Problem 1 (4 pts)

\[ T \]

\[ T_{AS} \]

A(\ell) + B(l)

B(s) + AB_x(s)

AB_x(s) + A(s)

\[ X_e = \text{eutectic composition} \]
Problem 2 (4 pto)

\[ A(l) + B(l), \quad p = 1 \]

\[ A(l) + B(l), \quad p = 2 \]

\[ A_2B_2(s) + \quad AB_2(s), \quad p = 2 \]

\[ X_A \rightarrow \]

\[ X_B \rightarrow \]
(a) At 500°C, both A and B are liquids and, based on the phase diagram, are completely miscible. Thus, B is 100% soluble in A.

(b) At 390°C, the solubility of AB₂ in A will be given by the eutectic composition. Thus, the solubility is \( x_B \approx 0.2 \Rightarrow x_A = 0.8 \).

(c) At 300°C, the solubility of AB₂ in B will be at \( x_B \approx 0.6 \).

Note: This problem was not a very clean, well posed problem. No credit will be taken off for this problem.
Problem 4 (4 pts)

During a phase transition in an isolated system
\[ U_\alpha + U_\beta = \text{constant} \quad (1\text{st law}) \quad \alpha, \beta \text{ are different phases} \]
\[ V_\alpha + V_\beta = \text{constant} \quad \text{(assuming no work)} \]
\[ dS = dS_\alpha + dS_\beta = 0 \]
\[ n_\alpha + n_\beta = \text{constant} \]

Thus, since
\[ dS = \frac{1}{T} \ dU + \frac{P}{T} \ dV - \frac{\mu}{T} \ dn \]
we obtain
\[ dS_\alpha + dS_\beta = \frac{1}{T_\alpha} \ dU_\alpha + \frac{1}{T_\beta} \ dU_\beta + \frac{P_\alpha}{T_\alpha} \ dV_\alpha + \frac{P_\beta}{T_\beta} \ dV_\beta - \frac{\mu_\alpha}{T_\alpha} \ dn_\alpha - \frac{\mu_\beta}{T_\beta} \ dn_\beta \]
\[ = 0 \]

Using
\[ dU_\alpha = -dU_\beta \quad dV_\alpha = -dV_\beta \quad dn_\alpha = -dn_\beta \]
gives
\[ \left( \frac{1}{T_\alpha} - \frac{1}{T_\beta} \right) dU_\alpha + \left( \frac{P_\alpha}{T_\alpha} - \frac{P_\beta}{T_\beta} \right) dV_\alpha - \left( \frac{\mu_\alpha}{T_\alpha} - \frac{\mu_\beta}{T_\beta} \right) dn_\alpha = 0 \]

This statement is true if and only if
\[ T_\alpha = T_\beta, \quad P_\alpha = P_\beta, \quad \text{and} \quad \mu_\alpha = \mu_\beta. \]
Problem 5 (4 pts)

Fig. 1 gives the temperature composition diagram of N,N-dimethylacetamide in heptane plotted as a function of N,N-dimethylacetamide mole fraction.

(b) If \( \frac{x_A}{1.00} = 0.750 \) and \( x_B = 0.250 \) where \( A \equiv \text{N,N-dimethylacetamide} \) and \( B \equiv \text{heptane} \), then the dashed line indicates the area of interest for this problem.

At 296 K,

\[
x_f = 0.168 \quad \text{and} \quad x_2 = 0.804
\]

The proportions of the two phases are given by the lever rule, or

\[
\frac{n_A}{n_B} = \frac{dx_B}{dx_f} = \frac{(0.804 - 0.750)}{(0.750 - 0.168)} = 0.093
\]

Thus there is only 9.3\% of the heptane rich phase. The remainder of the solution consists of the N,N-dimethylacetamide rich phase.

For the given composition, the solution will become single phase at 303.07 K.
Fig. 1. The liquid-liquid coexistence curve of N,N-dimethylacetamide in heptane plotted as a function of N,N-dimethylacetamide mole fraction $x$. (●) represents the N,N-dimethylacetamide in the upper phase while (■) is the N,N-dimethylacetamide in the lower phase of the two phase region.