

Standard Enthalpies of Formation

Chapter 5.5

Table 6.2 Heats of Some Typical Reactions Measured at Constant Pressure

Type of Reaction	Example	ΔH (kJ)
Heat of neutralization	$\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$	-56.2
Heat of ionization	$\text{H}_2\text{O(l)} \rightarrow \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$	56.2
Heat of fusion	$\text{H}_2\text{O(s)} \rightarrow \text{H}_2\text{O(l)}$	6.01
Heat of vaporization	$\text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{O(g)}$	44.0*
Heat of reaction	$\text{MgCl}_2(\text{s}) + 2\text{Na(l)} \rightarrow 2\text{NaCl(s)} + \text{Mg(s)}$	-180.2

* Measured at 25°C. At 100°C, the value is 40.7 kJ.



Because there is no way to measure the absolute value of the enthalpy of a substance, must measure the enthalpy change for every reaction of interest?

Establish an arbitrary scale with the **standard enthalpy of formation** (ΔH_f°) as a reference point for all enthalpy expressions.

Standard enthalpy of formation (ΔH_f°) is the heat change that results when **one mole** of a compound is formed from its **elements** at a pressure of 1 atm.

The standard enthalpy of formation of any element in its most stable form is zero.

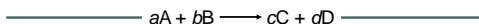
$$\Delta H_f^\circ (\text{O}_2) = 0 \qquad \Delta H_f^\circ (\text{C, graphite}) = 0$$

$$\Delta H_f^\circ (\text{O}_3) = 142 \text{ kJ/mol} \qquad \Delta H_f^\circ (\text{C, diamond}) = 1.90 \text{ kJ/mol}$$

Table 6.3 Standard Enthalpies of Formation of Some Inorganic Substances at 25°C

Substance	ΔH_f° (kJ/mol)	Substance	ΔH_f° (kJ/mol)
Ag(s)	0	H ₂ O ₂ (l)	-187.6
AgCl(s)	-127.04	Hg(l)	0
Al(s)	0	I ₂ (s)	0
Al ₂ O ₃ (s)	-1669.8	Mg(s)	-25.04
Br ₂ (l)	0	MgCl ₂ (s)	0
Br(g)	-36.2	MgO(s)	-601.8
Cl ₂ (g)	0	MgCO ₃ (s)	-1112.9
Cl(g)	119.8	N ₂ (g)	0
CO(g)	-110.5	NH ₃ (g)	-46.3
CO ₂ (g)	-393.5	NO(g)	90.4
Ca(s)	0	NO ₂ (g)	33.85
CaO(s)	-635.6	H ₂ O ₂ (l)	99.6
CaCO ₃ (s)	-1206.9	H ₂ O(g)	81.58
Cl ₂ (g)	0	O ₂ (g)	0
ClO(g)	-92.3	O ₃ (g)	142.2
Cl ₂ O	0	O ₂ (g)	0
Cl ₂ O ₂	-155.2	Srhombic	0
F ₂ (g)	0	Srhombic	0
F ₂ O	0	Srhombic	0
HF(g)	-271.3	SO ₂ (g)	-296.8
H ₂ (g)	0	SO ₃ (g)	-395.2
H ₂ O(l)	-285.8	H ₂ S(g)	-20.15
H ₂ O(g)	-241.8	ZnO(s)	-347.98
H ₂ O ₂	-187.8		

The **standard enthalpy of reaction** ($\Delta H_{\text{rxn}}^\circ$) is the enthalpy of a reaction carried out at 1 atm.



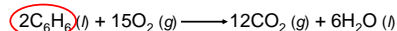
$$\Delta H_{\text{rxn}}^\circ = [c\Delta H_f^\circ (\text{C}) + d\Delta H_f^\circ (\text{D})] - [a\Delta H_f^\circ (\text{A}) + b\Delta H_f^\circ (\text{B})]$$

$$\Delta H_{\text{rxn}}^\circ = \sum n\Delta H_f^\circ (\text{products}) - \sum n\Delta H_f^\circ (\text{reactants})$$

Hess's Law: When reactants are converted to products, the change in enthalpy is the same whether the reaction takes place in one step or in a series of steps.

(Enthalpy is a state function. It doesn't matter how you get there, only where you start and end.)

Benzene (C₆H₆) burns in air to produce carbon dioxide and liquid water. How much heat is released per mole of benzene combusted? The standard enthalpy of formation of benzene is 49.04 kJ/mol.



$$\Delta H_{\text{rxn}}^\circ = \sum n\Delta H_f^\circ (\text{products}) - \sum n\Delta H_f^\circ (\text{reactants})$$

$$\Delta H_{\text{rxn}}^\circ = [12\Delta H_f^\circ (\text{CO}_2) + 6\Delta H_f^\circ (\text{H}_2\text{O})] - [2\Delta H_f^\circ (\text{C}_6\text{H}_6)]$$

$$\Delta H_{\text{rxn}}^\circ = [12(-393.5) + 6(-285.8)] - [2(49.04)] = -5946 \text{ kJ}$$

$$\frac{-5946 \text{ kJ}}{2 \text{ mol}} = -2973 \text{ kJ/mol C}_6\text{H}_6$$