N7 – Gibbs Free Energy

Gibbs free energy, *G* - the maximum amount of work energy that can be released to the surroundings by a system for a constant temp and pressure system.

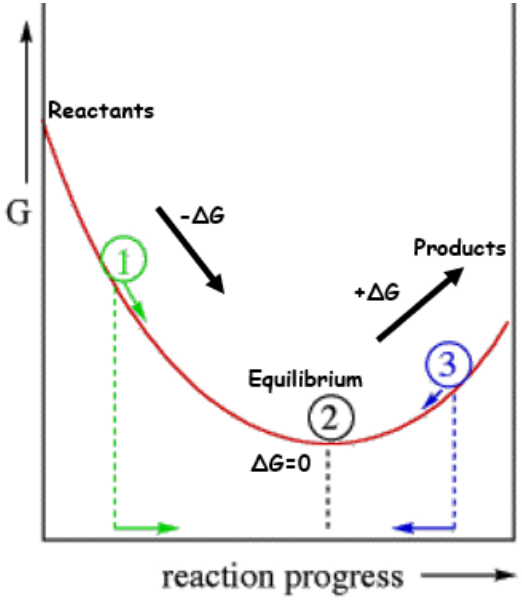
Gibbs free energy is often called the **chemical potential** because it is similar to the storing of energy in a mechanical system.

Gibbs Mental Math

$\Delta H_{sys} - T\Delta S_{sys} = \Delta G_{sys}$

ΔH	ΔS	ΔG	At...
− exothermic	+ more disorder	− ALWAYS spont.	Any temp
+ endothermic	− less disorder	+ NEVER spont.	Any temp
− exothermic	− less disorder	− spont.	Low Temp
− exothermic	− less disorder	+ NOT spont.	High Temp
+ endothermic	+ more disorder	− spont.	High Temp
+ endothermic	+ more disorder	+ NOT spont.	Low Temp

	$\Delta H < 0$	$\Delta H > 0$
$\Delta S > 0$	Spontaneous at all T ($\Delta G < 0$)	Spontaneous at high T (when $T\Delta S$ is large)
$\Delta S < 0$	Spontaneous at low T (when $T\Delta S$ is small)	Non-spontaneous at all T ($\Delta G > 0$)



ΔG	K vs Q	
ΔG = 0	K = Q	@ equilibrium
ΔG < 0	K > Q	Shift right
ΔG > 0	K < Q	Shift left

A Variety of Helpful Equations

$$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr}$$

$$\Delta S_{surr} = -\Delta H_{sys} / T$$

$$-T\Delta S_{univ} = \Delta H_{sys} - T\Delta S_{sys}$$

$$-\Delta G_{sys} = \Delta H_{sys} - T\Delta S_{sys}$$

$$\Delta G^0 = \sum n_p \Delta G^0_{f\,(\text{products})} - \sum n_r \Delta G^0_{f\,(\text{reactants})}$$

$$\Delta G° = -RT\,ln(K)$$

$$where\ R = 8.314 J/mol \bullet K$$

$$\Delta G = \Delta G° + RT\,ln(Q)$$

$$-RT\,ln(K) = \Delta H° - T\Delta S°$$

$$ln(K) = -\frac{\Delta H^0}{RT} + \frac{\Delta S^0}{R}$$

$$= -\frac{\Delta H^0}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^0}{R}$$

$$y = m x + b$$

1st - Graph ln(K) vs $\left(\frac{1}{T}\right)$
2nd - Find line of best fit (Excel or graphing calculator)
3rd - Slope = $-\frac{\Delta H°}{R}$ Intercept = $\frac{\Delta S°}{R}$

N7 – Gibbs Free Energy – still…sorry…not sorry ☺

Practice Problems

#1 - For the following Rx:
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
Calculate the standard Free Energy, $\Delta G°$ for the rxn at 25°C.
$\Delta H° = -264 kJ/mol$ $\Delta S° = -278$ J/mol•K

#2 - Calculate the Boiling Point of BCl_3.
$BCl_{3(l)} \leftrightarrow BCl_{3(g)}$. Given:

	H_f kJ/mol	S J/mol k
BCl_3 (*l*)	-418	209
BCl_3 (g)	-395	290

#3 - Under standard conditions (1 atm of NH_3, N_2 and H_2) and at 298 K, what substance(s) will be formed?
($\Delta G° = 33.4$ kJ)
$2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$

#4 - Calculate the equilibrium constant for this reaction at 298 K.
$2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$ ($\Delta G° = 33.4$ kJ)