

Derive Equilibrium Constant

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For fixed temperature and pressure the equilibrium condition is

$$\Delta \bar{g}_r(T, P) = 0$$

Equilibrium state given by

$$\begin{aligned}\Delta \bar{g}_r(T, P) &= - \sum_{react.} v_i \bar{g}_i(T, P_i) + \sum_{prod.} v_i \bar{g}_i(T, P_i) \\ &= \sum_{i=1}^{KK} (v_i'' - v_i') \bar{g}_i(T, P_i) = 0\end{aligned}$$

$$P_i = X_i P$$

$$\bar{g}_i(T, P_i) = \bar{h}_i(T, P_i) - T \bar{s}_i(T, P_i) \quad \bar{s}_i(T, P_i) = \left[\bar{s}_i^0(T) - R_u \ln \left(\frac{P_i}{P^0} \right) \right]$$

$$\bar{g}_i^0(T) = \bar{h}_i^0(T) - T \bar{s}_i^0(T)$$

$$\bar{g}_i(T, P_i) = \bar{g}_i^0(T) + R_u T \ln \left(\frac{P_i}{P^0} \right)$$

$$\Delta \bar{g}_r(T, P) = \Delta \bar{g}_r^0(T) + R_u T \left[\sum_{i=1}^{KK} (v_i'' - v_i') \ln \left(\frac{P_i}{P^0} \right) \right] = 0$$

$$\frac{-\Delta \bar{g}_r^0(T)}{R_u T} = \sum_{i=1}^{KK} \ln \left(\left(\frac{P_i}{P^0} \right)^{(v_i'' - v_i')} \right) = \ln \left[\prod_{i=1}^{KK} \left(\frac{P_i}{P^0} \right)^{(v_i'' - v_i')} \right]$$

$$K_p = \prod_{i=1}^{KK} \left(\frac{P_i}{P^0} \right)^{(v_i'' - v_i')} = \exp \left[\frac{-\Delta \bar{g}_r^0(T)}{R_u T} \right]$$

$$\frac{k_f(T)}{k_r(T)} = K_c(T)$$

$$K_c(T) = \prod_{i=1}^N c_i^{(v_i'' - v_i')} \quad c_i = \frac{P_i}{R_u T} = \frac{P_i}{P^0} \frac{P^0}{R_u T}$$

$$K_c(T) = \left(\frac{P^0}{R_u T} \right)^{\sum_{i=1}^N (v_i'' - v_i')} * K_p = \left(\frac{P^0}{R_u T} \right)^{\sum_{i=1}^N (v_i'' - v_i')} \exp \left[\frac{-\Delta \bar{g}_r^0(T)}{R_u T} \right]$$

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