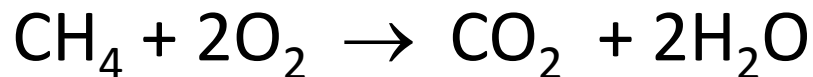# Standard Enthalpy, Hess, and Free Energy

Standard Enthalpy
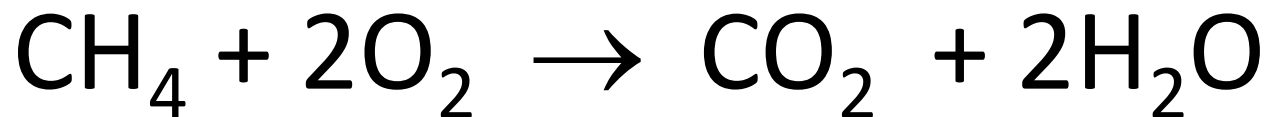
- In order to compare one thing to another, there must be a "standard"

- Standard temperature, $25^{\circ}C$.

- Enthalpy changes during a reaction at $25^{\circ}C$ are considered the standard enthalpy.

- ΔH_f° = standard enthalpy of formation
  (found in book)

- Standard enthalpies of formation for elements in their common form at $25^{\circ}C$ is 0kJ/mol

- Moles (mol) is just an amount for now (like puffs).

Standard Enthalpy of Formation

- Look up the enthalpies on a table

- $\Delta H = H_{Products} - H_{reactants}$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

	Substance	# of Moles	ΔH_f kJ/mole
Reactants	CH_4 O_2	1 2	-74.8 0
Products	CO_2 H_2O	1 2	-393.5 -285.8

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

	Substance	# of Moles	ΔH_f kJ/mole
Reactants	CH_4 O_2	1 2	-74.8 0
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$$\Delta H_f = [-393.5 + 2(-285.8)] - [-74.8 + 2(0)]$$
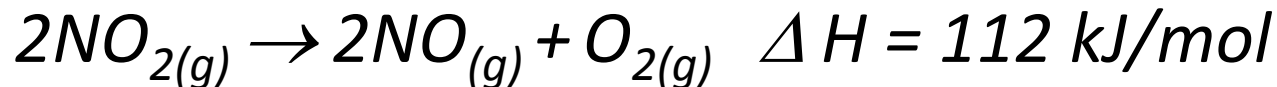
$$= -890.3 \text{ kJ/mol}$$

Hess's Law

- Enthalpy is a "state" function
  - It doesn't matter how you get there, the energies are the same
- Reaction can be broken down into a series of steps.
  - We can add, subtract, multiply, reverse reaction enthalpies for each step
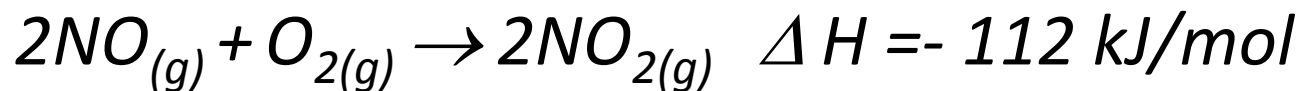 - To find the overall enthalpy change

Hess' Law or State Functions

$NO_{2(g)} \rightarrow 1NO_{(g)} + 1/2O_{2(g)}$ $\Delta H = 56 \ kJ/mol$
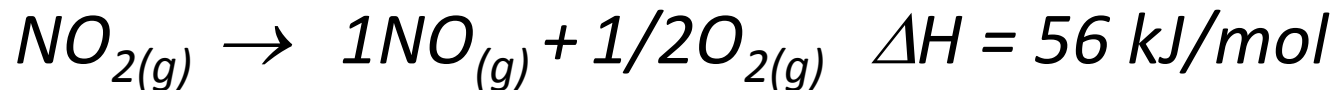
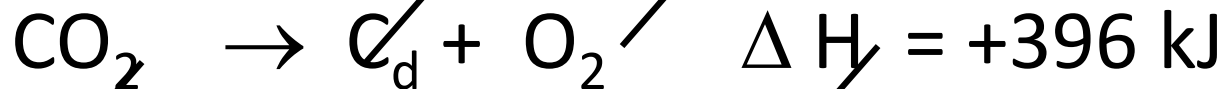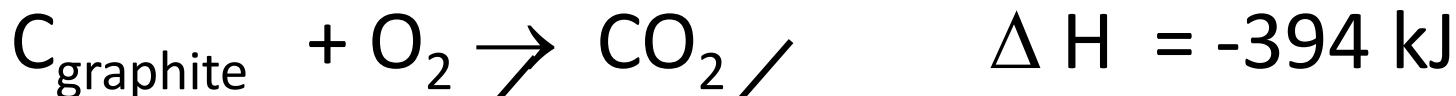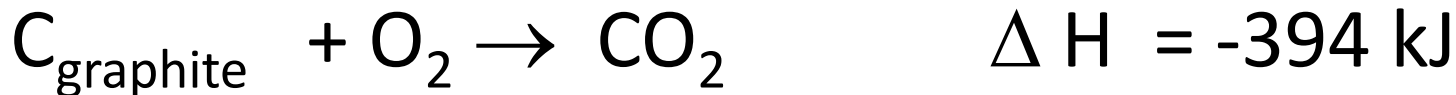Double the reaction = double the enthalphy

$2NO_{2(g)} \rightarrow 2NO_{(g)} + O_{2(g)}$ $\Delta H = 112 \ kJ/mol$

The reverse of the reaction, "negative"

$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$ $\Delta H = -112 \ kJ/mol$

Hess's Law

- $2H_2O_2 \rightarrow 2H_2O + O_2$ $\triangle H = -190kJ$
- $4H_2O_2 \rightarrow 4H_2O + 2O_2$ $\triangle H = -380kJ$
- $2H_2O + O_2 \rightarrow 2H_2O_2$ $\triangle H = +190kJ$
- $4H_2O + 2O_2 \rightarrow 4H_2O_2$ $\triangle H = +380kJ$
- $1H_2O_2 \rightarrow 1H_2O + \frac{1}{2}O_2$ $\triangle H = -95kJ$

$$C_{graphite} \rightarrow C_{diamond}$$

$$C_{graphite} + O_2 \rightarrow CO_2 \qquad \Delta H = -394 \text{ kJ}$$

$$C_{diamond} + O_2 \rightarrow CO_2 \qquad \Delta H = -396 \text{ kJ}$$

$$C_{graphite} + O_2 \rightarrow CO_2 \qquad \Delta H = -394 \text{ kJ}$$

$$CO_2 \rightarrow C_d + O_2 \qquad \Delta H = +396 \text{ kJ}$$

$$C_{graphite} \rightarrow C_{diamond} \qquad \Delta H = +2 \text{ kJ}$$

Calculate the ΔH

$$2C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)}$$

$$C_2H_{2(g)} + 5/2\ O_{2(g)} \rightarrow 2CO_{2(g)} + H_2O_{(l)} \qquad \Delta H= \quad -1300.\ kJ$$

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H= \quad +394kJ$$

$$H_{2(g)} + 1/2O_{2(g)} \rightarrow H_2O_{(l)} \qquad \Delta H= \quad -286\ kJ$$

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$2C + 2O_2 \rightarrow 2CO_2$
$H_2 + 1/2O_2 \rightarrow H_2O$
$2CO_2 + H_2O \rightarrow C_2H_2 + 5/2O_2$

$$2C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)}$$
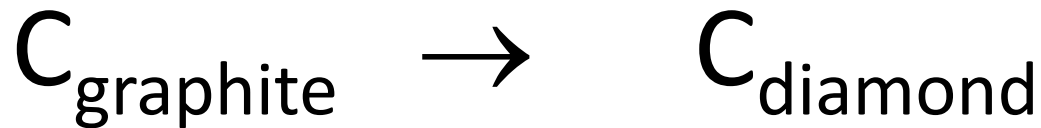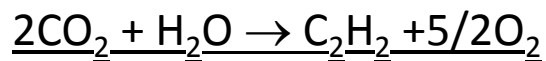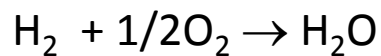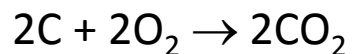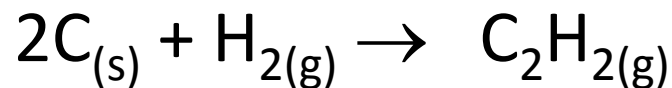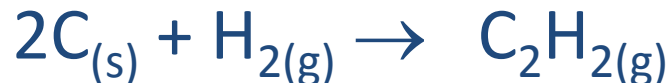
Spontaneity

- Some reactions happen on presumably on their own under certain conditions.

- These reactions are called spontaneous reactions.

- There are multiple factors that go into whether a reactions will be spontaneous or not.

- These are
  – Change in Enthalpy
  – Temperature
  – Change in Entropy

Entropy

- Entropy is referring to disorder of the substance.
- The higher the entropy, the more the disorder.
- For example:
  - a gas has a higher entropy than a liquid.
  - Aqueous solutions have more entropy than solid compounds.
- Nature moves toward raising entropy. This is why:
  - A gas will spread out in a room
  - It takes so much energy for your body to stay together.

Gibb's Free Energy

- Gibb's free energy is a way to measure the spontaneity of a reaction.

- It is denoted by the symbol ΔG.

- If ΔG is negative, then the reaction is spontaneous.

- If ΔG is positive, then the reaction is not spontaneous.

- The equation that relates this is:

$$\Delta G = \Delta H - T\,\Delta S$$

- ΔS is the change in entropy, T is temperature, and ΔH is the change in enthalpy.

Is it Spontaneous?

- If the enthalpy is negative (meaning the bonds in the products are stronger than the reactants) then it is more likely to be spontaneous.

- If the entropy is positive (meaning the reaction moves toward disorder) then it is likely to be spontaneous.

- If the temperature is high, then the reaction is more likely to be spontaneous as long as the entropy is positive.

- The opposite will decrease the probability of a spontaneous reaction.