Chemical Equilibrium:

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

Ideal Gases

$T, P \rightarrow$ mixture of ideal gases.

$$G = \sum_{i=1}^{\text{species}} \mu_i n_i \qquad \mu_i(T, P, \{\text{compositions}\})$$

For pure species:

$$G = \mu n$$

$$dG = \mu dn + n d\mu = Vdp - SdT + \mu dn$$

$$n d\mu = Vdp - SdT$$

$$d\mu = \left(\frac{V}{n}\right)dp - \left(\frac{S}{n}\right)dT$$

$$\boxed{d\mu = \bar{V}dp - \bar{S}dT}$$

Constant T $\quad d\mu = \bar{V}dp$

For I. G.

$$d\mu^{ig} = RT\, d(\ln p)$$

$$\mu(T,p) - \mu(T,p^0) = RT \ln\left(p/p^0\right)$$

reference pressure

often taken $p^0 = 1$ bar

For "i" in mixture:

partial pressure of "i"

$$\mu_i(T, p, \{\text{composition}\}) = \mu_i(T, p^0) + RT \ln\left(\frac{p_i}{p^0}\right)$$

$$\boxed{\Delta G^0 = -RT \ln\left(\frac{p_C^{|\nu_C|}\, p_D^{|\nu_D|}}{p_A^{|\nu_A|}\, p_B^{|\nu_B|}}\right)}$$

$p^0 = 1$ bar

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

$$\Delta G^0 = -RT \ln K_p$$

$$K_p = \frac{x_C^{\nu_C} \, p^{\nu_C} \, x_D^{\nu_D} \, p^{\nu_D}}{x_A^{\nu_A} \, p^{\nu_A} \, x_B^{\nu_B} \, p^{\nu_B}}$$

$$K_p = \frac{x_C^{\nu_C} \, x_D^{\nu_D}}{x_A^{\nu_A} \, x_B^{\nu_B}} \, p^{\left(\sum_i \nu_i\right)}$$

$$K_p = K_x \, p^{\left(\sum_i \nu_i\right)}$$

Ideal Gas.

$$\boxed{\begin{aligned} K_p &= e^{-\Delta G^0 / kT} \leftarrow K_p(T) \\ K_x &= K_p \, p^{-\left(\sum_i \nu_i\right)} = K_x(T, p) \end{aligned}}$$

Assume I.G. $\qquad N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\qquad T, P$

$P \uparrow$

Initial moles	n	0
Equilibrium moles	$n - x$	$2x$
X_i's @ Equil.	$\dfrac{n-x}{n+x}$	$\dfrac{2x}{n+x}$

$$K_p = \frac{P_{NO_2}^2}{P_{N_2O_4}} = \frac{P^2 X_{NO_2}^2}{P X_{N_2O_4}} = P \frac{X_{NO_2}^2}{X_{N_2O_4}}$$

$$= P \frac{\left(\frac{2x}{n+x}\right)^2}{\left(\frac{n-x}{n+x}\right)} = P \frac{4x^2}{(n+x)^2}\left(\frac{n+x}{n-x}\right)$$

$$K_p = P \frac{4x^2}{n^2 - x^2}$$

$$\alpha \equiv \frac{x}{n} \quad \text{fraction reacted}$$

$$K_p = \frac{P 4\alpha^2 n^2}{n^2 - \alpha^2 n^2} = \frac{P 4\alpha^2 n^2}{(1-\alpha^2) n^2}$$

$$K_p = \frac{4\alpha^2}{(1-\alpha^2)} p$$

solve for

$$\boxed{\alpha = \left(1 + \frac{4p}{K_p(T)}\right)^{-\frac{1}{2}}}$$

↑ fraction reacted

Negative Temperature (Absolute)

Isolated System

$$dU = T\,dS - p\,dV$$

$$dU = T\,dS$$

$$\frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)_V$$

2-state System

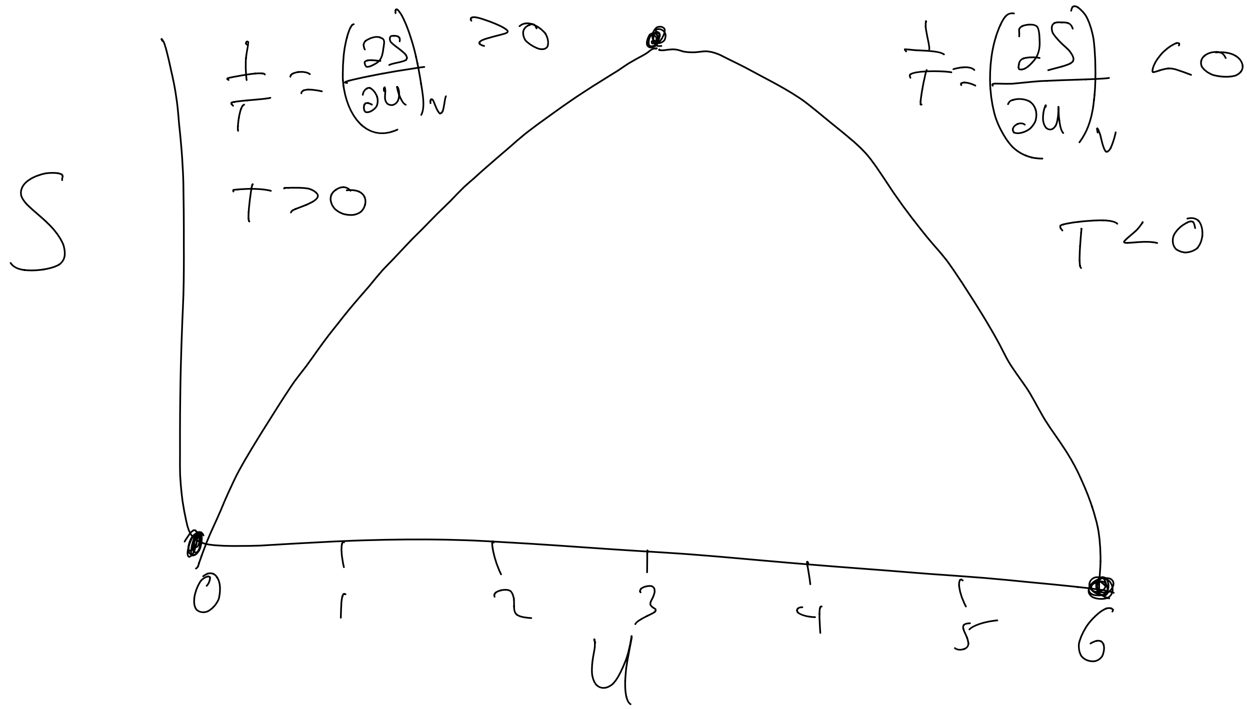
6-particles
distinguish them

$U=1$ ______________

$U=0$ ① ② ③ ④ ⑤ ⑥

Population Inversion

Energy, U^{TOTAL}	# Ways
0	1
1	6
2	36
3	>36
4	36
5	6
6	1



$\frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)_V > 0$
$T > 0$
$\frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)_V < 0$
$T < 0$
S
0
1
2
3
4
5
6
U