1. (35 pts) At $T = 400\, K$ and pressure $P$, a liquid mixture containing 25 mol% $A$ and 75 mol%$B$ is in equilibrium with a vapor phase that behaves as an ideal gas. The excess Gibbs energy of the liquid mixture is given by

$$g^E = \frac{x_A x_B}{\alpha x_A + \beta x_B}$$

where $\alpha = 0.15\, \text{mol kJ}^{-1}$ and $\beta = 0.30\, \text{mol kJ}^{-1}$. The fugacities of pure liquid $A$ and pure liquid $B$ at this temperature and pressure were found to be $f_A^{\text{liq}} = 2\, \text{bar}$ and $f_B^{\text{liq}} = 0.8\, \text{bar}$. Determine the composition of the vapor phase.

2. (30 pts) A binary gas mixture follows an equation of state given by

$$\frac{P_v}{RT} = 1 + (a y_A^2 + b y_A y_B + c y_B^2)P + \epsilon P^2$$

where $a$, $b$, $c$ and $\epsilon$ are constants. Obtain the equation for fugacity coefficient $\hat{\phi}_A$ in terms of $T$, $P$, $y_A$, $y_B$, and the constants $a$, $b$, $c$, and $\epsilon$.

3. (35 pts) The molar mixing change in Gibbs energy at $T = 420\, K$ and $P = 1\, \text{bar}$ for a liquid mixture containing $A$ and $B$ was found to be

$$\Delta g_{\text{mix}} = (20x_A + 10x_B - 2x_A x_B) \frac{J}{\text{mol}}$$

Determine the activity coefficient $\gamma_B$ when $x_A = 0.3$. 