10.32
Spring 2005
EXAM 1
Wednesday, March 2, 2005

1. (40 points) A mixture of three hydrocarbons is at equilibrium at 100°C and 15 atmospheres. The can be assumed to form an ideal mixture in both the liquid and vapor phases. The composition of the mixture and the constants for the vapor pressure functions for each component are given below. The vapor pressure functions are of the form

$$\ln P = A - \frac{D}{T}$$

where P is in atmospheres and T is in Kelvins.

Component	z	A	D
C_3	0.25	9.816	2260
C_4	0.40	9.922	2696
C_5	0.35	10.173	3141

   a) Determine whether the mixture is a subcooled liquid, a mixture of vapor and liquid, or a superheated vapor.

   b) It is desired to bring the mixture to its bubble point (saturated liquid). If temperature is maintained at 100°C, to what total pressure must the mixture be subjected to reach the bubble point?

   c) If pressure is maintained at 15 atmospheres, to what temperature must the mixture be adjusted to reach the bubble point? An answer within a few degrees centigrade is acceptable.

2. (60 points) We wish to separate a binary mixture of A and B by continuous distillation. The mixture consists of 20 percent A and 80 percent B at the bubble point. The relative volatility of A to B is 3.0 and the vapor-liquid equilibrium data are plotted in the attached figure. The binary mixture is available at 100 pound-mol/hr and we wish to obtain a distillate product that has a concentration of 95 percent A and that contains half of the component A in the feed stream.

   a) What are the minimum reflux ratio and minimum number of stages required to effect this separation?

b) If we were to design a distillation column with a partial reboiler and total condenser to operate at 1.2 times the minimum reflux ratio, how many stages, in addition to the reboiler, are needed? What is the optimum location for the feed?

We wish to determine if we can use an existing distillation column that is no longer being used for its original purpose. The column is equipped with a total condenser, a partial reboiler, and ten plates above the reboiler. There are only two possible locations at which the feed can be introduced without making modifications to the column. These locations are plate 5, counting up, and directly into the reboiler. The reboiler is equipped with steam coils that are capable of vaporizing up to 85 pound-mol/hour of the liquid in the reboiler. Although the column is not what you would design, we would like to determine whether the column can be used, as is, to make the desired product. You are asked to consider two cases, the feed introduced at plate 5 and the feed introduced into the reboiler.

c) The feed is introduced at plate 5 (not likely to be the optimum location) and the reflux ratio is set to four. Show the operating lines for this reflux ratio and show the equilibrium stages stepped off on a McCabe-Thiele diagram with the feed on plate 5 and a total of ten plates plus a reboiler. Can the column be operated at this reflux ratio? Does the reboiler have adequate capacity? It is acceptable to make a distillate that is purer in component A than specified.

d) The feed is introduced directly into the reboiler. Can the column now be operated at a reflux ratio of four? Demonstrate the validity of your answer graphically or algebraically. What is the lowest reflux ratio at which this column can be operated? Does the reboiler have adequate capacity at this reflux ratio?