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

A, B, C, D are gases

ν_i = stoichiometric coefficients

mixture

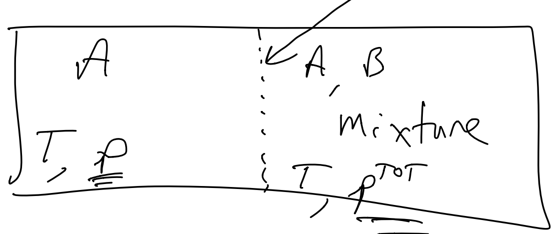
$$G = \sum_{i=1}^{m} \mu_i n_i$$

μ_i chemical potential of "i"

? $\mu_i \leftarrow \mu_i(T, P, \text{composition})$

Ideal Gases: Mixture

semipermeable to A only



$$P^{TOT} = P_A + P_B$$
$$= x_A P^{TOT} + x_B P^{TOT}$$

What is $\mu_A(\text{mixture}, T, P^{TOT})$?

$$\mu_A(T, p^{TOT}, \text{mixture}) = \mu_A(T, p, \text{pure})$$

$x_A p^{TOT}$

$$x_A p^{TOT} = p$$

pressure exerted by pure A

$$\mu_A(T, p^{TOT}, \text{mixture}) = \mu_A(T, x_A p^{TOT}, \text{pure})$$

$$= \mu_A(T, p^\circ) + RT \ln\left(\frac{x_A p^{TOT}}{p^\circ}\right)$$

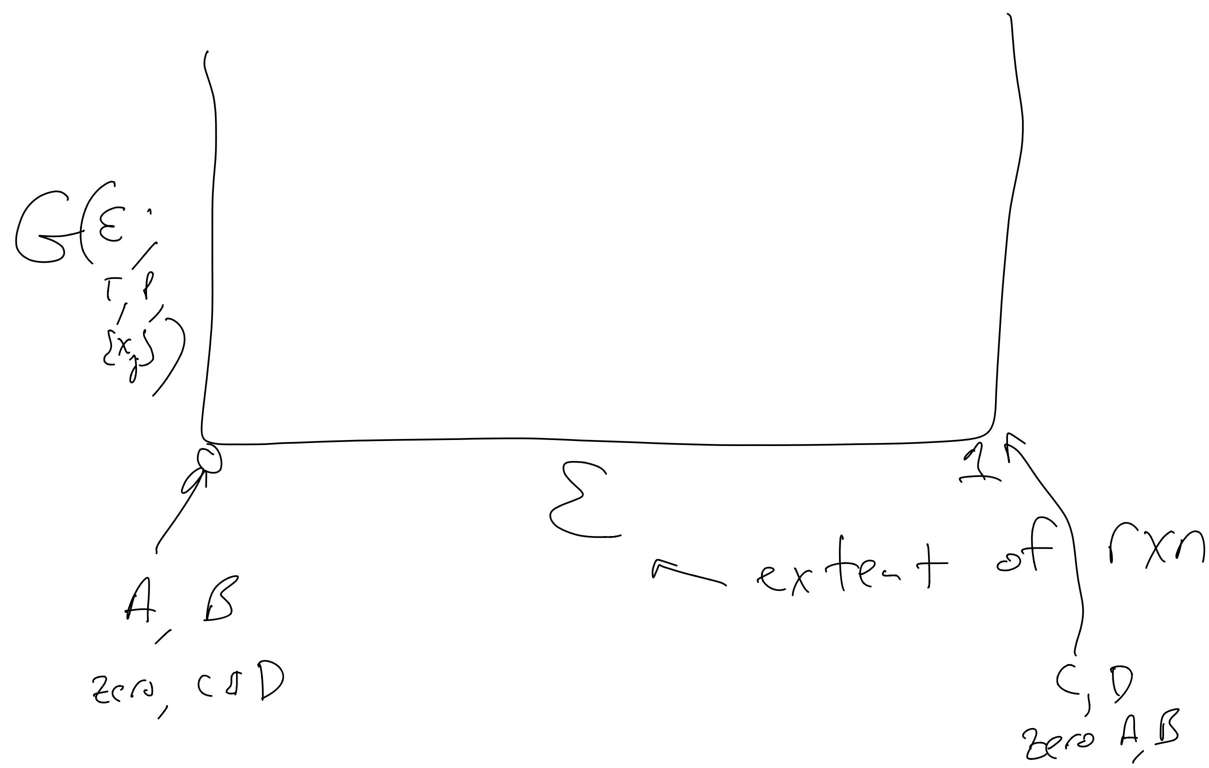
$$\boxed{\mu_A(T, p^{TOT}, \text{mixture}) = \mu_A(T, p^\circ) + RT \ln\left(\frac{p^{TOT}}{p^\circ}\right) + RT \ln x_A}$$

$$\boxed{\mu_A(\text{mixture}) < \mu_A(\text{pure}) \quad \text{at same } T \text{ \& } p^{TOT}}$$

So what? relate to $\underline{G}$

$$G = \sum_{i=1}^{m} \mu_i n_i$$

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



Initially, we have n_A^0, n_B^0, n_C^0, n_D^0 moles of each species,

ξ of rxn takes places

G initially & G after ξ rxn occurs

Initially: $G = \sum \mu_i n_i$

$$= \mu_A n_A^\circ + \mu_B n_B^\circ + \mu_C n_C^\circ + \mu_D n_D^\circ$$

After ε of rxn.

small ε so μ_A remains constant.

$$n_A = n_A^\circ + \nu_A \varepsilon \qquad n_C = n_C^\circ + \nu_C \varepsilon$$

$$n_B = n_B^\circ + \nu_B \varepsilon \qquad n_D = n_D^\circ + \nu_D \varepsilon$$

$$G(\varepsilon) = \mu_A n_A + \mu_B n_B + \mu_C n_C + \mu_D n_D$$

$$G(\varepsilon) = \mu_A(n_A^\circ + \nu_A \varepsilon) + \mu_B(n_B^\circ + \nu_B \varepsilon) + \mu_C(n_C^\circ + \nu_C \varepsilon) + \mu_D(n_D^\circ + \nu_D \varepsilon)$$

$$G(\varepsilon) - G = \varepsilon\left[\mu_A \nu_A + \mu_B \nu_B + \mu_C \nu_C + \mu_D \nu_D\right]$$

$$\frac{G(\varepsilon) - G}{\varepsilon} = \left[\mu_A \nu_A + \mu_B \nu_B + \mu_C \nu_C + \mu_D \nu_D\right]$$

limit $\varepsilon \to 0$ $\quad \dfrac{dG}{d\varepsilon} = \mu_A \nu_A + \mu_B \nu_B + \mu_C \nu_C + \mu_D \nu_D = 0$

$$\mu_A = \mu_A(T, P^0) + RT \ln\left(P_A/P^0\right) \qquad P_A = X_A P^{TOT}$$

$$\mu_B = \mu_B(T, P^0) + RT \ln\left(P_B/P^0\right) \qquad P_B = X_B P^{TOT}$$

$$\vdots$$

$$\nu_A\left(\mu_A(T,P^0) + RT\ln\left(P_A/P^0\right)\right) + \nu_B\left[\mu_B(T,P^0) + RT\ln\left(P_B/P^0\right)\right] + \underline{\text{C-term}}$$

$$+ \underline{\text{D-term}}$$

$$= 0 \; !$$

$$\underbrace{\nu_A \mu_A(T,P^0) + \nu_B \mu_B(T,P^0) + \nu_C \mu_C(T,P^0) + \nu_D \mu_D(T,P^0)}_{\Delta G^\circ}$$

$$+ RT\ln\left(P_A/P^0\right)^{\nu_A} + RT\ln\left(P_B/P^0\right)^{\nu_B} + RT\ln\left(P_C/P^0\right)^{\nu_C}$$

$$+ RT\ln\left(P_D/P^0\right)^{\nu_D}$$

$$= 0$$

$$\Delta G^\circ = -RT\left[\ln\left(P_A/P^0\right)^{\nu_A} + \ln\left(P_B/P^0\right)^{\nu_B} + \ln\left(P_C/P^0\right)^{\nu_C} + \ln\left(P_D/P^0\right)^{\nu_D}\right.$$

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

$$\Delta G^\circ = -RT \ln \left\{ \frac{(p_C)^{|\nu_C|}\, p_D^{|\nu_D|}}{(p_A)^{|\nu_A|}\,(p_B)^{|\nu_B|}} \left(p_0\right)^{\nu_A+\nu_B+\nu_C+\nu_D} \right\}$$

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

Equilibrium Constant!