SOLUTION

CHE 305 – Separation Processes
Spring 2010 – Homework # 1

1. Five hundred kmol/h of a liquid mixture of light alcohols containing, by moles, 40% methanol (M), 35% ethanol (E), 15% isopropanol (IP) and 10% normal propanol (NP) is distilled in a sequence of two distillation columns. The distillate from the first column is 98% pure M with a 96% recovery of M. The distillate from the second column is 92% pure E with a 95% recovery of E from the process feed. Assume no propanols in the distillate from Column C1, no M in the bottoms from Column C2, and no normal propanol in the distillate from Column C2.

   (a) By material balances, assuming negligible propanols in the distillate from the first column, compute the flow rates in kmol/h of each component in each feed, distillate, and bottoms. Draw a labeled block-flow diagram like Figure 1.9. Include the results of the material balances in a table like Table 1.5 and place the table below your block-flow diagram.
   (b) Compute the mole-percent purity of the propanol mixture leaving as bottoms from the second column in the sequence.
   (c) If the recovery of ethanol is fixed at 95%, what is the maximum purity that can be achieved for the ethanol in the distillate from the second column?
   (d) If instead, the purity of the ethanol is fixed at 92%, what is the maximum recovery of ethanol (based on the process feed) that can be achieved?

2. A stream containing 7,000 kmol/h of water and 3,000 parts per million (ppm) by weight of ammonia at 350 K and 1 bar is to be processed to remove 90% of the ammonia. What type of separation operation would you use? If it involves a mass-separating agent, propose one.

3. Calculate the vapor pressures of acetone, acetaldehyde, and acetic acid at 75 °C. Determine the boiling points for each component at 1.5 bar using the Antoine equation and coefficients given below. Which component is the most volatile? Which component is the least volatile?

$$\log_{10} P = A - \frac{B}{T + C}$$

where P is in mm Hg, and T is in degrees centigrade.

	acetone	acetaldehyde	acetic acid
A	7.02447	6.81089	7.18807
B	1161.0	992.0	1416.7
C	224	230	211

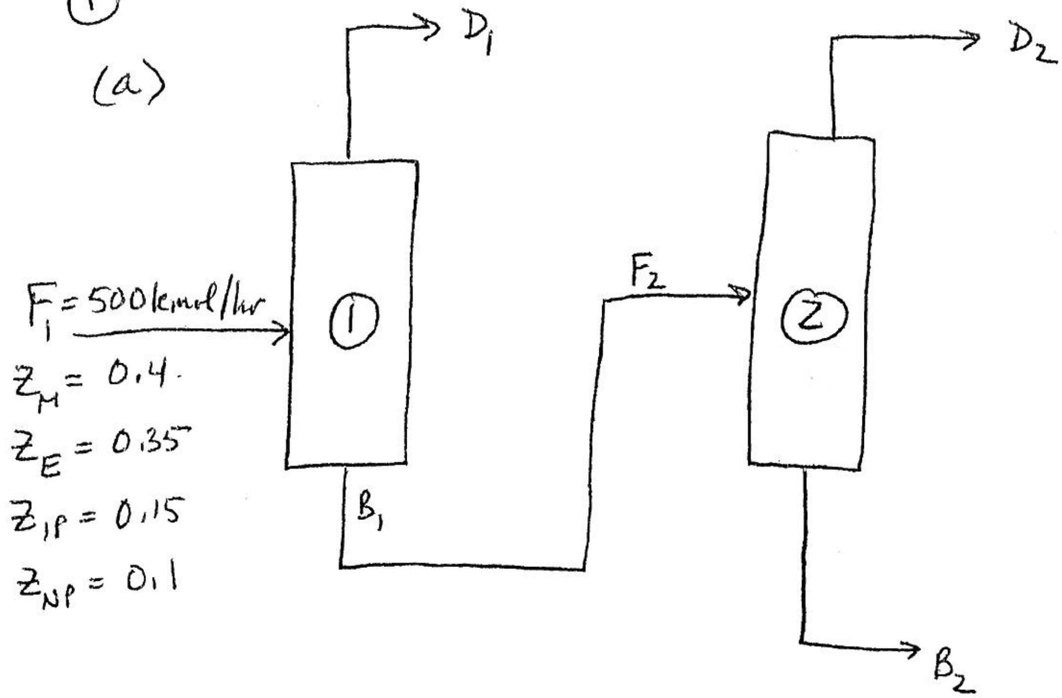
Source: Lange's Handbook of Chemistry, 10th Edition (1961)

SOLUTION

SEPARATIONS HW #1

(1)

(a)



kmol/hr

Component	F_1	D_1	$B_1 = F_2$	D_2	B_2
M	200	192	8	8	0
E	175	3.92	171.08	166.25	4.83
IP	75	0	75	6.46	68.54
NP	50	0	50	0	50
TOTAL	500	195.92	304.08	180.71	123.37

D_1:

96% recovery methanol (M)

$\Rightarrow 0.96(200) = 192$ kmol/hr M

$y_M = 0.98 \qquad \Rightarrow \text{Total} = \frac{192}{0.98} = 195.92$ kmol/hr

$\Rightarrow y_E = 0.02$

$\Rightarrow 0.02(195.92) = 3.92$ kmol/hr E

B_1/F_2 By Mat'l Balance

D_2: Rest of Methanol $\Rightarrow$ 8 kmol/hr M

$y_E = 0.92$

95% Recovery of Ethanol

$\Rightarrow 0.95(175) = 166.25$ kmol/hr E

$\text{Total} = \frac{166.25}{0.92} = 180.71$ kmol/hr Total

Balance from IP: $180.71 - 166.25 - 8 = 6.46$ kmol/hr IP

B_2 from Mat'l Balance (See table)

(b) Purity of mixed propanols in B_2

$$\frac{(68.54+50)}{123.37} = \boxed{0.9608}$$ ← mole fraction of propanols in B_2.

(c) Recovery of E fixed.

⇒ D_2: 166.25 kmol/hr E.

Only way to improve purity is to remove IP.
(let → 0)

New Total = M + E = 8 + 166.25 = 174.25 kmol/hr

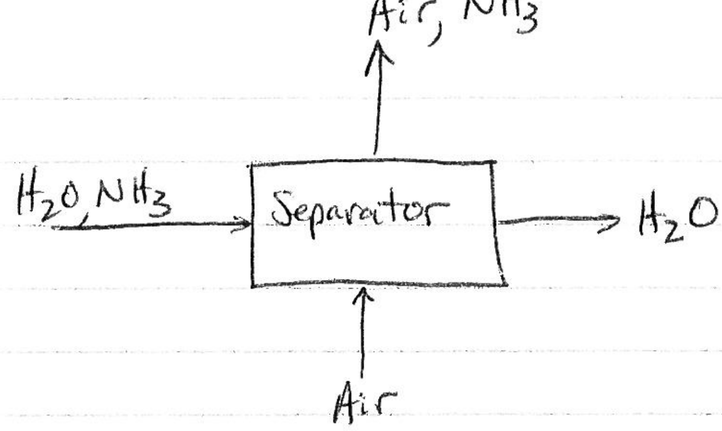
$$y_E = \frac{166.25}{174.25} = 0.9541$$

(d) Purity fixed. Recover all available E.

⇒ 166.25 + 4.83 = 171.08 kmol/hr E

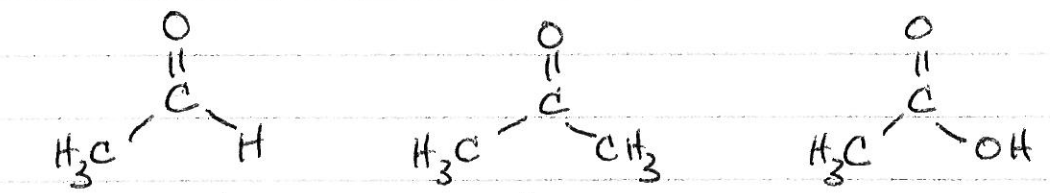
$$\text{Recovery} = \frac{171.08}{175} \times 100\% = \boxed{97.76\%}$$

(2)



MSA → AIR (ABSORPTION)

(3)



Acetaldehyde Acetone Acetic Acid

VAPOR PRESSURES AT 75°C

$$\log P = A - \frac{B}{T+C}$$

P in mm Hg
T in °C

Acetaldehyde: $P = 10^\wedge \left\{ 6.81089 - \frac{992.0}{75+230} \right\}$

$$P^{sat} = 3618 \text{ mm Hg}$$

Acetone: $P = 10^\wedge \left\{ 7.02447 - \frac{1161.0}{75+224} \right\}$

$\boxed{P^{sat} = 1385 \text{ mm Hg}}$

Acetic Acid: $P = 10^\wedge \left\{ 7.18807 - \frac{1416.7}{75+211} \right\}$

$\boxed{P^{sat} = 172 \text{ mm Hg}}$

Higher vapor pressure ⇒ More volatile

⇒ Acetaldehyde > Acetone > Acetic Acid

most volatile ... least volatile

Boiling Points @ 1.5 bar (1125 mm Hg)

Rearrange Antoine Eqn.

$$T^{sat} = \frac{B}{A - \log P} - C$$

P in mm Hg

T in °C

Acetaldehyde: $T^{sat} = \frac{992.0}{6.81089 - \log(1125)} - 230$

$\boxed{T^{sat} = 33.8\ °C}$

Acetone: $$T^{sat} = \frac{1161.0}{7.02447 - \log(1125)} - 224$$

$$\boxed{T^{sat} = 68.2°C}$$

Acetic Acid: $$T^{sat} = \frac{1416.7}{7.18807 - \log(1125)} - 211$$

$$\boxed{T^{sat} = 131.4°C}$$

Lower boiling point ⇒ more volatile

Acetaldehyde > Acetone > Acetic Acid

most volatile ... least volatile