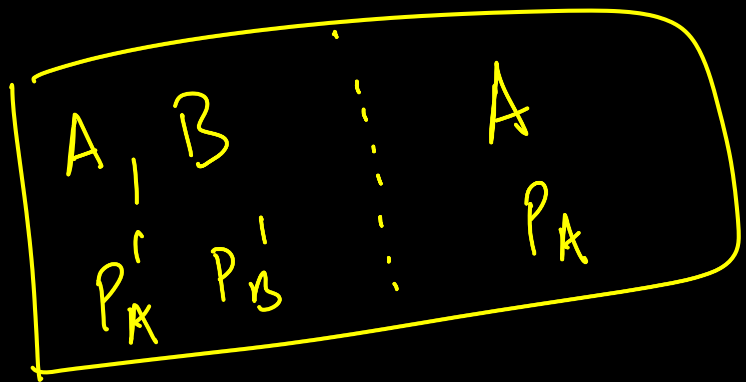
$$\mu_A(\text{mix}, T, p) < \mu_A(\text{pure}, T, p)$$



At equilibrium

$$\mu_A(\text{mix}, T, p_T) = \mu_A(\text{pure}, T, p_A)$$

$$= \mu_A(\text{pure}, T, x_A p_T)$$

$$= \mu_A^{\ominus}(T) + RT \ln(x_A p_T)$$

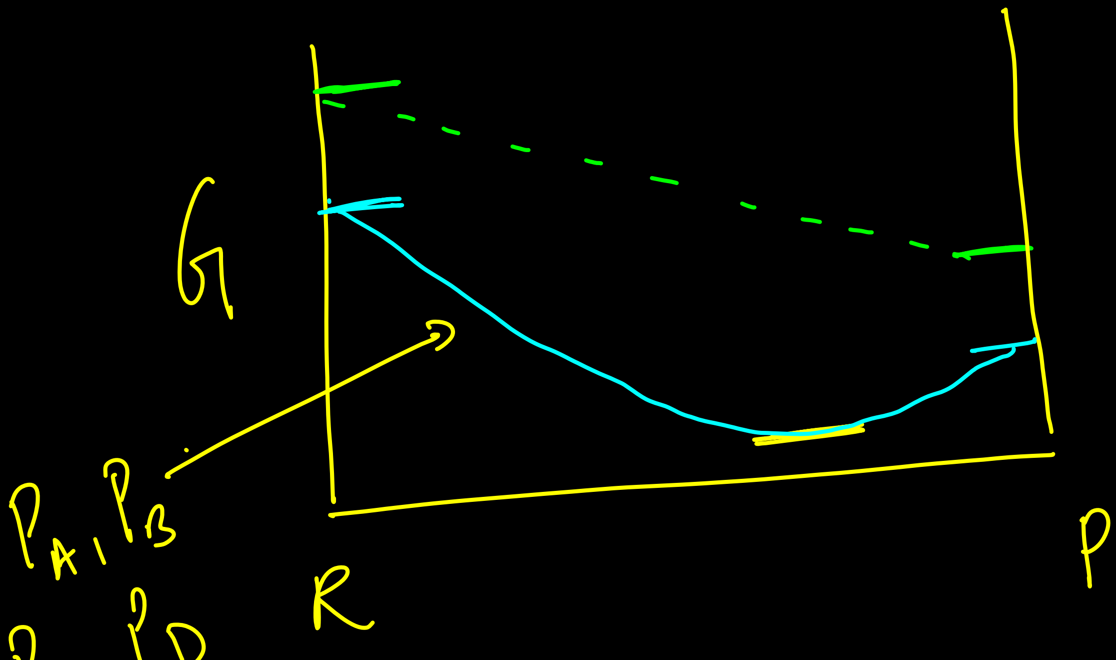
$$= \underbrace{\mu_A^\ominus(T) + RT\ln P_T} + RT\ln x_A$$

$$\mu_A(\text{mix}, T, P_T) = \mu_A(\text{pure}, T, P_T) + RT\ln x_A$$

$$\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftharpoons NH_3$$

T, P

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$



$$\boxed{A} + \boxed{B} \rightleftharpoons \boxed{C} + \boxed{D}$$

$$\boxed{A + B} \rightleftharpoons \boxed{A + B + C + D}$$

$$G_1 = a\mu_A + b\mu_B + c\mu_C + d\mu_D$$

$$G_2 = (a - \varepsilon a)\mu_A + (b - \varepsilon b)\mu_B + (c + \varepsilon c)\mu_C + (d + \varepsilon d)\mu_D$$

$$\Delta G(\varepsilon) = \varepsilon\left[c\mu_C + d\mu_D - (a\mu_A + b\mu_B)\right]$$

$$\left(\frac{\partial G}{\partial p}\right)_T \longrightarrow \mu(T) = \mu^\circ(T) + RT \ln p/p^\ominus$$

$$\Delta G(\varepsilon) = \varepsilon \left[c\mu_C^\ominus + d\mu_D^\ominus - (a\mu_A^\ominus + b\mu_B^\ominus) + RT \ln \frac{p_C^c\, p_D^d}{p_A^a\, p_B^b} \right]$$

$$\frac{p_C^c\, p_D^d}{p_A^a\, p_B^b} = Q$$

$$\Delta G = \Delta G^\ominus_{rxn} + RT \ln Q$$

reaction quotient

At eq.

$$\Delta G^\ominus_{rxn} = -RT \ln Q_{eq.}$$

$$Q_{eq} = K_p$$

$$\Delta G^{\ominus}_{rxn} = -RT \ln K_p$$

$$K_p = e^{-\frac{\Delta G^{\ominus}_{rxn}}{RT}}$$

$$K_p = \frac{P_C^{\,c}\, P_D^{\,d}}{P_A^{\,a}\, P_B^{\,b}} = P_T^{\,c+d-a-b}\ \frac{X_C^{\,c}\, X_D^{\,d}}{X_A^{\,a}\, X_B^{\,b}}$$

$$= P^{\Delta\nu} K_X$$

$$K_x = P^{-\Delta\nu} K_p$$

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

initial	n	0
at eq.	$n-x$	$2x$
	$\frac{n-x}{n+x}$	$\frac{2x}{n+x}$

$$K_p = \frac{p_{NO_2}^2}{p_{N_2O_4}} = P\frac{X_{NO_2}^2}{X_{N_2O_4}} = P\frac{4x^2}{n^2-x^2}$$

Extent of reaction = $\alpha = x/n$

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

$$\alpha = \left[1 + \frac{4P}{K_p}\right]^{-1/2}$$

Le Chatelier's principle for pressure

$$\ln K_p(T) = -\frac{\Delta G^\ominus}{RT}$$

$$\frac{d\ln K}{dT} = \frac{d\left(-\frac{\Delta G^\ominus}{RT}\right)}{dT} = \frac{\Delta G^\ominus}{RT^2} - \frac{1}{RT}\frac{d\Delta G^\ominus}{dT}$$

$$\left(\frac{\partial \Delta G^\ominus}{\partial T}\right)_{P=1\,\text{bar}} = -\Delta S^\ominus(T)$$

$$\frac{\Delta H^\ominus - \cancel{T\Delta S^\ominus}}{RT^2} + \cancel{\frac{1}{RT}\Delta S^\ominus}$$

$$\boxed{\frac{d\ln K}{dT} = \frac{\Delta H^\ominus}{RT^2}}$$

van't Hoff equation

$$\ln K_2 - \ln K_1 = \int_{T_1}^{T_2} \frac{\Delta H^\ominus}{RT^2}\, dT$$

$$\Delta H^\ominus(T_2) = \Delta H^\ominus(T_1) + \Delta C_p (T_2 - T_1)$$

$$\ln K_2 = \ln K_1 + \frac{\Delta H^\ominus}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

$$\frac{1}{2} N_2 (g, T, p) + \frac{3}{2} H_2 (g, T, p) \rightleftharpoons NH_3 (g, T, p)$$

$$\Delta H^{\ominus}_{rxn} (298\ K) = -46.21\ kJ\ mol^{-1}$$

$$\Delta G^{\ominus}_{rxn} (298\ K) = -16.74\ kJ\ mol^{-1}$$

$$K_p = \frac{p_{NH_3}}{p_{H_2}^{3/2}\ p_{N_2}^{1/2}} = p^{-1} \frac{x_{NH_3}}{x_{H_2}^{3/2}\ x_{N_2}^{1/2}} = e^{-\Delta G^{\ominus}/RT}$$

$$= 860$$

$800\ K \rightarrow K_p = 0.007$

$K_x = p K_p$

100 bar $K_x = 0.7$

Gerhard Ertl

$$\mu_A(T, P, C_A) = \mu_A^{\ominus}(T, P) + RT \ln C_A$$

std. conc.

$$[A]$$

$$K_{eq} = K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

$$aA(s) + bB(g) \rightleftharpoons cC(l) + dD(g)$$

$$\Delta G = \underbrace{c\mu_C^\circ + d\mu_D^\circ - a\mu_A^\circ - b\mu_B^\circ}_{\Delta G^\ominus_{rxn}} + RT \ln \frac{P_D^{\,d}}{P_B^{\,b}}$$

$$+ \; RT \ln Q_{eq}$$