2nd law of thermodynamics —

- Entropy always increases
- A spontaneous process (one that does not require outside energy) must cause an increase in entropy when both the system and surroundings are taken into account.

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

Free energy — the available potential energy (entropy change of universe)

System

$\Delta S > 0$ more disorder (favorable)

$\Delta S < 0$ more order (unfavorable)

Surroundings

$\Delta G < 0$ exergonic spontaneous

$\Delta G > 0$ endergonic non-spontaneous (requires outside energy)

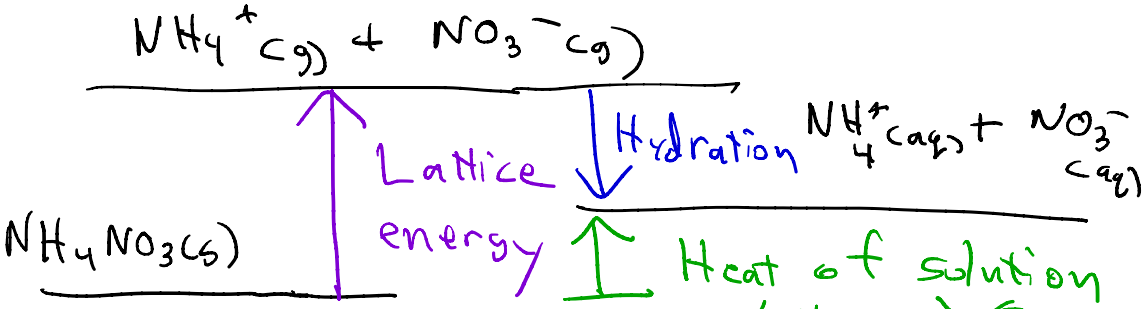
$\Delta G = 0$ in many cases → equilibrium

ΔG must be less than zero for this to occur

$\Delta G = \Delta H - T\Delta S$ ($\Delta H > 0$)

the only way this can happen is if $\Delta S > 0$

$NH_4NO_3(s) \xrightarrow{H_2O} NH_4NO_3(aq)$ $\Delta H > 0$



$\Delta H_{soln} > 0$

Hess's law - The energy change in a chemical rxn does not depend at all on how the rxn occurs, only on its reactants and products.

$\Delta H_{soln} = \text{lattice energy} + \Delta H_{hydration}$

lattice energy: automatically positive (pulling ions apart)

$\Delta H_{hydration}$: automatically negative (ions attracted to water)

In the case of dissolving ammonium nitrate in water, the lattice energy is greater than the heat of hydration, so the process is endothermic.

- In order for an ionic compound to dissolve in water, it must dissociate. The process of dissolving involves separating ions (unlike covalent compounds) so this automatically involves breaking ionic bonds (dissociate).

Based on heat alone, forming a solution of ammonium nitrate should not be possible, since it involves absorbing heat, ($\Delta H > 0$). But forming a solution involves a large increase of entropy ($\Delta S > 0$) because there is far more freedom of motion.

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

$\Delta H > 0$ $\quad$ $\Delta S > 0$

If the temperature is high enough, the favorable effects of a positive entropy change can counter the effects of a positive enthalpy change, making the process spontaneous (negative ΔG).

$$CH_3CH_2CH_{3(g)} + 5\,O_{2(g)} \longrightarrow 3\,CO_{2(g)} + 4\,H_2O_{(\ell)}$$

6 moles → 7 moles ($\Delta S > 0$?)

$\Delta H < 0$ (combustion)

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

$\Delta H < 0$ $\quad -T\Delta S$ ($\Delta S > 0$)

Regardless of T, the rxn is spontaneous ($\Delta G < 0$)

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

$\Delta H > 0$ $\quad -T\Delta S$ ($\Delta S < 0$)

Regardless of T, the rxn is non-spontaneous ($\Delta G > 0$)