$$\left(\frac{\partial G}{\partial T}\right)_p = -S$$

$$\left(\frac{\partial G}{\partial p}\right)_T = V$$

AT CONSTANT T $\quad dG = -S\,dT + V\,dP$

$$G(T,P) - G(T,P^\circ) = \int_{p^o}^{p} V\,dP$$

FOR SOLIDS AND LIQUIDS

$$G(T,P) \simeq G(T,P^\circ) + V(P - P_o)$$

FOR GASES

IDEAL

$$G(T,P) \simeq G(T,P^\circ) + \int_{p^o}^{p} \frac{nRT}{p'}\,dp'$$

$$G(T,p) = G(T,p^{\circ}) + nRT\ln\left(\frac{p}{p^{\circ}}\right) \qquad \boxed{T\text{ CONST}}$$

$$\left(\frac{\partial\, G/T}{\partial T}\right)_p = \frac{1}{T}\left(\frac{\partial G}{\partial T}\right)_p - \frac{1}{T^2}G$$

$$= -\frac{S}{T} - \frac{G}{T^2} = -\frac{G+TS}{T^2}$$

$$= -\frac{H}{T^2}$$

$$d\left(\frac{\Delta G}{T}\right) = -\Delta H\frac{dT}{T^2} \simeq +d\left(\frac{\Delta H}{T}\right)$$

ΔH TEMP INDEPENDENT

$$\boxed{\frac{\Delta G(T_2)}{T_2} - \frac{\Delta G(T_1)}{T_1} = \Delta H(T_1)\left[\frac{1}{T_2} - \frac{1}{T_1}\right]}$$

CHEMICAL RXN

$$G(T, P, n_1, n_2, \dots, n_N)$$

$$dG = \left(\frac{\partial G}{\partial T}\right)_{P, n_1, n_2 \cdots n_N} dT + \left(\frac{\partial G}{\partial P}\right)_{T, n_1, n_2 \cdots n_N} dP$$

$$+ \left(\frac{\partial G}{\partial n_1}\right)_{T, P, n_2, \cdots n_N} dn_1 + \left(\frac{\partial G}{\partial n_2}\right)_{T, P, n_1, n_3 \cdots n_N} + \cdots +$$

$$\left(\frac{\partial G}{\partial n_N}\right)_{T, P, n_1, n_2 \cdots n_{N-1}} dn_N$$

DEF CHEMICAL POTENTIAL

$$\mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T, P, n_j \cdots n_N} \qquad n_j \neq n_i$$

$$dG = \left(\frac{\partial G}{\partial T}\right)_{P, n_1, n_2 \cdots n_N} dT + \left(\frac{\partial G}{\partial P}\right)_{T, n_1, \cdots n_N} dP + \sum_i \mu_i dn_i$$

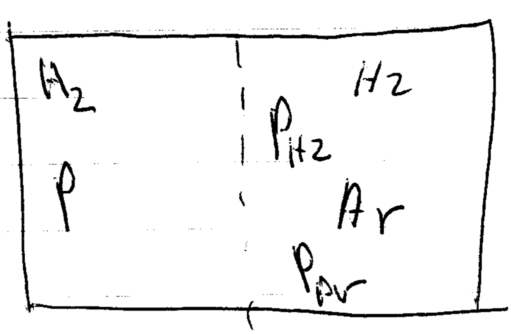
AT CONSTAT (T, P)

$$dG = \sum_i \mu_i \, dn_i$$

$$\int_0^G dG' = G = \sum_i \int_0^{n_i} \mu_i \, dn_i$$

$$\boxed{G = \sum_i n_i \mu_i}$$

μ_i is the molar Gibbs energy



$$\mu_{H_2}^{PURE} = \mu_{H_2}^{MIX}$$

FOR AN IDEAL GAS

$$\mu_{H_2}^{Pure}(T, P_{H_2}) = \mu_{H_2}^{o}(T, P^o) + RT \ln\left(\frac{P_{H_2}}{P^o}\right) = \mu_{H_2}^{Mix}(T, P)$$

But $\quad p^L_{H_2} = p^R_{H_2} = X_{H_2} P$

$$\mu^{mix}_{H_2}(T,P) = \mu^{o}_{H_2}(T,P^o) + RT\ln\left(\frac{P}{P_o}\right) + RT\ln X_{H_2}$$

$$\boxed{\mu^{mix}_{H_2}(T,P) = \mu^{pure}_{H_2}(T,P) + RT\ln X_{H_2}}$$

IN THE CASE OF FOUR GASES Xe, Ar, Ne, He

INITIAL CONDITION BEFORE MIXING

$$G_i = n_{He}\mu^{pure}_{He} + n_{Ne}\mu^{pure}_{Ne} + n_{Ar}\mu^{pure}_{Ar} + n_{Xe}\mu^{pure}_{Xe}$$

$$G_f = n_{He}\mu^{mix}_{He} + n_{Ne}\mu^{mix}_{Ne} + n_{Ar}\mu^{mix}_{Ar} + n_{Xe}\mu^{mix}_{Xe}$$

$$\Delta G_{mix} \equiv G_f - G_i$$

$$\boxed{\Delta G_{mix} = RT \sum_i n_i \ln X_i} < 0$$

$X_i < 1$

MIXING IS AN SPONTANEOUS PROCESS

$$-\left(\frac{\partial \Delta G_{mix}}{\partial T}\right)_p = \Delta S_{mix} = -R \sum_i n_i \ln X_i > 0$$

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

FOR IDEAL GASES OR IDEAL SOLUTIONS

$$\Delta G_{mix} = -T \Delta S_{mix}$$

$$\Rightarrow \quad \Delta H_{mix} = 0$$

$\boxed{\text{CHEMICAL RXN}}$

$$aA + bB + cC \rightleftharpoons xX + yY$$

AN INFINITESIMAL CHANGE =>

$$dG = \sum_i \mu_i \, dn_i$$

LET US DEFINE THE EXTENT OF REACTION

ξ AS

$$n_i = n_i^{\text{INITIAL}} + \nu_i \xi$$

$$dn_i = \nu_i \, d\xi$$

$$\Rightarrow \quad dG = \left(\sum_i \nu_i \mu_i \right) d\xi$$

$$\left(\frac{\partial G}{\partial \xi} \right)_{T,P} = \sum_i \nu_i \mu_i \equiv \Delta G_{rxn}$$

REMEMBER THAT

$$\mu_i^{\text{MIX}}(T, P) = \mu_i^{0}(T, P^0) + RT \ln\left(\frac{P_i}{P^0}\right)$$

$$\Delta G_{rxn} = \sum_i \nu_i \mu^{\circ}_{(T, p^{\circ})} + \sum_i \nu_i RT \ln\left(\frac{p_i}{p^{\circ}}\right)$$

$$\boxed{\Delta G_{rxn} \equiv \Delta G^{\circ}_{rxn} + \sum_i \nu_i RT \ln(p_i/p^{\circ})}$$

SINCE WE ONLY NEED ΔG°_{rxn}

WE CAN PICK ANY "ZERO" POINT AND

DEFINE $\Delta G^{\circ}_f(T, p^{\circ})$

WHICH, AS IN THE CASE OF ΔH°_f, IS

ZERO FOR THE ELEMENTS AT IS STANDARD STATE.

$$\Delta G^{\circ}_{rxn} = \sum_i \nu_i \Delta G^{\circ}_f[i]$$

$$\boxed{\Delta G_{rxn} = \Delta G^{\circ}_{rxn} + RT \sum_i \nu_i \ln\left(\frac{p_i}{p^{\circ}}\right)}$$

$$\Delta G_{rxn} = \Delta G^{\circ}_{rxn} + RT \sum_i \ln\left(\frac{p_i}{p^{\circ}}\right)^{\nu_i}$$

$$aA + bB \longrightarrow xX + yY$$

$$\Delta G_{rxn} = x\mu_X + y\mu_Y - a\mu_A - b\mu_B$$

$$= x\mu_X^o + y\mu_Y^o - a\mu_A^o - b\mu_B^o$$

$$+ xRT\ln\left(\frac{P_X}{P^o}\right) + yRT\ln\left(\frac{P_Y}{P^o}\right)$$

$$- aRT\ln\left(\frac{P_A}{P^o}\right) - bRT\ln\left(\frac{P_B}{P^o}\right)$$

$$= \sum_i \nu_i \mu_i^o + RT\ln\left\{\frac{\left(\frac{P_X}{P^o}\right)^x \left(\frac{P_Y}{P^o}\right)^y}{\left(\frac{P_A}{P^o}\right)^a \left(\frac{P_B}{P^o}\right)^b}\right\}$$

$$\boxed{\Delta G_{rxn} \equiv \Delta G^o_{rxn} + RT\ln Q}$$

AT EQUILIBRIUM

$$\Delta G_{rxn} = 0$$

$$0 \equiv \Delta G^o_{rxn} + RT\ln K_p$$

$$P_i = X_i P_T \implies \frac{P_i}{p^\circ} = X_i \frac{P_T}{p^\circ}$$

$$K_p \equiv \frac{\left(\frac{P_X^{eq}}{p^\circ}\right)^x \left(\frac{P_Y^{eq}}{p^\circ}\right)^y}{\left(\frac{P_A^{eq}}{p^\circ}\right)^a \left(\frac{P_B^{eq}}{p^\circ}\right)^b}$$

$$= \frac{X_X^x X_Y^y}{X_A^a X_B^b} \left(\frac{P_T}{p^\circ}\right)^{x+y-a-b}$$

$$\boxed{K_p = K_x \left(\frac{P_T}{p^\circ}\right)^{\Delta\nu}}$$

$$PV = nRT$$

$$\frac{P}{p^\circ} = \frac{n}{V}\frac{RT}{p^\circ} = \frac{c_i}{c^\circ}\frac{c^\circ RT}{p^\circ}$$

$$K_p = K_c \left(\frac{c^\circ RT}{p^\circ}\right)^{\Delta\nu}$$

$$a\,A(s) + b\,B(l) \longrightarrow x\,X(g)$$

$$\Delta G_{rxn} = x\mu_X - a\mu_A - b\mu_B$$

$$\mu_X = \mu_X^0 + RT\ln\left(\frac{P_X}{P^0}\right)$$

$$\mu_A \simeq \mu_A^0$$

$$\mu_B \simeq \mu_B^0$$

$$\Delta G_{rxn} = \Delta G_{rxn}^0 + RT\ln\left(\frac{P_X}{P^0}\right)^x$$

$$0 = -RT\ln K_p + RT\ln\left(\frac{P_X^{eq}}{P^0}\right)^x$$

$$\ln K_p = \ln\left(\frac{P_X^{eq}}{P^0}\right)^x$$

$$\boxed{K_p = \left(\frac{P_X^{eq}}{P^0}\right)^x}$$