Chemical Engineering Thermodynamics
10.213, Fall 1996
Quiz #3, November 27

1. The following equilibrium vapor pressure data is available for a binary liquid mixture at 27°C:

x_1	0.0	0.1	0.3	0.5	0.7	0.9	1.0
p_1	0.0	0.059	0.17	0.26	0.36	0.45	0.5 bar
p_2	0.7	0.63	.50	0.37	0.23	0.082	0.0 bar

$\Delta H_1^{vap} = 25$ kJ/mol

$\Delta H_2^{vap} = 35$ kJ/mol

The heat of vaporization for species 1 is 25 kJ/mol and for species 2 is 35 kJ/mol and is fairly constant over a reasonable temperature range. One liter of species 1 contains 30 moles, while one liter of species 2 contains 20 moles.

a) What are the activity coefficients for species 1 and 2 at a composition of $x_1 = 0.1$?

b) What is the G^E for a mixture containing $x_1 = 0.3$?

c) If one mole of species 1 and one mole of species 2 is evaporated isothermally at 27 °C leaving a liquid phase with a mole fraction of $x_1 = 0.3$, what is the composition and total number of moles in the liquid phase?

d) Make a qualitative plot of pressure vs x_1, y_1. Indicate the following:

the liquid region
the vapor region
the two phase region
P_1^{sat}
P_2^{sat}
the bubble point pressure for a molar composition of $z_1 = 0.5$
the dew point pressure for a molar composition of $z_1 = 0.5$
the pressure at which one half of the mixture is in the vapor phase for a total molar composition of $z_1 = 0.5$

e) Can this mixture form an azeotrope? State the basis of your reasoning.

solution

Quiz III Solutions

1 Data

x_1	0	.1	.3	.5	.7	.9	1.0
P_1	0	.059	.17	.26	.36	.45	.5 bar
P_2	.7	.63	.50	.37	.23	.082	0 bar

P_1^{sat}

P_2^{sat}

a) Modified Raoult's Law

$$\gamma_1 x_1 P_1^{sat} = P_1 \implies \gamma_1 = \frac{.059}{(.1)(.5)} = \boxed{1.18}$$

$$\gamma_2 x_2 P_2^{sat} = P_2 \implies \gamma_2 = \frac{.63}{(.9)(.7)} = \boxed{1.0}$$

b) $$\frac{G^E}{RT} = x_1 \ln \gamma_1 + x_2 \ln \gamma_2$$

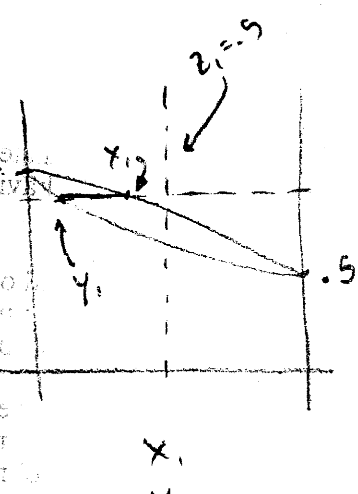
$$\frac{G^E}{RT} = (.3) \ln \frac{.17}{(.3)(.5)} + (.7) \ln \frac{.5}{(.7)(.7)} = .05$$

$$G^E = (.05)(8.314)(300) = \boxed{128\ J/mol}$$

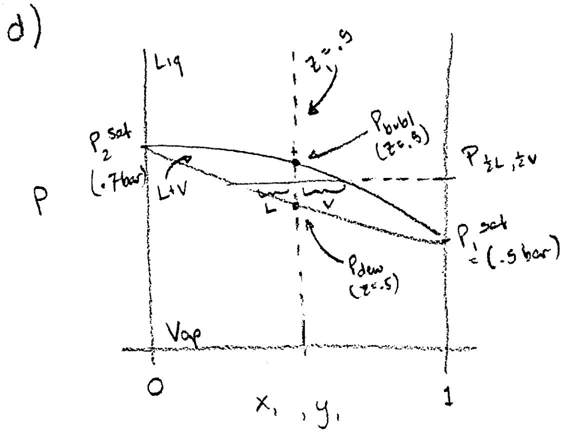
c) $L + V = 2$ mol $\qquad \boxed{z_1 = .5}$

$x_1 = .3 \qquad x_2 = .7$

$y_1 = \frac{P_1}{P_{Tot}} = \frac{.17}{.67} = \boxed{.25} \qquad y_2 = \frac{.50}{.67} = \boxed{.75}$



The desired result is not possible. See HW 8, Problem 3 d)



$P_{bubl} = P_1 + P_2$

$= .63$

$P_{\frac{1}{2}L,\frac{1}{2}V}$ = Use Lever rule, L = V (on diagram)

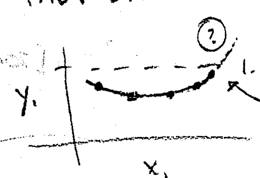
e) Azeotrope $\rightarrow$ $y_1 = x_1$

Look at x_1, y_1

From data and mod Raoult's law...

x_1	0	.1	.3	.5	.7	.9	1.0
y_1	N/A	.86	.83	.82	.87	.94	N/A

$\frac{x_1}{y_1}$ never equals 1 over the range of data. It is possible, but not likely that an azeotrope forms.



the curve is sloping up, but it may or may not reach $x_1/y_1 = 1.0$.