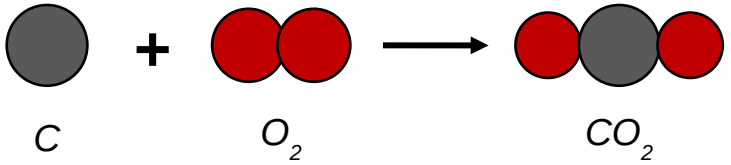
Enthalpy of Formation

Essential Question

How can we find ΔH without doing an experiment?

Standard Enthalpy of Formation

- Make 1 mol of a compound
- From its elements
- In standard states



$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H_f^\circ = -393.5\ \text{kJ/mol}$$

elements in, 1 mol of compound out

Standard States

- 25°C and 1 atm
- Most stable form of each element

$O_2(g)$ *diatomic gas*	**$H_2(g)$** *diatomic gas*
C(s) *graphite*	**Na(s)** *solid metal*
$Br_2(l)$ *liquid*	**Hg(l)** *liquid*

Br_2 and Hg: the only liquid elements

Elements Are Zero

Elements in standard states

$O_2(g)$	$H_2(g)$	Fe(s)
$\Delta H_f^\circ = 0$	$\Delta H_f^\circ = 0$	$\Delta H_f^\circ = 0$

Not zero

$O_3(g)$	$H_2O(l)$	$H_2O(g)$
ΔH_f° = not 0	$\Delta H_f^\circ = -285.8$	$\Delta H_f^\circ = -241.8$

- **State matters!**

values in kJ/mol

Writing a Formation Equation

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$$

- Exactly 1 mol of product
- Fractions are OK
- Elements in standard states

Not a formation equation

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

makes 2 mol of product

Enthalpy of Formation

$\Delta H°_{rxn}$ from a Table

$$\Delta H°_{rxn} = \Sigma n \Delta H_f°(\text{products}) - \Sigma n \Delta H_f°(\text{reactants})$$

Products minus reactants

Σ products − Σ reactants

Multiply by coefficients

n = coefficient

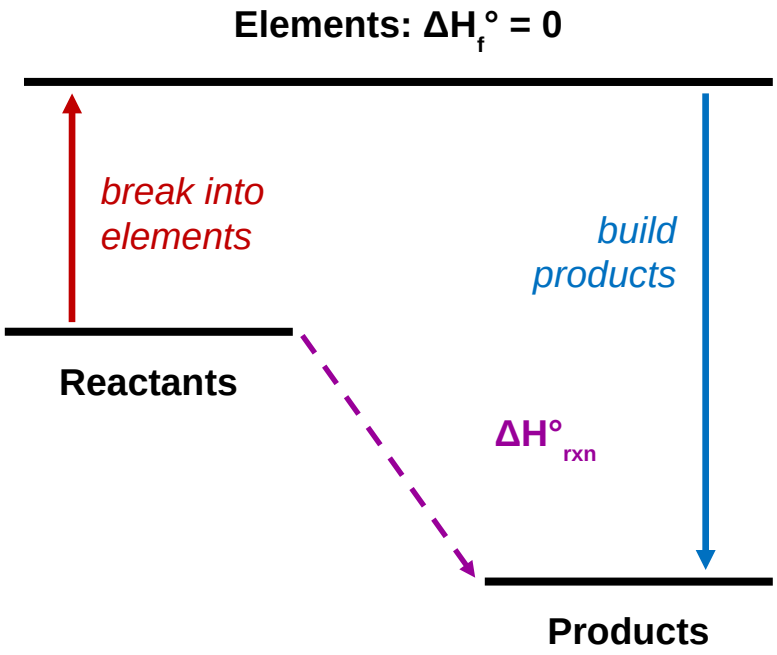
Elements are zero

$O_2(g)$, $H_2(g)$, $N_2(g)$

Bond enthalpies (6.7) are the opposite: reactants − products

Why It Works

- Break reactants into elements
- Then build products
- Same start, same end



Example: Decomposing Limestone

Calculate $\Delta H°_{rxn}$ for the decomposition of limestone:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Substance	$\Delta H_f°$ (kJ/mol)
$CaCO_3(s)$	−1206.9
$CaO(s)$	−635.1
$CO_2(g)$	−393.5

Example: Burning Methane

Calculate $\Delta H°_{rxn}$ for the combustion of methane:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

Substance	$\Delta H_f°$ (kJ/mol)
$CH_4(g)$	−74.8
$O_2(g)$	0
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8

Example: Solve for an Unknown

Find ΔH_f° of $C_2H_5OH(l)$, given:

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

$$\Delta H^\circ_{rxn} = -1367\ kJ/mol_{rxn}$$

Substance	ΔH_f° (kJ/mol)
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8
$O_2(g)$	0
$C_2H_5OH(l)$	**?**

Enthalpy of Formation

Big Ideas

- ΔH_f°: 1 mol from elements
- Elements in standard state = 0
- Products − reactants, times coefficients
- State matters

$$\Sigma \text{ products} - \Sigma \text{ reactants}$$

Elements
$\Delta H_f^\circ = 0$

$H_2O(l)$
−285.8

$H_2O(g)$
−241.8