Department of Chemical Engineering, Indian Institute of Technology Delhi
CHL101: Introduction to Chemical Engineering Thermodynamics
Semester I, 2008-2009

Major Examination
Closed Book & Closed Notes

Date: 22/11/08 | Marks: 40

Note:

1. Do not answer a question in more than one place. If the answer to a question is given at different places, only the first continuous attempt will be evaluated.
2. Show all the intermediate steps of the methods employed for the solution of the problems.
3. Supplementary answer-sheets will not be provided.

1. Derive the following
   a. [6 Marks] 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.
   b. [6 Marks] Show $\mu \overset{D}{=} \left(\frac{\partial H}{\partial n_i}\right)_{S,P,n_{j\neq i}} = \left(\frac{\partial U}{\partial n_i}\right)_{S,V,n_{j\neq i}} = \left(\frac{\partial G}{\partial n_i}\right)_{T,P,n_{j\neq i}}$

2. [12 Marks] Assuming validity of Raoult's law for benzene(1)/toluene(2) system, calculate x_1 and T given $y_1 = 0.33$ and P = 120 kPa.

$$\ln P_i^{sat}/kPa = A_i - \frac{B_i}{t/{}^0C + C_i};\quad A_1 = 13.8594;\ B_1 = 2773.78;\ C_1 = 220.07;\ A_2 = 14.0098;\ B_2 = 3103.01;\ C_2 = 219.79$$

3. [4 Marks] A system formed initially by 2 mol CO_2, 5 mol H_2, and 1 mol CO undergoes reaction:

$$CO_2(g) + 3H_2(g) \rightarrow CH_3OH(g) + H_2O(g)$$
$$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$$

Develop expressions for the mole fractions of the reacting species as function of reaction coordinates for the two reactions

4. [5 Marks] Find the partial molar enthalpies using the following expression of enthalpy of the binary mixture

$$H = x_1(a_1 + b_1x_1) + x_2(a_2 + b_2x_2)$$

5. [7 Marks] For the ammonia synthesis reaction written:

$$\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightarrow NH_3(g)$$

For 0.5 mol N_2 and 1.5 mol H_2as initial amount of reactants and with the assumption that equilibrium mixture is ideal gas, show that

$$\varepsilon_e = 1 - \left(1 + 1.299K\frac{P}{P_o}\right)^{-1/2}$$