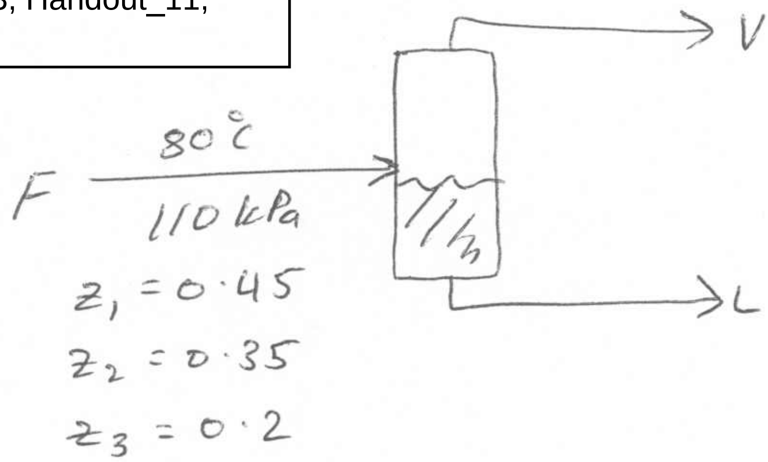
Example 10.5 The system acetone(1)/acetonitrile(2)/nitromethane(3) at 80°C and 110 kPa has the overall composition, $z_1 = 0.45$, $z_2 = 0.35$, $z_3 = 0.20$. Assuming that Raoult's law is appropriate to this system, determine $\mathcal{L}$, $\mathcal{V}$, $\{x_i\}$, and $\{y_i\}$.

The vapor pressures of the pure species at 80°C are

$$P_1^{sat} = 195.75 \qquad P_2^{sat} = 97.84 \qquad P_3^{sat} = 50.32 \text{ kPa}$$

Chemica Engineering Dept., KFUPM, CHE303, Handout_11, Flash



First make sure that the feed is a two phase system. To do that, check:

$$P_{dew} < P = 110 \text{ kPa} < P_{bubl}$$

Raoult's law: $\quad y_i P = x_i P_i^{sat}$

BUBL P: $\quad \sum y_i = 1 \Rightarrow P_{bubl} = \sum_{i=1}^{N} x_i P_i^{sat}$

replace $\quad x_i = z_i$

$$P_{bubl} = (0.45)(195.75) + (0.35)(97.84) + (0.2)(50.32)$$

$$= 132.4 \text{ kPa}$$

DEW P: $\quad \sum x_i = 1 \Rightarrow P_{dew} = \dfrac{1}{\sum_{i=1}^{N} \dfrac{y_i}{P_i^{sat}}}$

replace $y_i = z_i$

$$P_{dew} = \frac{1}{\frac{0.45}{195.75} + \frac{0.35}{97.84} + \frac{0.20}{50.32}}$$

$$= 101.52 \text{ kPa}$$

Indeed $P_{dew} < P < P_{buble} \Rightarrow$ Two phase system.

Since P and T are known

$$\sum_{i=1}^{N} \frac{z_i k_i}{1 + V(k_i - 1)} = 1 \leftarrow \left(\begin{matrix}\text{bassis} \\ F = 1 \text{ mole/s}\end{matrix}\right)$$

$$k_i = \frac{P_i^{sat}}{P} \quad \text{(Raoult's Law)}$$

$\Rightarrow K_1 = 1.7795$, $k_2 = 0.8895$, $k_3 = 0.4575$

substitute in the above equation

$$\Rightarrow \frac{(0.45)(1.7795)}{1 + 0.7795 V} + \frac{(0.35)(0.8895)}{1 - 0.1105 V} + \frac{(0.20)(0.4575)}{1 - 0.5425 V} = 1$$

by trail and error $V = 0.7364$ mole/s

$\Rightarrow L = 0.2636$ mole/s

now $y_i = \dfrac{z_i k_i}{1 + V(k_i - 1)}$ $(i = 1, 2, \cdots, N)$

$\Rightarrow y_1 = 0.5087$, $y_2 = 0.3389$ & $y_3 = 0.1524$

$x_i = y_i / k_i$

$\Rightarrow x_1 = 0.2859$, $x_2 = 0.3810$ & $x_3 = 0.3331$

A 3.5 mole/s binary mixture of acetone(1)/methanol(2) contains 25-mole% acetone is flashed at 60 °C. The composition of the liquid leaving the drum contains 17.5-mole% acetone. Assuming that Raoult's is an adequate description for the VLE of this system, calculate:

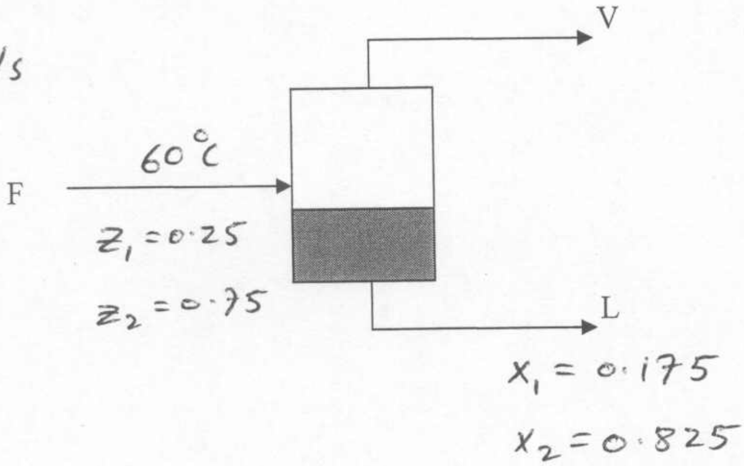
(a) The pressure of the flash drum.
(b) The flow rates of the vapor and liquid streams leaving the drum.
(c) The composition of the vapor stream.

Table 10.2

$P_1^{sat} = 115.68$ kPa

$P_2^{sat} = 84.47$ kPa

basis F = 1 mole/s



$$\sum_{i=1}^{N} \frac{z_i k_i}{1 + V(k_i - 1)} = 1 \quad ---(10.17)$$

Since P is unknown, $k_i = \frac{P_i^{sat}}{P}$ also unknown

=> the above equation has two unknowns V and P. => we need one more equation

$$y_i = \frac{z_i k_i}{1 + V(k_i - 1)} \quad (i = 1, 2, \cdots, N) \quad (10.16)$$

↑ unknown

$$y_i = k_i x_i$$

$$\Rightarrow x_i = \frac{z_i}{1 + V(k_i - 1)}, \quad (i = 1, \cdots, N) \quad (10.16 \text{ modified})$$

now, we have two equations 10.17 & 10.16 modified with two unknowns V & P.

For i=1, solve for V from (10.16 modified)

$$0.175 = \frac{0.25}{1 + V\left(\frac{115.68}{P} - 1\right)}$$

$$\Rightarrow V = \frac{\frac{0.25}{0.175} - 1}{\frac{115.68}{P} - 1} = \frac{1.429P - P}{115.68 - P} \quad --- (*)$$

substitute in (10.17)

$$\frac{(0.25)\frac{115.68}{P}}{1 + \left(\frac{1.429P - P}{115.68 - P}\right)\left(\frac{115.68}{P} - 1\right)} + \frac{(0.75)\frac{84.47}{P}}{1 + \left(\frac{1.429P - P}{115.68 - P}\right)\left(\frac{84.47}{P} - 1\right)} - 1 = 0$$

simplify,

$$\frac{28.92}{1 + \frac{0.429}{\cancel{(115.68 - P)}}\cancel{(115.68 - P)}} + \frac{63.35}{1 + \frac{0.429}{(115.68 - P)}(84.47 - P)} - P = 0$$

$$\Rightarrow \frac{63.35}{1 + \frac{0.429}{(115.68 - P)}(84.47 - P)} - P + 20.238 = 0$$

$P \simeq 90$ kPa by trail and error

$\Rightarrow$ from (*) $V = 0.017 \frac{mol}{s} \Rightarrow L = 1 - V = 0.983$

note L & V where calculated based on F = 1 mole/s. But F = 3.5 mol/s

$\Rightarrow V = (3.5)(0.017) = 0.058$ mole/s

$L = 3.442$ mol/s

$$y_i = \frac{z_i k_i}{1 + V(k_i - 1)}$$

↑ (based on F = 1 mole/s)

$$\Rightarrow y_1 = \frac{0.25 \frac{115.68}{90}}{1 + 0.017\left(\frac{115.68}{90} - 1\right)}$$

$= 0.32 \quad \Rightarrow y_2 = 0.68$