Ex/Che/PC/B/T/223/2024

B.E. Chemical Engineering, 2nd year 2nd Semester Exam, 2024
Chemical Engineering Thermodynamics

Time : Three hours **Full Marks : 100**

Answer any two questions
Assume any missing data
The symbols have their usual meaning

Problem 1: [CO-1]

(a) Estimate the difference in enthalpy (in J/mol) between saturated liquid carbon tetrachloride at 80 °C, and carbon tetrachloride vapor at 100 °C and 0.6 bar. Sketch the path taken on P-v diagram.
The following data is given
Equation of state of the gas phase is given by $z = 1 + \frac{BP}{RT}$ where B/R = -8.5 K bar^{-1} and is a constant.
Saturated vapour pressure of carbon tetrachloride at 80 °C and 100 °C is 1.1 bar and 1.95 bar respectively
Latent heat of vaporization at normal boiling point (334.3 K) is 29.8 kJ/mol.
$T_c = 536.6\,K$, $\omega = 0.218$
Heat capacity of carbon tetrachloride vapour is 130 J/mol-K and may be assumed to be constant.

(b) Determine the internal energy departure function for carbon tetrachloride vapor at 100 °C and 0.6 bar.

© Starting from $s = f(T, v)$, derive the relation $Tds = C_v dT + \frac{T\beta}{k} dv$

[14+5+6]

Problem 2: [CO-3]

(a) The fugacity of a particular binary mixture is given by the formula $\ln f = A + Bx_1 - Cx_1^2$ where A, B and C are functions of T and P. Determine the corresponding expression of $\ln\gamma_1$ for standard states of the components based on Lewis-Randall rule.

(b) The partial molar volume of component 1 of a binary mixture is given by $\bar{V}_1 = A + Bx_1 + Cx_1^2$ where A, B and C are functions of T and P. Determine the corresponding expression of $\bar{V}_2$. The partial molar volume of pure component 2 is V_2.

(c) VLE data for ethanol (1)-toluene (2) binary system at T = 45 °C and P = 183 mm Hg gave the following result $x_1 = 0.3$ $y_1 = 0.634$. The saturation pressure at 45 °C for the pure ethanol and toluene are 173 mm Hg and 75.4 mm Hg

respectively. Stating the assumption made for low pressure VLE calculate (i) the liquid-phase activity coefficient (ii) $\frac{\Delta G}{RT}$. [10+7+8]

Problem 3: [CO-2]

(a) Consider toluene and water to be immiscible. Stating the assumptions in deriving the equation relevant to your calculation

(i) Determine the temperature at which the vapor phase is in equilibrium with both pure liquid toluene and pure liquid water at P = 800 Torr. (Take initial guess of temperature to be 85 °C. Do upto two iterations.) Determine the vapor composition of toluene.

(ii) Determine the temperature at which the vapor phase having toluene mole fraction = 0.2 is in equilibrium with pure liquid water at P = 800 Torr

(iii) Draw the T-x,y diagram for this system at constant pressure. Mark the point/tieline on the sketch for (b) and (c).

The vapor pressure can be estimate from

$$\text{Toluene: } log_{10}P(\text{Torr}) = 6.95 - \frac{1342.3}{t(oC)+219.2};$$

$$\text{Water: } log_{10}P(\text{Torr}) = 8.07 - \frac{1730.6}{t(oC)+233.5}$$

(b) The fugacity of methane dissolved in a liquid, X is given by Henry's law. At 300 K, the Henry's law constant for methane in the liquid is 200 atm. Determine the total pressure at this temperature at equilibrium, when the liquid contains 5 mol% methane. Make necessary assumptions and state then explicitly. [18+7]

The vapor pressure of X is given by

$$log_{10}P(\text{Torr}) = 7.36 - \frac{1305.2}{t(oC)+173.4};$$

Problem 4: [CO-2]

(a) Consider the following reaction $CO_2(g) + H_2(g) \leftrightarrow CO(g) + H_2O(g)$. Making suitable assumptions

(i) Determine the standard heat of reaction at 25 °C and chemical equilibrium constant at 1000 °C.

(ii) Obtain the mole fraction of CO in the reaction mixture at equilibrium at 1000 °C and 10 bar if the feed consist of 1 moles of CO_2 and 2 moles of H_2.

	$CO_2(g)$	$CO(g)$	$H_2O(g)$
ΔH_f^o (kJ/mol)	-393.9	-110.53	-242.0
ΔG_f^o(kJ/mol)	-394.8	-137.3	-168.4

(b) In steam cracking of methane, H_2O, CO, CO_2, and H_2 are present to a significant amount in the product gas. Determine a set of primary reactions. [18 + 7]