

Chemical energetics

A-Level Chemistry

Enthalpy change, ΔH



Burning fuel is exothermic, releasing energy to the surroundings.

Image: OKWE DARIOUS, CC BY-SA 4.0 (commons.wikimedia.org)



An instant cold pack uses an endothermic reaction that takes in heat.

Image: photo: Qurren (talk) Taken with Canon PowerShot G9 X, CC BY-SA 4.0 (commons.wikimedia.org)

Every chemical reaction takes in or gives out energy. This energy change, measured at constant pressure, is the **enthalpy change** 焓变, with symbol ΔH .

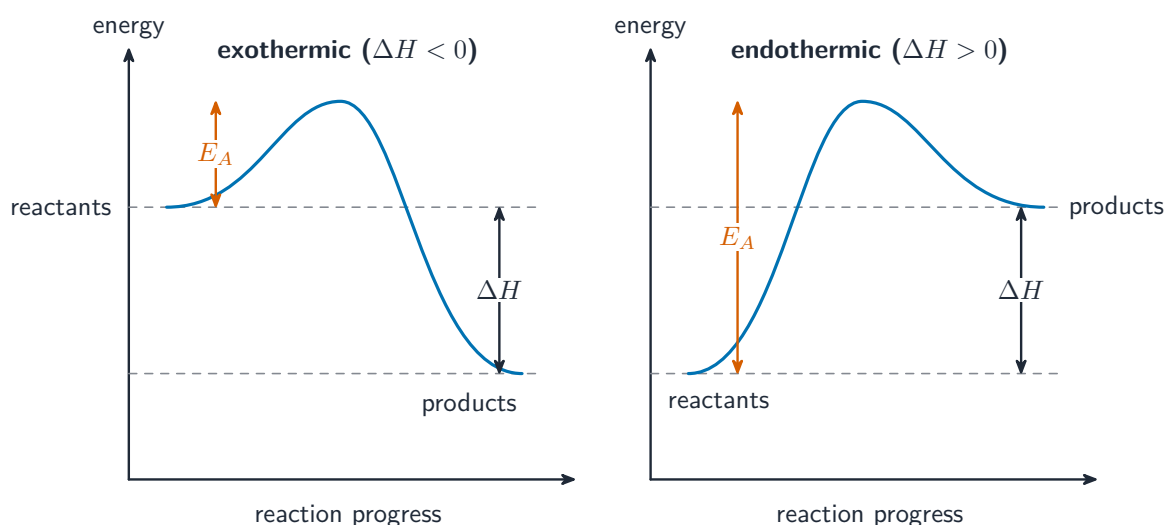
- in an **exothermic** 放热 reaction the system gives out heat, so the products have less energy than the reactants and ΔH is **negative**.

- in an **endothermic** 吸热 reaction the system takes in heat, so the products have more energy than the reactants and ΔH is **positive**.

Reaction pathway diagrams

A **reaction pathway diagram** 反应路径图 shows the energy of the reactants and products, and the energy "hill" between them. The height of the hill is the **activation energy** 活化能—the least energy the particles need before they can react.

- exothermic: products sit **lower** than reactants ($\Delta H < 0$).
- endothermic: products sit **higher** than reactants ($\Delta H > 0$).



Exothermic reactions end lower than they start ($\Delta H < 0$); endothermic reactions end higher ($\Delta H > 0$)

Standard conditions and types of enthalpy change

Energy values are compared under **standard conditions** 标准条件: 298 K and 101 kPa, shown by the symbol $^\ominus$. Each substance is in its normal physical state at those conditions.

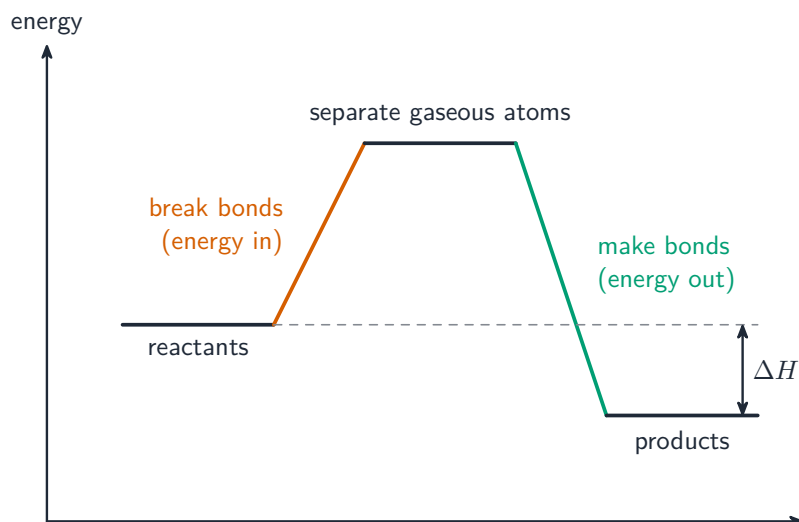
Symbol	Name	Definition (per mole, under standard conditions)
ΔH_r^\ominus	enthalpy change of reaction 反应焓变	for the amounts shown in the equation
ΔH_f^\ominus	enthalpy change of formation 生成焓变	one mole of a compound forms from its elements
ΔH_c^\ominus	enthalpy change of combustion 燃烧焓变	one mole of a substance burns completely in oxygen
$\Delta H_{\text{neut}}^\ominus$	enthalpy change of neutralisation 中和焓变	one mole of water forms from an acid and an alkali

Energy from breaking and making bonds

During a reaction, old bonds break and new bonds form. **Breaking** a bond needs energy (endothermic); **making** a bond releases energy (exothermic). The enthalpy change of the reaction is the difference between the two:

$$\Delta H_r = \sum(\text{bond energies broken}) - \sum(\text{bond energies made})$$

The **bond energy** 键能 is the energy needed to break one mole of a particular bond in the gas state, so it is always positive. Some bond energies are exact (for one specific molecule); others are averages taken over many different molecules, so calculations using them are only approximate.



Breaking bonds takes energy in; making bonds gives energy out. ΔH is the difference between the two

Measuring enthalpy change in the lab

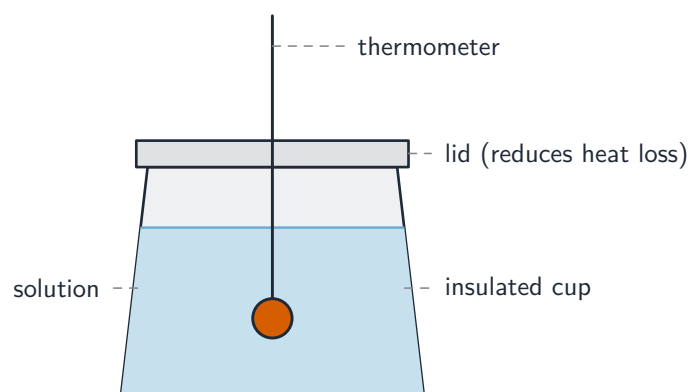
When a reaction heats up (or cools down) a known mass of water or solution, the heat transferred is:

$$q = mc\Delta T$$

where m is the mass, c is the **specific heat capacity** 比热容 (how much energy raises 1 g by 1 K), and ΔT is the temperature change. The enthalpy change per mole is then:

$$\Delta H = -\frac{mc\Delta T}{n}$$

The minus sign makes ΔH negative when the temperature rises (an exothermic reaction).

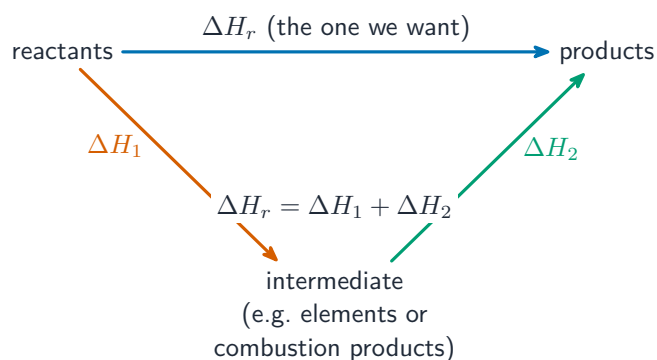


An insulated cup and a thermometer measure the temperature change of a known mass of solution

Hess's law

Hess's law 盖斯定律 says that the total enthalpy change for a reaction is the same, no matter which route you take from reactants to products. This is because energy is conserved.

This lets you draw an **energy cycle** 能量循环: link the reactants and products by a direct step and by an indirect route, then add the steps so that both routes give the same total.



The direct route equals the indirect route, so $\Delta H_r = \Delta H_1 + \Delta H_2$

Hess's law is useful in two ways:

- it lets you find an enthalpy change that you **cannot** measure directly (for example, the formation of a compound that forms slowly or with side reactions).
- it lets you calculate ΔH_r from bond energy data, or from formation or combustion data given in the question.