Chemical Equilibrium:

$$\nu_A A + \nu_B B \rightleftharpoons \nu_C C + \nu_D D$$

Ideal Gases

T, P

$$\Delta G^\circ = -RT \ln (K_p)$$

pressure-based Equil. Constant.

$$K_p = e^{-\Delta G^\circ / RT}$$

$$K_p(T)$$

"mu"

$$\Delta G^\circ = \sum_{i=1}^{\text{species}} \nu_i \mu_i^\circ$$

chemical potential of "i" in standard (reference state)

"nu" Stoichiometric Coefficient

$$\boxed{\Delta G^\circ = \Delta H^\circ - T \Delta S^\circ}$$

What is T dependence of $K_p(T)$?

$$\ln K_p = \frac{1}{-RT}\Delta G^\circ = \frac{-1}{RT}\Delta G^\circ$$

If I know K_p at T_1

what is K_p at T_2?

$$\left(\frac{d(\ln K_p)}{dT}\right)_P = \frac{d}{dT}\left(\frac{-1}{RT}\Delta G^\circ\right)$$

$$= \frac{-1}{RT}\frac{d(\Delta G^\circ)}{dT} + \Delta G^\circ \frac{d}{dT}\left(\frac{-1}{RT}\right)$$

$$= \left(\frac{-1}{RT}\right)\left(-\Delta S^\circ\right) + \Delta G^\circ\left(\frac{1}{RT^2}\right)$$

$$= \frac{\Delta S^\circ}{RT} + \frac{1}{RT^2}\left[\Delta H^\circ - T\Delta S^\circ\right]$$

$$= \frac{\Delta S^\circ}{RT} + \frac{\Delta H^\circ}{RT^2} - \frac{\Delta S^\circ}{RT}$$

$$\boxed{\frac{d(\ln K_p)}{dT} = \frac{\Delta H^\circ}{RT^2}}$$

$$\int_{T_1}^{T_2} d(\ln K_p) = \int_{T_1}^{T_2} \frac{\Delta H^\circ}{RT^2}\, dT$$

Assume over $[T_1, T_2]$

ΔH° is constant

$$\ln K_p(T_2) - \ln K_p(T_1) = \frac{-\Delta H^\circ}{R} \frac{1}{T}\Big|_{T_1}^{T_2}$$

$$= \frac{\Delta H^\circ}{R} \frac{1}{T}\Big|_{T_2}^{T_1}$$

$$\boxed{\ln K_p(T_2) - \ln K_p(T_1) = \frac{\Delta H^\circ}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]}$$

$$\ln K_p(T_2) - \ln K_p(T_1) = \frac{\Delta H^\circ}{R}\left[\frac{T_2 - T_1}{T_1 T_2}\right]$$

endo $\Delta H^\circ_{Rxn} > 0$

exo $\Delta H^\circ_{Rxn} < 0$

$$\text{Heat} + A + B \rightleftharpoons C + D \quad \text{endo}$$

$$A + B \rightleftharpoons C + D + \text{heat} \quad \text{exo}$$

$$A + B \rightleftharpoons C + D$$

gas	gas	gas	gas
liq	solid	solid	$\equiv$

$$K_p = \frac{p_C^{\nu_C}\, p_D^{\nu_D}}{p_A^{\nu_A}\, p_B^{\nu_B}} = p_D^{\nu_D}$$

$$\Delta G^\circ = -RT \ln K_p$$

$$\Delta G^\circ = \sum \nu_i \mu_i^\circ$$

$$= \nu_A \mu_A^\circ + \nu_B \mu_B^\circ + \nu_C \mu_C^\circ + \nu_D \mu_D^\circ$$