Chemical Engineering Thermodynamics II

Worksheet – III and IV

Submission Date: 22-May-2018

1. Starting with the fact that for a spontaneous process $\Delta S^{total} = \Delta S^{sys} + \Delta S^{sur} \geq 0$, derive criterion for equilibrium of a closed system at constant temperature and pressure.
2. Assuming validity of Raoult's law for benzene (1)/toluene (2) system, calculate the following: (Iterate till the two successive temperature values are within 1%.)
   a. y_1 and P given $x_1 = 0.33$ and T = 100 ^{0}C
   b. x_1 and P given $y_1 = 0.33$ and T = 100 ^{0}C
   c. y_1 and T given $x_1 = 0.33$ and P = 120 kPa
   d. x_1 and T given $y_1 = 0.33$ and P = 120 kPa.

$$\ln P_i^{sat}/kPa = A_i - \frac{B_i}{T/^oC + C_i};$$

$$A_1 = 13.8594; \quad B_1 = 2773.78; \quad C_1 = 220.07$$

$$A_2 = 14.0098; \quad B_2 = 3103.01; \quad C_2 = 219.79$$

3. A process stream contains light species 1 and heavy species 2. A relatively pure liquid stream containing mostly 2 is desired, obtained by a single-stage liquid/vapor separation. Specifications on the equilibrium composition are: $x_l = 0.002$ and $y_l = 0.950$. Use data given below to determine BUBL and DEW P(bar) at T=350K for the separator. Assume that Eq. (10.5) applies; the calculated P should validate this assumption. Data: For the liquid phase:

$$\ln \gamma_1 = 0.93x_2^2 \qquad \ln \gamma_2 = 0.93x_1^2$$

$$\ln P_i^{sat}/\text{bar} = A_i - \frac{B_i}{T/\text{K}}$$

$$A_1 = 10.08,\ B_1 = 2572.0,\ A_2 = 11.63,\ B_2 = 6254.0$$

4. What is the change in entropy when 0.7 m^3 of $C0_2$ and 0.3 m^3 of N_2, each at 1 bar and 298.15 K (25°C) blend to form a gas mixture at the same conditions? Assume ideal gases.
5. The molar volume ($cm^3\ mol^{-1}$) of a binary liquid mixture at T and P is given by:

$$V = 120x_1 + 70x_2 + (15x_1 + 8x_2)x_1x_2$$

   a. Find expressions for the partial molar volumes of species 1 and 2 at T and P.
   b. Show that when these expressions are combined in accord with Eq. (11.11) the given equation for V is recovered.

c. Show that these expressions satisfy Eq. (11.14), the Gibbs/Duhem equation.

d. Show that $\left(d\bar{V}_1/dx_1\right)_{x_1=1} = \left(d\bar{V}_2/dx_1\right)_{x_1=0} = 0$.

6. Estimate the fugacity of isobutylene as a gas:
   a. At 553.15 K (280°C) and 20bar. (Generalized fugacity charts)
   b. At 553.15 K (280°C) and 100bar. (Lee-Kesler Correlation)
7. From data in the steam tables, determine a good estimate for f/f^{sat} for liquid water at 423.15 K (150°C) and 150 bar, where f ^{sat} is the fugacity of saturated liquid at 423.15 K (150°C).
8. For the system ethylene (l)/propylene (2) as a gas, estimate $\hat{f}_1, \hat{f}_2, \hat{\emptyset}_1 \; and \; \hat{\emptyset}_2$ at T/t = 423.15 K (150^{o}C), P = 30 bar, and y_l = 0.35: