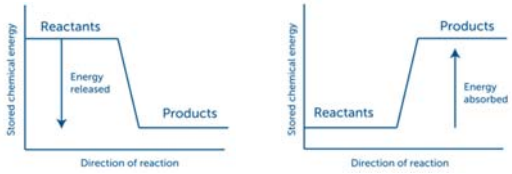
Hess's Law of Additivity

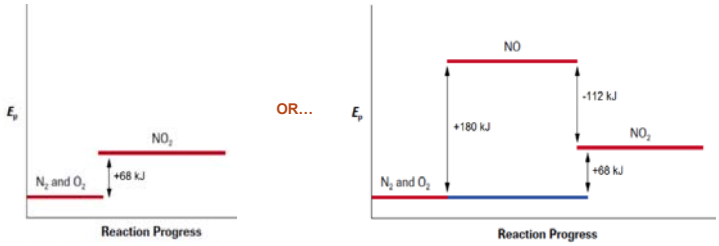
Section 5.4

The enthalpy change of a reaction is dependent only on two things:

1. The potential energy of the **reactants**
2. The potential energy of the **products**



$N_2 + 2\ O_2 \rightarrow 2\ NO_2$



(1) $N_2 + O_2 \rightarrow 2\ NO$ $\quad \Delta H = +180$ kJ

(2) $2\ NO + O_2 \rightarrow 2\ NO_2$ $\quad \Delta H = -112$ kJ

Hess's Law

The value of ΔH for any reaction that can be written in steps, equals the sum of the values of ΔH for each of the individual steps.

Rules for Adding Equations

- If the equation is reversed, the sign of ΔH changes
- If the equations are multiplied/divided by a factor in order to alter the coefficients, then ΔH must be altered in the same way.

Example 1

What is the enthalpy change for the formation of one mole of butane (C_4H_{10}) gas from its elements? The reaction is:

$4\ C + 5\ H_2 \rightarrow C_4H_{10}$ $\quad \Delta H = ?$

The following known equations, determined by calorimetry, are provided:

(1) $C_4H_{10} + \frac{13}{2} O_2 \rightarrow 4\ CO_2 + 5\ H_2O$ $\quad \Delta H_1 = -2657.5$ kJ

(2) $C + O_2 \rightarrow CO_2$ $\quad \Delta H_2 = -393.5$ kJ

(3) $2\ H_2 + O_2 \rightarrow 2\ H_2O$ $\quad \Delta H_3 = -483.6$ kJ

Strategy:
- Make sure equations are balanced.
- Flip equations around if necessary, to cancel out terms on opposite sides. This requires a change in the sign of ΔH for that step too!
- Multiply equations to obtain correct coefficients. Do the same to ΔH for that step.
- Sum up the individual steps

$4\ C + 5\ H_2 \rightarrow C_4H_{10}$ $\Delta H = ?$

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(2) $C + O_2 \rightarrow CO_2$ $\Delta H_2 = -393.5$ kJ

(3) $2\ H_2 + O_2 \rightarrow 2\ H_2O$ $\Delta H_3 = -483.6$ kJ

Example 2

What is the enthalpy change for the formation of two moles of liquid propanol?

$6\ C + 8\ H_2 + O_2 \rightarrow 2\ C_3H_7OH$ $\Delta H = ?$

The standard enthalpies of combustion of propanol, carbon, and hydrogen gas are -2008 kJ/mol, -394 kJ/mol, and -286 kJ/mol, respectively.

$C_3H_7OH + O_2 \rightarrow CO_2 + H_2O$

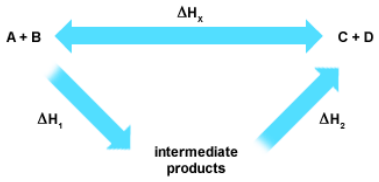
$C + O_2 \rightarrow CO_2$

$H_2 + O_2 \rightarrow H_2O$

	ΔH
$2\ C_3H_7OH + 9\ O_2 \rightarrow 6\ CO_2 + 8\ H_2O$	- 4016 kJ
$C + O_2 \rightarrow CO_2$	- 394 kJ
$2\ H_2 + O_2 \rightarrow 2\ H_2O$	- 572 kJ

Summary

Hess's Law: Regardless of the number of steps taken, the overall enthalpy change for a reaction is the sum of the enthalpy changes of the steps.



Homework

- Pg. 317 #1-3
- Pg. 318 #1-8