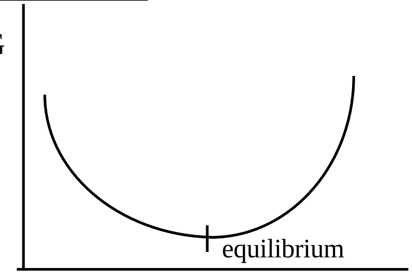
Gibbs Free Energy and Chemical Equilibrium



reaction progress

What is $\Delta_r G$ under non-standard conditions?

$$a\ A(P_A) + b\ B(P_B) \rightleftarrows e\ E(P_E) + f\ F(P_F)$$

$$\mu_A = \mu_A^{\Theta} + RT \ln(P_A/p^{\Theta})$$

$$-\frac{dn_A}{a} = -\frac{dn_B}{b} = \frac{dn_E}{e} = \frac{dn_F}{f} = d\xi$$

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at constant T and P $\quad dG = \mu_E\, dn_E + \mu_F\, dn_F + \mu_A\, dn_A + \mu_B\, dn_B$

$$dG = (e\,\mu_E + f\,\mu_F - a\,\mu_A - b\,\mu_B)\, d\xi$$

$$\int dG = \int_0^1 (e\,\mu_E + f\,\mu_F - a\,\mu_A - b\,\mu_B)\, d\xi$$

$$\Delta_r G = e\,\mu_E + f\,\mu_F - a\,\mu_A - b\,\mu_B$$

$$\Delta_r G = e\left(\mu_E^{\Theta} + RT\ln(P_E/p^{\Theta})\right) + f\left(\mu_F^{\Theta} + RT\ln(P_F/p^{\Theta})\right) - a\left(\mu_A^{\Theta} + RT\ln(P_A/p^{\Theta})\right) - b\left(\mu_B^{\Theta} + RT\ln(P_B/p^{\Theta})\right)$$

$$\Delta_r G = e\mu_E^{\Theta} + f\mu_F^{\Theta} - a\mu_A^{\Theta} - b\mu_B^{\Theta} + RT\left(e\ln(P_E/p^{\Theta}) + f\ln(P_F/p^{\Theta}) - a\ln(P_A/p^{\Theta}) - b\ln(P_B/p^{\Theta})\right)$$

$$\Delta_r G = \Delta_r G^{\Theta} + RT \ln\left(\frac{(P_E/p^{\Theta})^e (P_F/p^{\Theta})^f}{(P_A/p^{\Theta})^a (P_B/p^{\Theta})^b}\right)$$

$$\Delta_r G = \Delta_r G^{\Theta} + RT \ln Q$$

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at equilibrium

$$\Delta_r G^{\Theta} = -RT \ln Q_{eq} = -RT \ln K_p$$

$$K_p = \left(\frac{(P_E/p^{\Theta})^e (P_F/p^{\Theta})^f}{(P_A/p^{\Theta})^a (P_B/p^{\Theta})^b}\right)_{eq}$$

$$\Delta_r G = RT \ln \frac{Q}{K_p}$$