AE 335 Separation Processes

(by PTS)

Problem Set 4

(Multi-component Distillation)

1. For five-component distillation with one LK, one HK, one HNK, and 2 LNKs, where is the *lowest* temperature in the column?

2. A distillation column is separating methane, ethane, propane, and butane.
   2.1) If methane and propane are selected as the *key* components, what are ethane and butane?
   2.2) If propane and butane are selected as the *key* components, what are methane and ethane?

3. We are separating the mixture of 10 mol% methanol, 20% ethanol, 30% *n*-propanol, and 40% *n*-butanol using a distillation column. We desire to recover 98% of ethanol in the distillate and 97% *n*-propanol in the bottom product
   3.1) What are the heavy key and the light key components, respectively?
   3.2) Specify the light non-key(s), if any (ถ้ามี)
   3.3) Specify the heavy non-key(s), if any (ถ้ามี)
   3.4) What is the *best* assumption we should make if we are going to perform the external mass balance? (by selecting an appropriate answer from the following choices)
      a) All of methanol and *n*-propanol are in the distillate
      b) All of methanol is in the distillate and all of *n*-butanol is in the bottom product
      c) All of ethanol is in the distillate and all of *n*-propanol is in the bottom product
      d) All of the *n*-propanol and *n*-butanol are in the bottom product

4. A mixture of 60 wt% benzene, 35% toluene, and 5% naphthalene is being distilled. The distillate product should contain 99.5 wt% benzene. Also, 99% of benzene fed should be recovered in the distillate. Determine/calculate:
   4.1) distillate and bottom product flow rates (D and B) *per* 1 kg of feed
   4.2) compositions of distillate and bottom product
   4.3) fraction of toluene fed that is recovered in the bottom product

5. The 10,000 kmol/day of the mixture of 22 mol% methanol, 47% ethanol, 18% propanol, and 13% *n*-butanol is fed into a distillation column as a saturated liquid. We desire to have 99.8 mol% methanol recovered in the distillate and the mole fraction of methanol in the distillate is 0.99. Find
   5.1) D and B
   5.2) compositions of distillate and bottom product

6. We are separating a mixture of 40 mol% *iso*-pentane, 30% *n*-hexane, and 30% *n*-heptane fed into the distillation column at the feed rate of 1,000 kmol/h. We desire a 98 mol% recovery of *n*-hexane in the bottom product and a 99% recovery of *iso*-pentane in the distillate. The feed is a two-phase mixture with 40% vapour, and the reflux ratio $\left(\frac{L}{D}\right)$ is 2.5
   6.1) Find D and B
   6.2) Find compositions of distillate and bottom products
   6.3) Calculate the values of L, V, $\bar{L}$, and $\bar{V}$, assuming that CMO is valid

7. A distillation column is separating methanol, ethanol, and butanol at a pressure of 2 atm. The column has a total condenser and a partial re-boiler. The feed is saturated liquid with the flow rate of 100 kmol/h comprising 45 mol% methanol, 30% ethanol, and 25% butanol. The reflux ratio $\left(\frac{L}{D}\right)$ is 2.0 and the reflux is a saturated liquid. We desire a 98% recovery of ethanol in the distillate and a 99.1% recovery of butanol in the bottom product. Find D and B, and compositions of distillate and bottom products

8. We have 10 kmol/h of a saturated liquid that is composed of 40 mol% benzene (B) and 60% toluene (T). We desire a distillate composition with 99.2 mol% of benzene and a bottom product composition with 98.6 mol% of toluene. The relative volatility, α_{BT}, is 2.4. The reflux is returned as a saturated liquid, and the column has a total condenser and a partial re-boiler. Assume that CMO is valid.
   8.1) Use the Fenske equation to determine $N_{\min}$
   8.2) Use the Underwood equations to find $\left(\frac{L}{D}\right)_{\min}$
   8.3) For actual $\frac{L}{D} = 1.1\left(\frac{L}{D}\right)_{\min}$, use the previous results (from 8.1 & 8.2) and the Gilliland correlation to estimate the total number of stages and optimal feed location

9. We have designed a special column that acts as exactly 3 equilibrium stages, operated at total reflux. We measure vapour composition leaving the top stage and the liquid composition leaving the bottom stage. The column is separating phenol (A) from *o*-cresol (B). The phenol liquid mole fraction leaving the top stage is 0.545. What is the relative volatility of phenol with respect to *o*-cresol $\left(\alpha_{AB}\right)$?

10. A column with 29 equilibrium stages and a partial reboiler is being operated at total reflux to separate the mixture of ethylene dibromide (A) and propylene dibromide (B). Ethylene dibromide is more volatile, and the relative volatility, α_{AB}, is 1.30. The concentration of A in the distillate is 98.4 mol%. The column has a total condenser and saturated liquid reflux, and CMO is valid. Use the Fenske equation to estimate the composition of the bottom product

11. We are separating a mixture of ethanol (A) and *n*-propanol (B), in which ethanol is more volatile. The relative volatility, α_{AB}, is 2.10. The feed flow rate is 1,000 kmol/h. The feed is with 60 mol% ethanol and of saturated vapour. We desire an ethanol concentration in the distillate of 99% and in the bottom product of 0.8%. Reflux is a saturated liquid. The column has 30 stages. Use the Fenske-Underwood-Gilliland techniques to determine

    11.1) the number of stages at the total reflux condition

    11.2) $\left(\frac{L}{D}\right)_{\min}$

    11.3) actual $\frac{L}{D}$