1. The molar volume of a binary liquid mixture as a function of $x_1$ is given by
   \[ v(x_1) = 5.33x_1^2 - 3.33x_1 + 20 \]
   a) (15 pts) What is $\bar{V}_2$ at $x_1 = 0.2$? (Hint: you can use the slope-intercept equation for partial molar properties.)
   b) (15 pts) Show that $\bar{V}_1$ as a function of $x_1$ is given by
   \[ \bar{V}_1(x_1) = -5.33x_1^2 + 10.66x_1 + 16.67 \]

2. (35) A binary system at $T = 50^\circ C$ obeys the Margules 3-suffix rule, where the activity coefficients are given by
   \[ RT \ln \gamma_1 = x_2^2 (A_{12} + 2(A_{21} - A_{12})x_1) \]
   \[ RT \ln \gamma_2 = x_1^2 (A_{21} + 2(A_{12} - A_{21})x_2) \]
   where $A_{12} = 1 \frac{J}{mol}$ and $A_{21} = 0.5 \frac{J}{mol}$. Assume that the liquid fugacities of pure substance 1 and 2 at this temperature are $f_1 = P_{sat,1} = 40 \text{ kPa}$ and $f_2 = P_{sat,2} = 90 \text{ kPa}$, respectively. Further, assume that the vapor phase in equilibrium with the liquid phase behaves as an ideal gas. Determine the vapor composition corresponding to $x_1 = 0.15$.

3. (35 pts) 100 moles/min of a binary liquid mixture at $T = 25^\circ C$ containing 25 mole% of substance 1 and 75 mole % substance 2 is to mixed with 20 moles/min of pure substance 2 also at $T = 25^\circ C$. Assume that the heat of mixing at $T = 25^\circ C$ is given by the following equation
   \[ \Delta_{mix}h = 2400x_1x_2 \frac{J}{mol} \]
   Determine the rate of heating or cooling (specify which) to maintain the output at $T = 25^\circ C$. 
