

Lecture 15: Enthalpy Reactions

Formation, Bond breaking/making, Hess's Law

3 Ways to Find $\Delta H_{\text{rxn}}^{\circ}$

- **Standard Enthalpies of Formation**

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

- **Bond Enthalpies**

$$\Delta H_{\text{rxn}}^{\circ} = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$$

- **Hess's Law**

$$\Delta H_{\text{rxn}}^{\circ} = \sum \Delta H_{\text{steps}}^{\circ}$$

- Multiply equations, multiply ΔH
- Flip equations, flip sign of ΔH
- Add equations, sum ΔH

Standard Enthalpy of Formation

Gen Chem: Look up ΔH_f° and use $\Delta H_{\text{rxn}}^\circ = \sum n\Delta H_f^\circ(\text{prod}) - \sum n\Delta H_f^\circ(\text{react})$

Standard Enthalpy of Formation

Energy required to form one mol product from components in their standard state

If naturally occurring, then $\Delta H_f^\circ = 0$

Otherwise, form it from elements in their standard state

- LHS: elements in standard state (SATP)
- RHS: 1 mol of product

Examples:



$$\Delta H_f^\circ = 0$$



$$\Delta H_f^\circ = -6 \frac{\text{kJ}}{\text{mol}}$$



$$\Delta H_f^\circ = +226 \frac{\text{kJ}}{\text{mol}}$$

Bond Breaking/Making Reactions

Gen Chem: Use bond enthalpies in $\Delta H_{\text{rxn}}^{\circ} = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$

Bond Breaking/Making Reactions

Bond enthalpies: energy required to break a bond

Bond breaking: $\Delta H > 0$ (endothermic)

Bond forming: $\Delta H < 0$ (exothermic)

One Side: atoms in gas phase

Other Side: substance with single bond type, gas phase

Examples:



Example: Comparing Enthalpies

Rank the following enthalpies from smallest to largest.

- $\Delta H_f^\circ(\text{Br}_2(\text{l}))$
- $\Delta H_f^\circ(\text{Br}_2(\text{g}))$
- $\Delta H_f^\circ(\text{Br}(\text{g}))$

Formation is always more accurate than bond enthalpies.

- Formation measured experimentally, very precise
- Bond enthalpy is average energy to break bond, varies per molecule

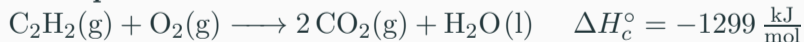
Combustion Reactions

Standard Enthalpy of Combustion ΔH_c°

Energy produced when 1 mol of substance reacts with excess oxygen

Combustion is always exothermic

Examples:



Example: Hess's Law



Do Hess's Law:



$$\Delta H_{\text{rxn}}^\circ = 103.82 \text{ kJ} - 1180.5 \text{ kJ} - 967.28 \text{ kJ} = \boxed{-2044 \text{ kJ}}$$

Phase Change Terminology

Definitions for Phase Changes

Phase Change	Name	Heat
Solid \rightarrow Liquid	Melting / Fusion	$q = +\Delta H_{\text{fus}}$
Liquid \rightarrow Solid	Freezing	$q = -\Delta H_{\text{fus}}$
Liquid \rightarrow Gas	Evaporation / Vaporization	$q = +\Delta H_{\text{vap}}$
Gas \rightarrow Liquid	Condensation	$q = -\Delta H_{\text{vap}}$
Solid \rightarrow Gas	Sublimation	$q = +\Delta H_{\text{sub}}$
Gas \rightarrow Solid	Deposition	$q = -\Delta H_{\text{sub}}$

$$\Delta H_{\text{sub}} = \Delta H_{\text{fus}} + \Delta H_{\text{vap}} \quad \Delta H_{\text{vap}} > \Delta H_{\text{fus}}$$