Qualify Exam

Chemical Engineering Thermodynamics

Part (I) Undergraduate level (50%)

1. List the complete energy balance equation for an open system, and explain the physical meanings term by term. (10 %)

2. Qualitatively draw a phase diagram in the $P-T$ plane for a pure substance. Indicate each of the following items on the graph: (a) liquid phase region; (b) vapor phase region; (c) solid phase region; (d) vapor pressure curve; (e) sublimation pressure curve; (f) melting curve; (g) critical point; (h) triple point. (8 %)

3. The enthalpy changes on mixing of triethylamine (EA)-benzene (B) system at 298.15 K are given by

$$H_m - [x_B H_B + (1 - x_B) H_{EA}] = x_B (1 - x_B) \left[ 1418 - 482.4(1 - 2x_B) + 187.4(1 - 2x_B)^2 \right]$$

where $x_B$ is the mole fraction of benzene and $H_m$, $H_B$, and $H_{EA}$ are the molar enthalpies of the mixture, pure benzene, and pure triethylamine, respectively, with units of J/mol.

(a) Calculate value for $\overline{H_B} - \overline{H_B}$ at $x_B = 0.5$, where $\overline{H_B}$ is the partial molar enthalpy of benzene. (6 %)

(b) One mole of a 25 mol % benzene mixture ($x_B = 0.25$ & $x_{EA} = 0.75$) is to be mixed with one mole of a 75 mol % benzene mixture ($x_B = 0.75$ & $x_{EA} = 0.25$) at 298.15 K. How much heat must be added or removed for the process to be isothermal? (6 %)

4. The sublimation pressure of ice ($P_{\text{sub}}$) and the vapor pressure of water ($P_{\text{vap}}$) varying with temperature can be expressed, respectively, by the following two equations:

$$\ln P_{\text{sub}} \ (\text{Pa}) = 28.8926 - 6140.1 / T \ (\text{K})$$

$$\ln P_{\text{vap}} \ (\text{Pa}) = 26.3026 - 5432.8 / T \ (\text{K})$$

(a) If a closed vessel contains water-ice-steam simultaneously, what is the degree of freedom of this system? (5 %)

(b) Calculate the coexisting temperature and pressure of this three-phase system. (10 %)

(c) Calculate the heat of fusion at the triple point of water. (5 %)
Part (II) Graduate level (50%)

1. A close container is maintained at a temperature of 80°C. Then, a binary gas mixture is introduced to the system until the pressure in the container reaches 60 bar. If, the gas mixture contains 35 mol % of gas A, and 65 % of gas B and the fugacity coefficients of A is 0.71, and B is 0.86, what is the fugacity of the gaseous mixture in the container? (20 %)

2. Suppose that you have P-x-y data, what kind of method would you use to know whether these data are thermodynamic consistent or not? (15 %)

3. The \( P = P(v,T) \) equation of state for a gas is given by virial equation of state
\[
\frac{Pv}{RT} = 1 + \frac{B}{v} + \frac{C}{v^2}.
\]
Derive the expression for the internal energy function \( U = U(T,v) \) and for entropy function \( S = S(T,v) \). (15 %)