# Hess's Law

**Unit:** Thermodynamics

### Skills:

* solve ΔHrxn problems using Hess’s Law

### Notes:

Hess’s Law, named for the Russian chemist Germain Hess, states that because enthalpy change is a state function (is independent of the path), the enthalpy change of a reaction can be calculated by performing algebraic manipulations on a set of other reactions that involve the same chemical species.

**If:** CO(g) + H2(g) → C(graphite) + H2O(g)                  ΔH° = -131.3 kJ

**And:** C(graphite) + 2H2(g) → CH4(g)                      ΔH° = -74.8 kJ

**Then:** CH4(g) + H2O(l) → CO(g) + 3H2(g)                 ΔHrxn° = ??

Rules for Applying Hess’s Law:

* Add and subtract chemical equations just as you do with algebraic equations, such as when solving simultaneous equations in multiple variables.
* If you multiply an entire equation by a coefficient, ΔH is multiplied by that same coefficient.
* If you reverse an equation, it changes the sign of ΔH.

For example, suppose we wanted to find ΔHrxn for the reaction:

2 B (s) +  O2 (g) → B2O3 (s)

Suppose we have ΔH data for the following reactions:

1. B2O3 (s) + 3 H2O (g) → 3 O2 (g) + B2H6 (g) ΔHrxn = +2,035 kJ/mol
2. H2O (ℓ) → H2O (g) ΔHrxn = +44 kJ/mol
3. H2 (g) +  O2 (g) → H2O (ℓ) ΔHrxn = −286 kJ/mol
4. 2 B (s) + 3 H2 (g) → B2H6 (g) ΔHrxn = +36 kJ/mol

We would perform the following steps:

|  |  |  |
| --- | --- | --- |
| Eqn # | Equation | ΔH () |
| (d) | 2 B (s) + 3 H2 (g) → B2H6 (g) | +36 |
| +(−a) | 3 O2 (g) + B2H6 (g) → B2O3 (s) + 3 H2O (g) | −2,035 |
|  | 2 B (s) + 3 H2 (g) + 3 O2 (g) → B2O3 (s) + 3 H2O (g) | −1,999 |
| +(−3b) | 3 H2O (g) → 3 H2O (ℓ) | −132 |
|  | 2 B (s) + 3 H2 (g) + 3 O2 (g)  → B2O3 (s) + 3 H2O (ℓ) | −2,131 |
| +(−3c) | 3 H2O (ℓ) → 3 H2 (g) +  O2 (g) | +858 |
|  | 2 B (s) +  O2 (g) → B2O3 (s) | −1,273 |

Therefore, according to Hess’s Law, ΔHrxn for the reaction: 2 B (s) +  O2 (g) → B2O3 (s) ΔHrxn = −1,273 .

**Steps to Solve Hess’s Law Problems**

1. Identify the overall reaction being described and familiarize yourself with the chemical species that should be left after all you cancelations.
2. Pick any of those chemical species in the overall reaction (usually the first reactant)
3. Find the step reaction that has that chemical species in it.
   1. Flip the step equation if necessary to get it on the proper side of the reaction (reactant vs product)
   2. Multiply the step equation by a factor if necessary.
4. Identify a species in the step reaction that doesn’t show up in the overall reaction. Find a step reaction that has the unwanted species in it and add it to the other step reaction so that the unwanted species cancel out.
   1. Flip the step equation if necessary to get it on the proper side of the reaction (reactant vs product)
   2. Multiply the step equation by a factor if necessary.
5. Repeat step 4 until the sum of your step reactions matches the overall reaction.
6. Add all of the step reaction ΔH values together