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

$$\underline{H}_m - [x_B \underline{H}_B + (1-x_B)\underline{H}_{EA}] = x_B(1-x_B)\{1418 - 482.4(1-2x_B) + 187.4(1-2x_B)^3\}$$

where x_B is the mole fraction of benzene and $\underline{H}_m$, $\underline{H}_B$, and $\underline{H}_{EA}$ are the molar enthalpies of the mixture, pure benzene, and pure triethylamine, respectively, with units of J/mol.

(a) Calculate value for $\left(\overline{H}_B - \underline{H}_B\right)$ 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^{sub}) and the vapor pressure of water (P^{vap}) varying with temperature can be expressed, respectively, by the following two equations:

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

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

(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 %)