Soft Matter Exercise - Chapter 6: Phase Transitions

1. Spinodal Decomposition

a. Draw the Gibbs free energy as a function of the composition of a binary mixture that separates if cooled below the critical temperature for $T_1 < T_c$.
b. Draw a phase diagram that contains the data points that can be extracted from the Gibbs free energy graph you plotted in (a).
c. Indicate the compositions of the two phases formed at T_1 in the Gibbs free energy diagram you made in (a) and in the phase diagram you made in (b).
d. What is spinodal decomposition and when does it occur?
e. If spinodal decomposition occurs, why can chemical species (e.g. atoms, molecules, or ions) diffuse in the opposite direction to their concentration gradient?
f. Sketch the microstructures of polymer mixtures that underwent spinodal and binodal decomposition respectively. What is different between the two?

2. Solubility

The value of χ between water and linear hydrocarbons may be approximated as $\chi = 3.04+1.37n_C$ where n_C is the number of carbons contained in the hydrocarbon chain. Calculate the solubility of the following in water at 25°C:
a. Hexane
b. Octane
c. Dodecane

3. Phase Diagram of a Liquid Mixture

The phase behavior of a polymer solution can be described by the regular solution model, with the interaction parameter being $\chi = 600$ K/T, where T is the temperature.
a. Calculate the temperature at the critical point.
b. Does the system phase separate at 273 K?
c. Calculate the volume fractions of the two existing co-phases at 5°C.
d. What would change if you had a polymer with 1000 repeat units dissolved in a solvent? Would the interaction parameter change? Why or why not?

4. Phase Diagram of a Polymer Mixture

You prepare a mixture of two polymers whose critical compositon is $\phi_{c,1} = 0.4$. You prepare the mixture above the critical temperature, where the two phases are soluble, and then subsequently cool the mixture below the temperature of the critical point. Describe the microstructure of a mixture composed of:
a. $\phi_1 = 0.3$ and $\phi_2 = 0.7$
b. $\phi_1 = 0.4$ and $\phi_2 = 0.6$
c. What is $\phi_{c,1}$ of an ideal solution? Why can it be different for polymer solutions?