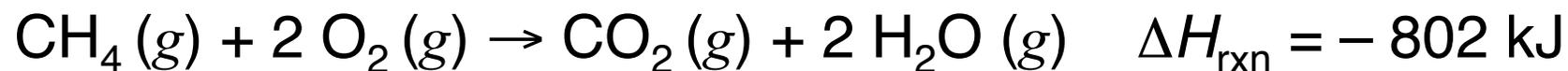


Thermochemical Equations (Stoichiometry and ΔH)



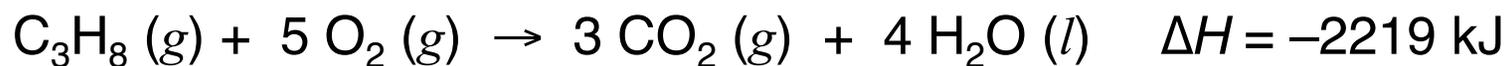
- The above equation states that when 1 mol methane is burned, 802 kJ of heat is released (heat is a product).
- Enthalpy is an **extensive** property – the magnitude of ΔH is directly proportional to the amount of reactants.

Thermochemical Equations (contd.)

- Manipulating thermochemical equations:
 1. Reversing a reaction exchanges the reactants and products and thus **changes the sign** of ΔH_{rxn}
 2. If you multiply all the coefficients in an equation by a certain factor, you must multiply ΔH_{rxn} by the same factor.

Example: Use the thermochemical equation below to calculate the amount of heat released when 15.5 g propane burns at constant pressure?

[Molar mass of C₃H₈ = 44.10 g/mol]

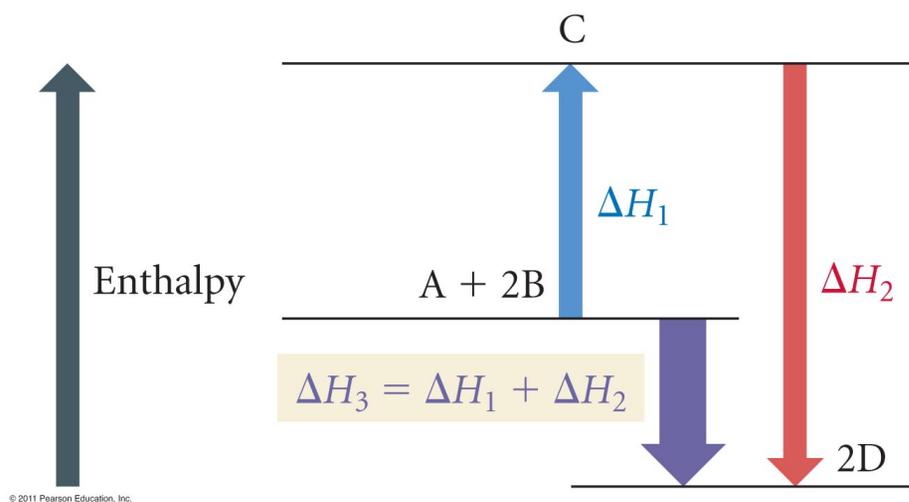


6.8 Hess's Law

Figure 6.10

Hess's Law

The change in enthalpy for a stepwise process is the sum of the enthalpy changes of the steps.



Hess's Law (contd.)

- Combining reactions:

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 for (1 mol) liquid water represents the enthalpy change for this reaction:



- ΔH_f^0 for any element in its most stable form is **zero**.
- See Table 6.5 and Appendix II, part B for ΔH_f^0 values.

Standard Enthalpies of Formation

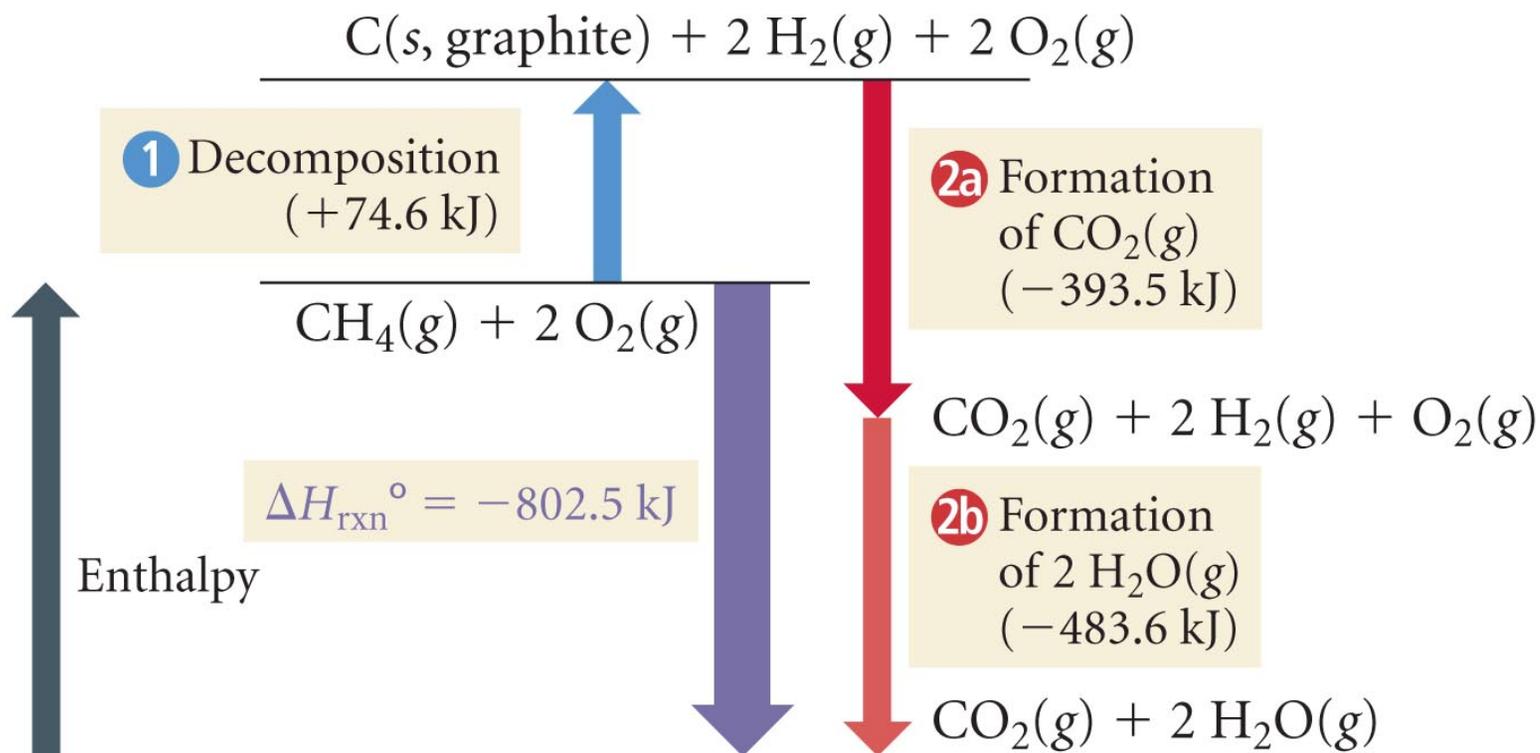
TABLE 6.5 Standard Enthalpies (or Heats) of Formation, ΔH_f° , at 298 K

Formula	ΔH_f° (kJ/mol)	Formula	ΔH_f° (kJ/mol)	Formula	ΔH_f° (kJ/mol)
Bromine		C ₃ H ₈ O(<i>l</i> , isopropanol)	-318.1	Oxygen	
Br(<i>g</i>)	111.9	C ₆ H ₆ (<i>l</i>)	49.1	O ₂ (<i>g</i>)	0
Br ₂ (<i>l</i>)	0	C ₆ H ₁₂ O ₆ (<i>s</i> , glucose)	-1273.3	O ₃ (<i>g</i>)	142.7
HBr(<i>g</i>)	-36.3	C ₁₂ H ₂₂ O ₁₁ (<i>s</i> , sucrose)	-2226.1	H ₂ O(<i>g</i>)	-241.8
Calcium		Chlorine		H ₂ O(<i>l</i>)	-285.8
Ca(<i>s</i>)	0	Cl(<i>g</i>)	121.3	Silver	
CaO(<i>s</i>)	-634.9	Cl ₂ (<i>g</i>)	0	Ag(<i>s</i>)	0
CaCO ₃ (<i>s</i>)	-1207.6	HCl(<i>g</i>)	-92.3	AgCl(<i>s</i>)	-127.0
Carbon		Fluorine		Sodium	
C(<i>s</i> , graphite)	0	F(<i>g</i>)	79.38	Na(<i>s</i>)	0
C(<i>s</i> , diamond)	1.88	F ₂ (<i>g</i>)	0	Na(<i>g</i>)	107.5
CO(<i>g</i>)	-110.5	HF(<i>g</i>)	-273.3	NaCl(<i>s</i>)	-411.2
CO ₂ (<i>g</i>)	-393.5	Hydrogen		Na ₂ CO ₃ (<i>s</i>)	-1130.7
CH ₄ (<i>g</i>)	-74.6	H(<i>g</i>)	218.0	NaHCO ₃ (<i>s</i>)	-950.8
CH ₃ OH(<i>l</i>)	-238.6	H ₂ (<i>g</i>)	0	Sulfur	
C ₂ H ₂ (<i>g</i>)	227.4	Nitrogen		S ₈ (<i>s</i> , rhombic)	0
C ₂ H ₄ (<i>g</i>)	52.4	N ₂ (<i>g</i>)	0	S ₈ (<i>s</i> , monoclinic)	0.3
C ₂ H ₆ (<i>g</i>)	-84.68	NH ₃ (<i>g</i>)	-45.9	SO ₂ (<i>g</i>)	-296.8
C ₂ H ₅ OH(<i>l</i>)	-277.6	NH ₄ NO ₃ (<i>s</i>)	-365.6	SO ₃ (<i>g</i>)	-395.7
C ₃ H ₈ (<i>g</i>)	-103.85	NO(<i>g</i>)	91.3	H ₂ SO ₄ (<i>l</i>)	-814.0
C ₃ H ₆ O(<i>l</i> , acetone)	-248.4	N ₂ O(<i>g</i>)	81.6		

Determining Enthalpies of Reaction from Standard Enthalpies of Formation

- Enthalpies of formation can be used to calculate ΔH_{rxn} :

Figure 6.11 Calculating the Enthalpy Change for the Combustion of Methane



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



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

(from Table 6.5)

Substance	ΔH_f^0 (kJ/mol)
$\text{NH}_3 (g)$	-45.9
$\text{NO} (g)$	90.3
$\text{H}_2\text{O} (g)$	-241.8