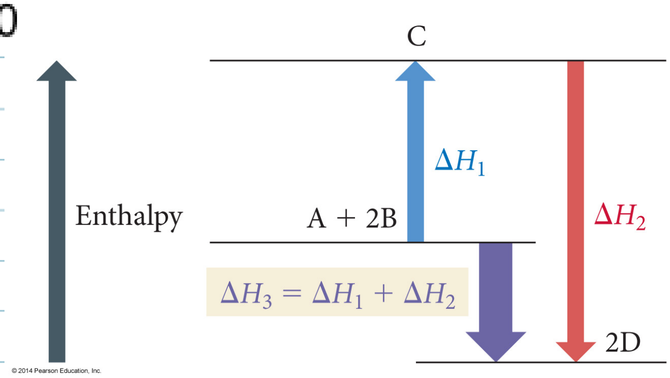
6-8 Hess's Law

$$\Delta H_{total} = \Delta H_1 + \Delta H_2 + \Delta H_3 \text{ etc...}$$

Hess's Law
The change in enthalpy for a stepwise process is the sum of the enthalpy changes of the steps.

Figure 6.10



$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H = -110 \text{ kJ}$$
$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -283 \text{ kJ}$$

$$C(s) + \cancel{CO(g)} + O_2(g) \rightarrow \cancel{CO(g)} + CO_2(g)$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H_{rxn} =$$
$$-110 \text{ kJ} + -283 \text{ kJ}$$
$$= \underline{-393 \text{ kJ}}$$

6.9: Determining Enthalpies of Reaction from Standard Enthalpies of Formation

As a reference point for enthalpy, the **Standard Enthalpy of Formation (ΔH_f^0)** of a substance has been defined as the enthalpy change on forming 1 mol of the substance from its elements in their most stable states at a given temperature (generally 25 °C).

- for example, ΔH_f^0 represents the enthalpy change for the reaction: $H_2\ (g) + ½\ O_2\ (g) \rightarrow H_2O\ (l)$
- ΔH_f^0 for an element in its most stable form is **zero**.
- See Table 6.5 and Appendix II, part B for ΔH_f^0 values.

Enthalpies of formation can be used to calculate ΔH for a reaction (Figure 6.11):

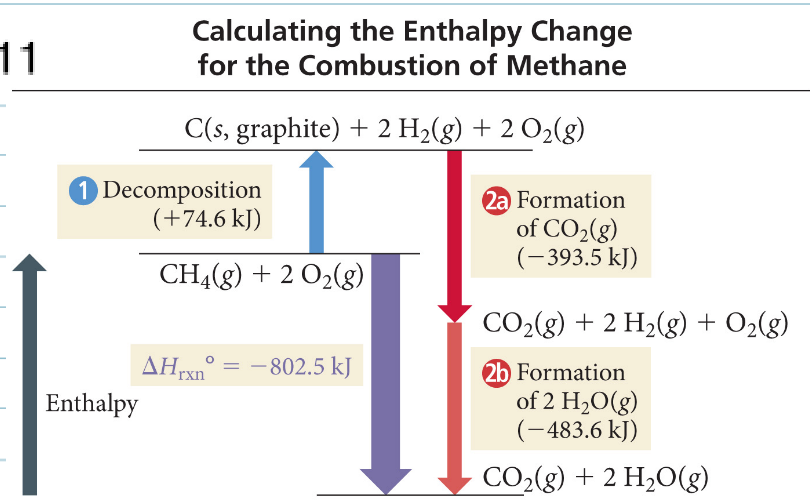
$$\Delta H_{rxn} = \Sigma(n_p\, \Delta H_f^\circ \text{ products}) - \Sigma(n_r\, \Delta H^\circ \text{ reactants})$$

Sum for all products

moles of each reactant or product

ΔH_f° all substances are in their standard states

Figure 6.11



Example: Use ΔH^0_f values to Calculate ΔH^0_{rxn} for the oxidation of ammonia, the first step in the production of nitric acid:

$$4\ NH_3\,(g) + 5\ O_2\,(g) \longrightarrow 4\ NO\,(g) + 6\ H_2O\,(g)$$

$$\Delta H_{rxn} = \Sigma\,[n_p \Delta H^0_f\,(\text{products})] - [\Sigma\, n_r \Delta H^0_f\,(\text{reactants})]$$

(from Table 6.5)

Substance	**ΔH^0_f (kJ/mol)**
$NH_3(g)$	–45.9
$NO(g)$	90.3
$H_2O(g)$	–241.8

$$\Delta H_{rxn} = 4 \times \Delta H^0_f\ NO(g) + 6 \times \Delta H^0_f\ H_2O(g) - [4 \times \Delta H^0_f\ NH_3(g) + 5 \times \Delta H^0_f\ O_2(g)]$$

$$= 4 \times 90.3\ \text{kJ} + 6 \times -241.8\ \text{kJ} - (4 \times -45.9\ \text{kJ} + 0)$$

$$= -902.0\ \text{kJ}$$