1. (35 pts) A binary system at $T = 72^\circ C$ obeys the Van Laar model for excess Gibbs energy, where the activity coefficients are given by

$$RT \ln \gamma_1 = A \left( \frac{Bx_2}{Ax_1 + Bx_2} \right)^2 \quad \text{and} \quad RT \ln \gamma_2 = B \left( \frac{Ax_1}{Ax_1 + Bx_2} \right)^2$$

At this temperature the fugacity of pure liquid components are $f_1^{liq} = P_{sat,1} = 80 \text{ kPa}$ and $f_2^{liq} = P_{sat,2} = 40 \text{ kPa}$, respectively. The activity coefficients at infinite dilution are given by $\gamma_1^{\infty} = 0.5$ and $\gamma_2^{\infty} = 0.72$. Assuming that the fugacity coefficients of each substance are given by $\hat{\phi}_1 = 0.75$ and $\hat{\phi}_2 = 0.88$ in the vapor phase. Determine the vapor composition corresponding to $x_1 = 0.6$.

2. (30 pts) The excess Gibbs energy for a binary mixture of substance $a$ and $b$ at temperature $T$ and pressure $P$ is given by

$$g^E = RT \left[ Ax_a \ln(x_b) + Bx_b \ln(x_a) \right]$$

Where $A$ and $B$ are constant parameters. Obtain the formula for activity coefficients $\gamma_a$ as a function of $T$, $x_a$ and $x_b$.

3. (35 pts) A binary gas mixture has an equation of state given by

$$\frac{P_v}{RT} = 1 + (A\gamma_a + B\gamma_b)^2 P$$

where

$$A = \left( \frac{1}{5} \right) \text{bar}^{-1/2} \quad \text{and} \quad B = \left( \frac{1}{7} \right) \text{bar}^{-1/2}$$

Obtain the equation for $\hat{\phi}_a$ at $\gamma_a = 0.4$ and $P = 10 \text{ bar}$. 