$$\beta \frac{df_{free}}{d\phi_A} = \frac{1}{2}\frac{dy}{d\phi_A}\left(\frac{1}{y(y+1)} - \frac{\ln(y+1)}{y^2}\right)\sum_S \frac{\phi_S y_S}{v_S} + \frac{1}{2}\sum_S \frac{d\phi_S}{d\phi_A}\frac{1}{v_S}\left[\frac{y_S}{y}\ln(1+y) - \ln(1+y_S)\right] + \sum_S \frac{d\phi_S}{d\phi_A}\frac{1+ln\phi_S}{v_S}$$

$$\beta \frac{d^2 f_{free}}{d\phi_A{}^2} = \frac{dy}{d\phi_A}\left(\frac{1}{y(y+1)} - \frac{\ln(y+1)}{y^2}\right)\sum_S \frac{y_S}{v_S} * \frac{d\phi_S}{d\phi_A} + \frac{1}{2}\left(\frac{dy}{d\phi_A}\right)^2\left(\frac{2\ln(y+1)}{y^3} - \frac{2+3y}{(y+y^2)^2}\right)\sum_S \frac{\phi_S y_S}{v_S} + \sum_S \frac{1}{v_S \phi_S}$$

For 2 substances (A and B):

$$\frac{dy}{d\phi_A} = (y_A - y_B)$$

$$\frac{d\phi_S}{d\phi_A} = \pm 1$$