HESS'S LAW and
CALCULATING THE ENTHALPY OF REACTION

Energy is the capacity to do work. It is measured in units of work. The SI unit of work, and therefore of energy, is the Joule (J). A thousand Joules is a kilojoule (kJ).

Heat is a form of energy that flows from a place of high temperature to a place of low temperature.

Enthalpy is a measure of internal chemical energy, corrected for temperature and pressure changes.

An **Endothermic reaction** is one whose components increase in energy content, so ΔH is positive. "Endothermic" means "heat goes into" the reaction.

An **Exothermic reaction** is one whose components lose energy, so ΔH is negative. The energy lost by the reactants can be used as a source of heat for another process, like heating a home or propelling a vehicle. "Exothermic" means "heat goes out."

A State Function is a quantity whose values are additive. Any change in the value of a state function depends only on the initial and final values, independently of the path taken (or the intermediate steps). Latitude is a state function because the change in latitude from Boston to Miami is the same whether one goes directly or takes a detour by way of Omaha or Shanghai. Other common state functions include altitude, longitude, time, and many forms of energy.

Hess's law states that enthalpy is a state function, so the enthalpy change of a multi-step process is the algebraic sum of the changes of all the individual steps.

REACTIONS IN REVERSE:

Any reaction and its reverse add up to no net change, or no overall change in enthalpy ($\Delta H = 0$). If the two changes add up to zero, then each one is the additive inverse of the other. Therefore:

(a) if any reaction is reversed, the value of ΔH is multiplied by -1;
(b) the reverse of an endothermic process is exothermic, and *vice versa*.

Example: $H_2O\,(l) \;{-}{-}{-}{-}{>}\; H_2O\,(g)$ $\quad \Delta H = +44.0$ kJ per mole at 25^oC
$H_2O\,(g) \;{-}{-}{-}{-}{>}\; H_2O\,(l)$ $\quad \Delta H = -44.0$ kJ per mole at 25^oC

The sum of these two reactions is that liquid water changes to water vapor (steam) and back again.

COMBUSTION REACTIONS:

$H_2\,(g) + \frac{1}{2}\,O_2\,(g) \;{-}{-}{-}{-}{>}\; H_2O\,(l)$ $\quad \Delta H = -285.8$ kJ per mole at 25^oC
$C\,(graphite) + O_2\,(g) \;{-}{-}{-}{-}{>}\; CO_2\,(g)$ $\quad \Delta H = -393.5$ kJ per mole at 25^oC
$S\,(s) + O_2\,(g) \;{-}{-}{-}{-}{>}\; SO_2\,(g)$ $\quad \Delta H = -296.8$ kJ per mole at 25^oC

Since each of these reactions is also a synthesis of a compound from its elements, it is also called the enthalpy of formation, symbolized by ΔH_f. Thus, ΔH_f of CO_2 is -393.5 kJ per mole.

A table of ΔH_f ("heat of formation") values is given on the reverse side of this page.

Note that $\Delta H_f = 0$ for any element in its standard state, because it's already synthesized.

We can use Hess's law to calculate ΔH for many other reactions, if we know the ΔH_f values:

$H_2S\,(g) + 1\frac{1}{2}\,O_2\,(g) \;{-}{-}{-}{-}{>}\; H_2O\,(l) + SO_2\,(g)$ $\quad \Delta H = ?$ We can add up:

$H_2S\,(g) \;{-}{-}{-}{-}{>}\; H_2\,(g) + S\,(s)$ $\quad \Delta H = +20.6$ kJ per mole at 25^oC $(= -\,\Delta H_f)$
$S\,(s) + O_2\,(g) \;{-}{-}{-}{-}{>}\; SO_2\,(g)$ $\quad \Delta H = -296.8$ kJ per mole at 25^oC
$\underline{H_2\,(g) + \frac{1}{2}\,O_2\,(g) \;{-}{-}{-}{-}{>}\; H_2O\,(l)}$ $\quad \Delta H = -285.8$ kJ per mole at 25^oC
$H_2S\,(g) + 1\frac{1}{2}\,O_2\,(g) \;{-}{-}{-}{-}{>}\; H_2O\,(l) + SO_2\,(g)$ $\quad \Delta H = 20.6 - 296.8 - 285.8 = -562.0$ kJ