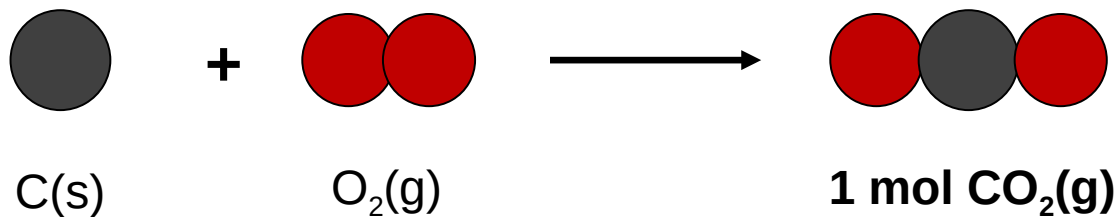


Essential Question

How can we find ΔH without a lab?

What Is ΔH°_f ?

- ΔH°_f : energy change to form **1 mol** of a compound
- Made from its elements in their standard states

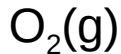
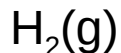
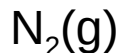


$$\Delta H^\circ_f = -393.5 \text{ kJ/mol}$$

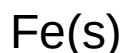
Standard Conditions

- ° means standard: **25 °C** and **1 atm**
- **Standard state**: an element's form at those conditions

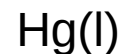
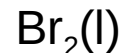
Gas



Solid



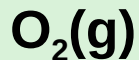
Liquid



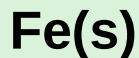
Elements Have $\Delta H^\circ_f = 0$

- Already in standard state: nothing to form

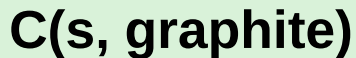
$$\Delta H^\circ_f = 0$$



standard state

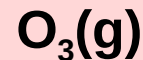


standard state

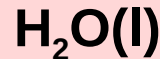


standard state

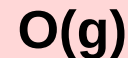
$$\Delta H^\circ_f \neq 0$$



not the standard form



a compound



single atoms, not O_2

Reading a ΔH_f° Table

Substance	ΔH_f° (kJ/mol)
CO ₂ (g)	-393.5
H ₂ O(l)	-285.8
H ₂ O(g)	-241.8
CH ₄ (g)	-74.8
NO(g)	+90.3
O ₂ (g)	0

- Units: **kJ/mol**
- **State matters!**

H₂O(l): -285.8 kJ/mol

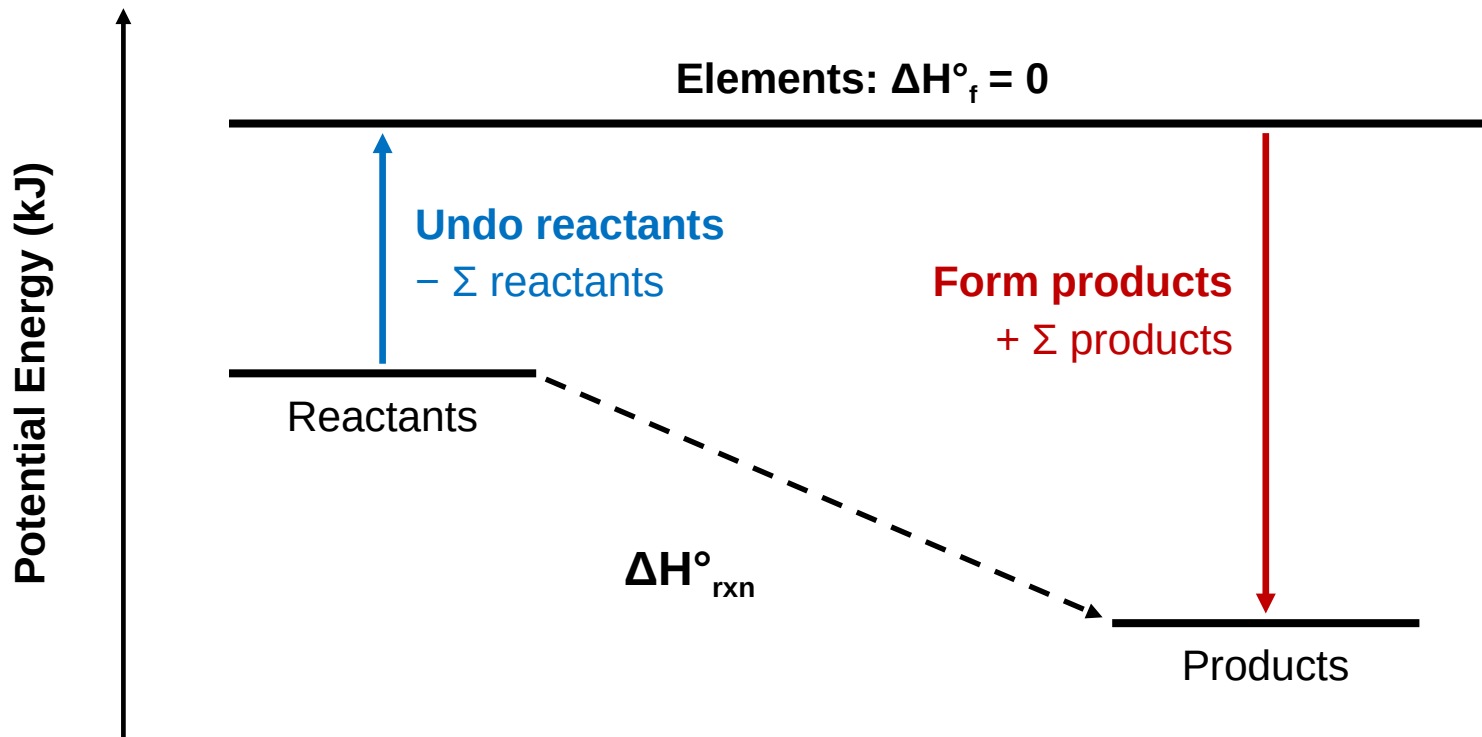
H₂O(g): -241.8 kJ/mol

The Formula

$$\Delta H^{\circ}_{\text{rxn}} = \sum n \Delta H^{\circ}_{\text{f}}(\text{products}) - \sum n \Delta H^{\circ}_{\text{f}}(\text{reactants})$$

- Products minus reactants
- n = coefficient in the balanced equation

Why Products Minus Reactants?



Step by Step

1. Balance the equation
2. Multiply each ΔH°_f by n
3. Products – reactants

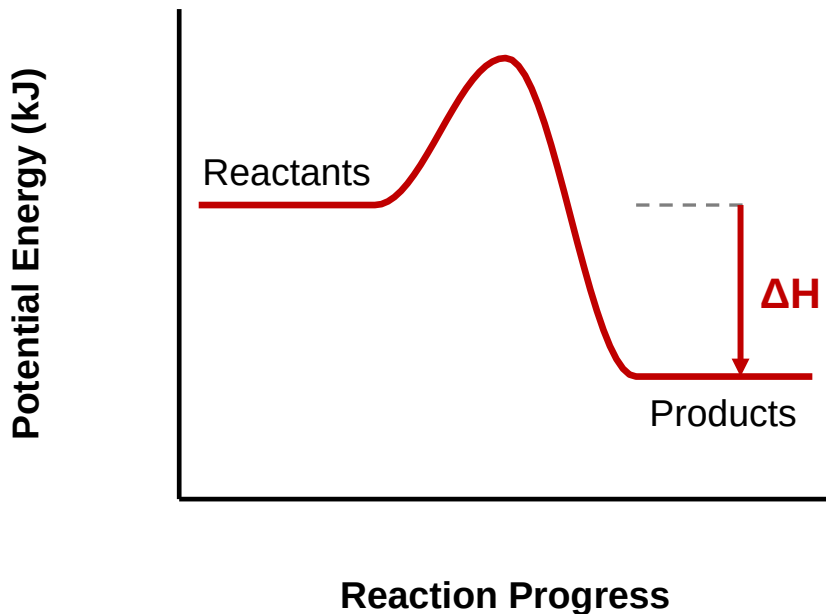
Step 2 example

$$\begin{aligned} 2 \text{ mol Fe}_2\text{O}_3(\text{s}) &\times (-824.2 \text{ kJ/mol}) \\ &= -1648.4 \text{ kJ} \end{aligned}$$

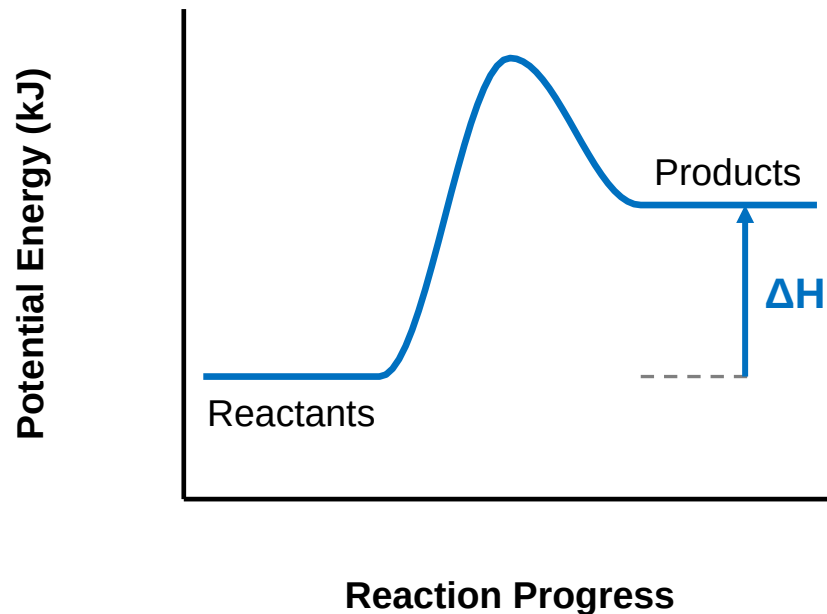
Heat of Formation Calculations

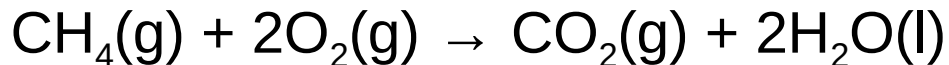
Negative or Positive?

$\Delta H^\circ_{\text{rxn}}$ negative: exothermic



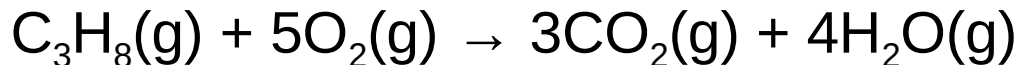
$\Delta H^\circ_{\text{rxn}}$ positive: endothermic



Example 1: Burning Methane

Calculate $\Delta H^\circ_{\text{rxn}}$.

Substance	$\text{CH}_4(\text{g})$	$\text{O}_2(\text{g})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$\Delta H^\circ_{\text{f}}$ (kJ/mol)	-74.8	0	-393.5	-285.8

Example 2: Burning Propane

Calculate $\Delta H^\circ_{\text{rxn}}$.

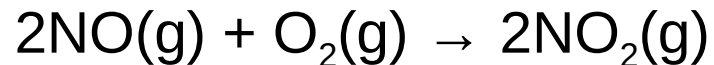
Substance	$\text{C}_3\text{H}_8(\text{g})$	$\text{O}_2(\text{g})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta H^\circ_{\text{f}}$ (kJ/mol)	-103.8	0	-393.5	-241.8

Example 3: Making Lime



Calculate $\Delta H^\circ_{\text{rxn}}$. Is it exothermic or endothermic?

Substance	$\text{CaCO}_3(\text{s})$	$\text{CaO}(\text{s})$	$\text{CO}_2(\text{g})$
$\Delta H^\circ_{\text{f}}$ (kJ/mol)	-1206.9	-635.1	-393.5

Example 4: Smog Formation

Calculate $\Delta H^\circ_{\text{rxn}}$.

Substance	NO(g)	O ₂ (g)	NO ₂ (g)
ΔH°_f (kJ/mol)	+90.3	0	+33.2

Big Ideas

- ΔH°_f : energy to form 1 mol from its elements
- Elements in standard state: $\Delta H^\circ_f = 0$
- $\Delta H^\circ_{\text{rxn}} = \Sigma \text{ products} - \Sigma \text{ reactants}$
- Negative = exothermic, positive = endothermic