverse the chain to find the fuel needed to release a target amount of heat.

06 Hess's law

CORE RULE

ΔH of an overall reaction = sum of ΔH of any steps that add to it. Reverse a step $\rightarrow$ flip the sign of ΔH ; scale a step $\rightarrow$ scale ΔH . Intermediates must cancel exactly.

07 $q = m \cdot s \cdot \Delta T$

CORE RULE

$Q = m \cdot s \cdot \Delta T$, $\Delta T = T_{\text{final}} - T_{\text{initial}}$. A ΔT in K equals a ΔT in $^\circ\text{C}$ (offset cancels).

Water: $s = 4.184 \text{ J/(g} \cdot ^\circ\text{C)} = 1.000 \text{ cal/(g} \cdot ^\circ\text{C)}$. Use this for 'water' unless told otherwise; use the given value for other substances.

08 Calorimetry

CORE RULE

Heat is conserved: $Q_{\text{hot}} + Q_{\text{cold}} + Q_{\text{cal}} = 0$. The calorimeter constant C_{cal} ($\text{J/}^\circ\text{C}$) is the whole-device value; negligible for a coffee cup unless stated, always significant for a bomb.

09 Thermal equilibrium (mixing)

CORE RULE

Same substance, no calorimeter: $T_{\text{eq}} = (m_{\text{hot}} \cdot T_{\text{hot}} + m_{\text{cold}} \cdot T_{\text{cold}}) / (m_{\text{hot}} + m_{\text{cold}})$. Equal masses $\rightarrow$ the midpoint. Any consistent temperature scale works (no phase change).

10 Bomb calorimetry

CORE RULE

Constant volume: $Q = (m_{\text{water}} \cdot s_{\text{water}} + C_{\text{cal}}) \cdot \Delta T$. Convert mass burned $\rightarrow$ moles, then $|Q| \div \text{moles} = \text{heat of combustion per mole}$ (negative). C_{cal} covers bomb + thermometer + stirrer (given).

11 Bond energies (gas phase)

CORE RULE

$\Delta H \approx \sum E(\text{bonds broken}) - \sum E(\text{bonds formed})$, E = average bond enthalpy (always positive; breaking is endothermic). Estimate only, gas-phase species only.