Chem 111

Lecture 16

Announcements

- Take home are done 89%.

Homework

- Finish reading Chapter 5

- OWL online homework

Recap

- Phase Change
- Internal Energy
- State Function

Enthalpy

Many changes occur under constant pressure.

So most energy transfers that take place are in the form of heat.

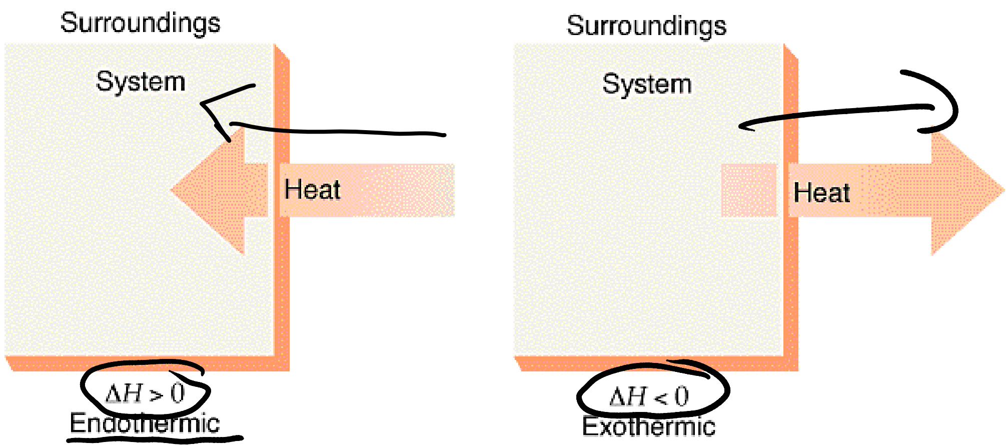
Enthalpy is the heat absorbed or released under constant pressure.

It is a state function.

The change in enthalpy, ΔH, equals the heat, q_p, gained or lost by the system when the process occurs under constant pressure.

$$\Delta H = H_{final} - H_{intitial} = q_p$$

Δ ↓ q



Enthalpies of Reaction

$\Delta H = H_{final} - H_{initial}$

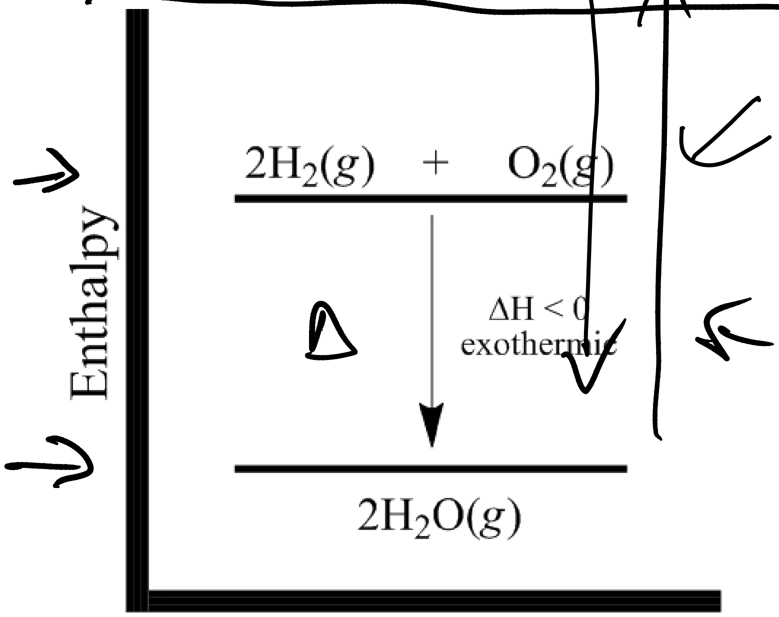
So for a reaction

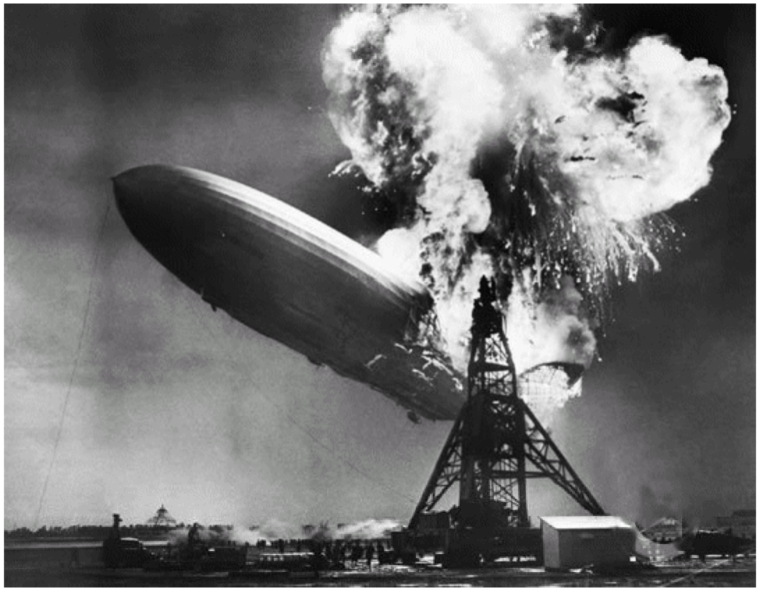
$\underline{\Delta H_{rxn}} = \underline{H(products)} - \underline{H(reactants)}$

$2H_2O(l)$

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

$\Delta H_{rxn} = \underline{-483.6\ kJ}$





Enthalpies of Reaction

Enthalpy is an extensive property. The magnitude of ΔH is directly proportional to the amount of reactant consumed in the process.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ ΔH = -802 kJ/mol

$2CH_4 + 4O_2 \rightarrow 2CO_2 + 4H_2O$ 2×(-802) kJ

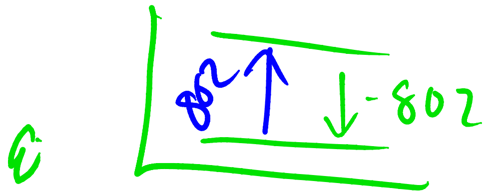
The enthalpy change for a reaction is equal in magnitude but opposite in sign to ΔH for the reverse reaction.

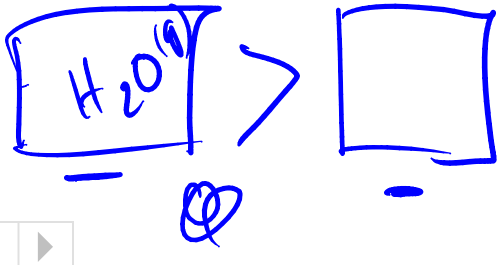
$CO_2(g) + 2H_2O(g) \rightarrow CH_4(g) + 2O_2(g)$ ΔH = 802 kJ

The enthalpy change for a reaction depends on the state of reactants and products.

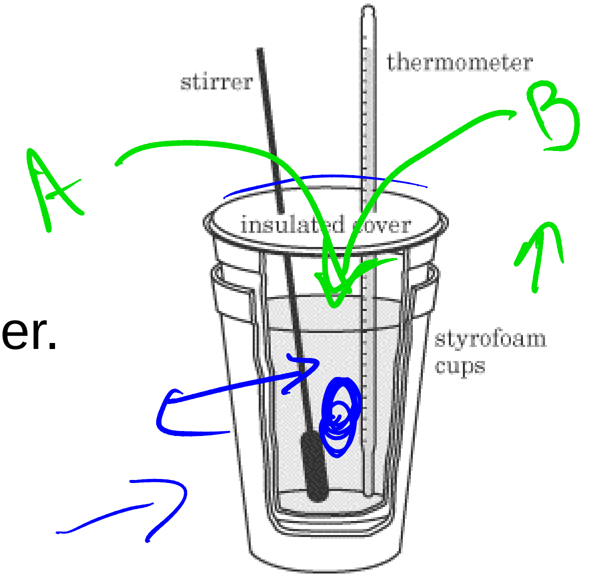
Δfinal - Δinitia

$2H_2O(g) \rightarrow 2H_2O(l)$ ΔH = - 88 kJ





Calorimetry



The measurement of heat flow.
Apparatus used to measure is called a calorimeter.

Not sealed, so constant pressure.

The heat gained by the solution, q_{soln}, is readily calculated from the mass of the solution, it specific heat, and the temperature change.

$$q_{soln} = \underline{C_{soln}}\,\underline{m_{soln}}\,\boxed{\Delta T_{soln}} \leftarrow$$

Calorimeter is isolating the system from surroundings, therefore the heat of reaction, q_{rxn}, must be equal in magnitude and opposite in sign from q_{soln}.

$$\boxed{q_{rnx}} = \underline{-\,q_{soln}} = -\{C_{soln} m_{soln}\,\Delta T_{soln}\}$$

Bomb Calorimetry

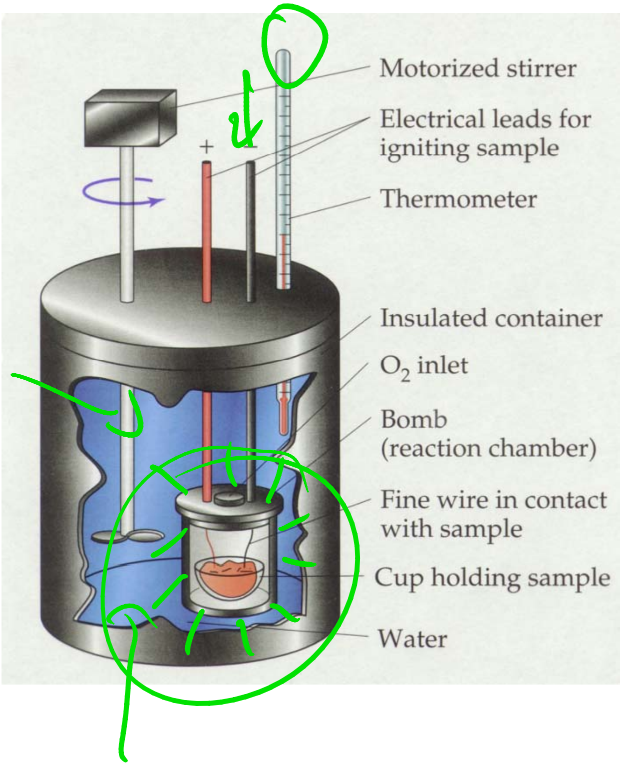
Usually used with organic compounds.

$$q_{rxn} = -C_{calorimeter}\Delta T$$

-Cm

=

ΔT



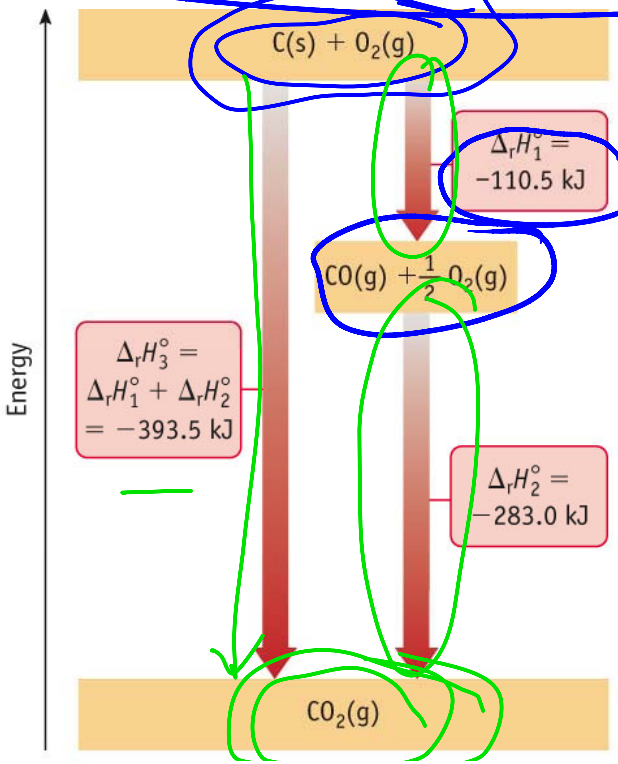
Hess' Law

Remember enthalpy is a state function.

$C + \frac{1}{2}O_2 \rightarrow CO \quad \Delta H° = –110.5\text{ kJ}$

$CO + \frac{1}{2}O_2 \rightarrow CO_2 \quad \Delta H° = –283.0\text{ kJ}$

$C + O_2 \rightarrow CO_2 \quad \Delta H° = –393.5\text{ kJ}$



Hess's Law states that if a reaction is carried out in a series of steps, ΔH for the reaction will be equal to the sum of the enthalpy changes for the individual steps.

Let’s Practice

~~Calculate ΔH for the reaction~~

$NO(g) + O(g) \rightarrow NO_2(g)$

Using:

$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ ΔH =-198.9kJ

$O_3(g) \rightarrow 3/2\ O_2(g)$ ΔH =-142.3kJ

$O_2(g) \rightarrow 2O(g)$ ΔH = 495.0kJ

$\frac{1}{2}O_2 \rightarrow O(g)$

$NO(g) + \cancel{O_3} \rightarrow NO_2 + \cancel{O_2}$

$O_g \rightarrow \cancel{\frac{1}{2}O_2}$

$\cancel{\frac{3}{2}O_2} \rightarrow \cancel{O_3}$

ΔH

-198.9

$-\frac{495.0}{2}$

142.3k

Enthalpies of Formation

Great number of enthalpies of reactions of been tabulated.

Enthalpy of Formation: sometime called the heat of formation, ΔH_f, is the enthalpy it takes to form a substances from its elements.

Standard Enthalpy ΔH^o: enthalpy change when all reactants and products are in their standard state (pure form at 1 atm and 298 K)

$$2C(\text{graphite}) + 3H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow C_2H_5OH(l) \qquad \Delta H^o_f = -277.7\,\text{kJ}$$

Enthalpies of Formation

$\Delta H_{rxn}^{o} = \Sigma\Delta H_f^{o}(\text{products}) - \Sigma\Delta H_f^{o}(\text{reactants})$

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

	ΔH^{o}_{f} kJ/mol
$C_3H_8(g)$	-103.85
$CO_2(g)$	-393.5
$H_2O(l)$	-285.5

$C_3H_8(g) \rightarrow 3C(s) + 4H_2(g)$ $\quad -\Delta H^{o}_{f}[C_3H_8(g)]$

$3C(s) + 3O_2(g) \rightarrow 3CO_2(g)$ $\quad 3\,\Delta H^{o}_{f}[CO_2(g)]$

$4H_2(g) + 2O_2(g) \rightarrow 4H_2O(l)$ $\quad 4\,\Delta H^{o}_{f}[H_2O(l)]$

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

$\Delta H_{rxn}^{o} = 3\,\Delta H^{o}_{f}[CO_2(g)] + 4\,\Delta H^{o}_{f}[H_2O(l)] - \Delta H^{o}_{f}[C_3H_8(g)]$

$\Delta H_{rxn}^{o} = -2220$ kJ

Let's Practice

$\Delta H_{rxn}^{o} = \Sigma\Delta H_f^{o}(\text{products}) - \Sigma\Delta H_f^{o}(\text{reactants})$

Calculate the standard enthalpy change for the combustion of 1 mol of benzene, $C_6H_6(l)$

	ΔH^{o}_{f} kJ / mol
$C_3H_8(g)$	-103.85
$CO_2(g)$	-393.5
$H_2O(l)$	-285.5
$C_6H_6(l)$	49.04