Practice Exam 3

1.) benzene(1)/toluene(2)/p-xylene(3)

$$\ln P_1^{sat} = 13.7819 - \frac{2726.81}{t/°C + 217.572}$$

$$\ln P_2^{sat} = 13.9320 - \frac{3056.96}{t/°C + 217.625}$$

$$\ln P_3^{sat} = 14.0579 - \frac{3331.45}{t/°C + 214.627}$$

$T = 110°C \quad P = 90 \text{ kPa}$

$z_1 = 1/3 \quad z_2 = 1/3 \quad z_3 = 1/3$

$P_1^{sat}(110) = 234.53 \text{ kPa}$

$P_2^{sat}(110) = 99.62 \text{ kPa}$

$P_3^{sat}(110) = 44.50 \text{ kPa}$

$$P_{bubl} = \sum_i x_i P_i^{sat} \quad \text{when } \{x_i\} = \{z_i\}$$

$$= 126.22 \text{ kPa}$$

$$P_{dew} = 1 / \sum_i y_i / P_i^{sat} \quad \text{when } \{y_i\} = \{z_i\}$$

$$= 81.58 \text{ kPa}$$

$P_{dew} < P < P_{bubl}$: Flash!

$$K_1 = \frac{P_1^{sat}}{P} = 2.6059 \quad K_2 = 1.1069 \quad K_3 = 0.4945$$

Flash equation: $\displaystyle \sum_i \frac{z_i k_i}{1 + V(K_i - 1)} = 1$

$$1 = \frac{0.8686}{1 + 1.6059V} + \frac{0.3690}{1 + 0.1069V} + \frac{0.1648}{1 - 0.5055V}$$

or $$\frac{0.8686}{1 + 1.6059V} = 1 - \frac{0.3690}{1 + 0.1069V} - \frac{0.1648}{1 - 0.5055V}$$ ... iterate!

guess $V^0 = 0.5$

$V^1 = 0.64 \quad V^2 = 0.69 \quad V^3 = 0.72$

$V^4 = 0.74 \quad V^5 = 0.74 \quad .. \quad \underline{V^\infty = 0.760}$

$$y_1 = \frac{z_1 K_1}{1 + V(K_1 - 1)} = \underline{0.391}$$

$y_2 = \underline{0.341} \qquad y_3 = \underline{0.268}$

$$x_1 = \frac{y_1}{K_1} = \underline{0.150}$$

$x_2 = \underline{0.308} \qquad x_3 = \underline{0.542}$

(2) $P_1^{sat} = 35.2 \text{ kPa}$ $\quad z_1 = 0.3$

$P_2^{sat} = 93.1 \text{ kPa}$ $\quad z_2 = 0.7$

$\ln \gamma_1 = 0.55 x_2^2 \quad \ln \gamma_2 = 0.55 x_1^2$

a.) $P_{bubl} = \sum_i x_i \gamma_i P_i^{sat}$ when $\{x_i\} = \{z_i\}$

$= \underline{96.42 \text{ kPa}}$

$P_{dew} = 1 / \sum_i \frac{y_i}{\gamma_i P_i^{sat}}$ when $\{y_i\} = \{z_i\}$

$= \underline{72.18 \text{ kPa}}$

b.) $P = \sum_i x_i \gamma_i P_i^{sat}$ $\quad x_1 = x_2 = 0.5$

$= \underline{73.61 \text{ kPa}}$

$y_1 = \frac{x_1 \gamma_1 P_1^{sat}}{P} = 0.274$

$y_2 = 0.726$

$$z_1 = x_1(1-V) + y_1 V = x_1 - x_1 V + y_1 V$$

$$\frac{z_1 - x_1}{y_1 - x_1} = V = \underline{0.886}$$

c.) $$\alpha_{12} = \frac{\gamma_1 P_1^{sat}}{\gamma_2 P_2^{sat}}$$

at $x_1 = 0$: $\gamma_1 = \exp(0.55)$ $\gamma_2 = 1.0$

$x_1 = 1$: $\gamma_1 = 1.0$ $\gamma_2 = \exp(0.55)$

$$\alpha_{12}\big|_{x_1=0} = 0.655$$

$$\alpha_{12}\big|_{x_1=1} = 0.218$$

since $\alpha_{12}\big|_{x_1=0}$ and $\alpha_{12}\big|_{x_1=1} < 1$

<u>no azeotrope!</u>

③ $V = 120x_1 + 70x_2 + (15x_1 + 8x_2)x_1x_2$

$x_2 = 1 - x_1$

$V = 120x_1 + 70(1-x_1) + 15x_1^2(1-x_1) + 8x_1(1-x_1)^2$

$= 120x_1 + 70 - 70x_1 + 15x_1^2 - 15x_1^3 + 8x_1(1 - 2x_1 + x_1^2)$

$= 70 + 50x_1 + 15x_1^2 - 15x_1^3 + 8x_1 - 16x_1^2 + 8x_1^3$

$= 70 + 58x_1 - x_1^2 - 7x_1^3$

$$\frac{dV}{dx_1} = 58 - 2x_1 - 21x_1^2$$

$$\bar{V}_1 = V + x_2\frac{dV}{dx_1}$$

$= 70 + 58x_1 - x_1^2 - 7x_1^3 + (1-x_1)(58 - 2x_1 - 21x_1^2)$

$= 70 + 58x_1 - x_1^2 - 7x_1^3 + 58 - 2x_1 - 21x_1^2$
$\quad - 58x_1 + 2x_1^2 + 21x_1^3$

$\bar{V}_1 = 128 - 2x_1 - 20x_1^2 + 14x_1^3$

$$\bar{V}_2 = V - x_1 \frac{dV}{dx_1}$$

$$= 70 + 58x_1 - x_1^2 - 7x_1^3 - x_1\left(58 - 2x_1 - 21x_1^2\right)$$

$$= \overset{\checkmark}{70} + \overset{\checkmark}{58x_1} - \overset{\checkmark}{x_1^2} - 7x_1^3 - \overset{\checkmark}{58x_1} + \overset{\checkmark}{2x_1^2} + 21x_1^3$$

$$= 70 + x_1^2 + 14x_1^3$$

$$V_1 = V\Big|_{x_1 = 1.0} = 70 + 58 - 1 - 7$$

$$= 120 \ cm^3/mol$$

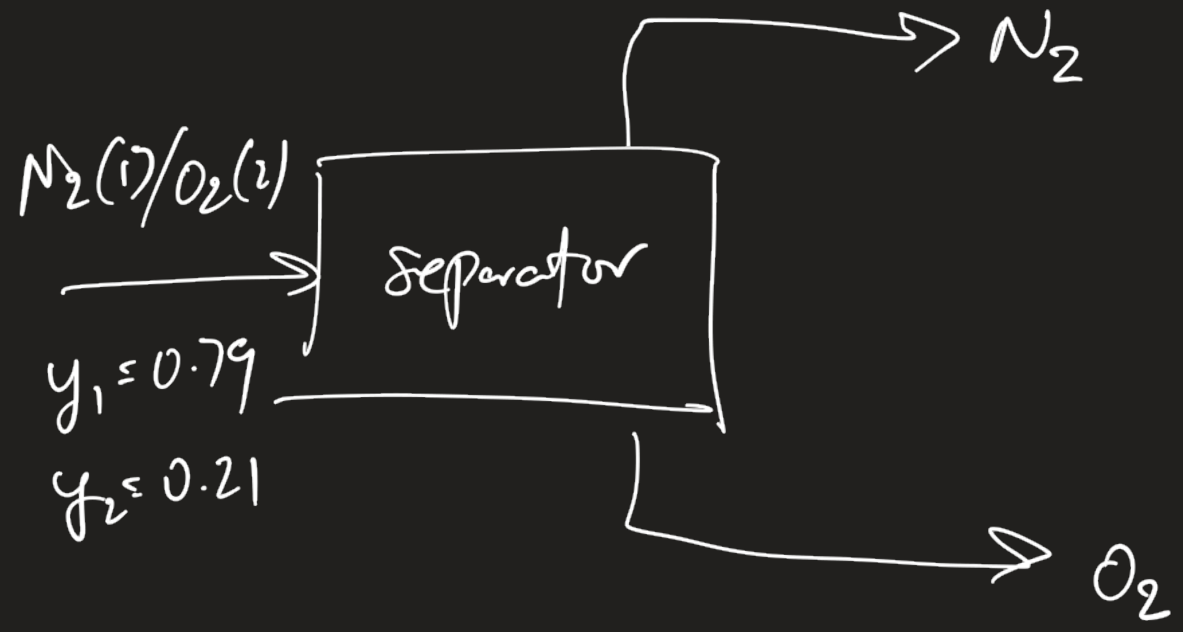
$$V_2 = V\Big|_{x_1 = 0.0} = 70 \ cm^3/mol$$

$$\bar{V}_1^{\infty} = \bar{V}_1\Big|_{x_1 = 0.0} = 128 \ cm^3/mol$$

$$\bar{V}_2^{\infty} = \bar{V}_2\Big|_{x_1 = 1.0} = 70 + 1 + 14$$

$$= 85 \ cm^3/mol$$

(4)



$T = 25\,°C$

$P = 1$ bar

$\eta = 8\%$

$T_\sigma = 300$ K

basis : 1 mol of air

inlet : mixed ideal gases

$$S_{in} = \sum_i y_i S_i^{ig} - R \sum_i y_i \ln y_i$$

outlet : fully seperated ideal gases

$$S_{out} = \sum_i y_i S_i^{ig}$$

$$\Delta S = S_{out} - S_{in}$$

$$= R \sum_i y_i \ln y_i$$

$$= (8.314\ \text{J/mol K})\left[0.79 \ln 0.79 + 0.21 \ln 0.21\right]$$

$$= -4.273\ \text{J/mol K}$$

$$W_{ideal} = -T_0 \Delta S$$

$$= 1281.9 \text{ J/mol}$$

$$W = \frac{W_{ideal}}{\eta} = \underline{25638.2} \text{ J/mol}$$

(5) n-Hexane $T = 525\ K$

$P = 10\ bar$

use RK EOS

$\alpha(T_r) = T_r^{-1/2}$ $\sigma = 1$ $\epsilon = 0$

$\Omega = 0.08664$ $\Psi = 0.42748$

$T_c = 507.6\ K$ $P_c = 30.25\ bar$

$T_r = \frac{T}{T_c} = 1.0343$ $P_r = \frac{P}{P_c} = 0.3306$

$$q = \frac{\Psi \alpha(T_r)}{\Omega T_r} = \frac{\Psi T_r^{-3/2}}{\Omega} = 4.691$$

$$\beta = \Omega \frac{P_r}{T_r} = 0.0277$$

$$Z = 1 + \beta - q\beta \cdot \frac{Z - \beta}{(Z + \epsilon\beta)(Z + \sigma\beta)}$$

$$= 1 + \beta - q\beta \frac{Z - \beta}{Z + \beta}$$

guess $Z^0 = 1.0$

$$z^1 = 0.9048 \quad z^1 = 0.9055 \quad z^2 = 0.9055 \checkmark$$

$$I = \begin{cases} \dfrac{1}{\sigma - \epsilon} \ln \dfrac{z + \sigma\beta}{z + \epsilon\beta} & \sigma \neq \epsilon \\ \dfrac{\beta}{z + \epsilon\beta} & \sigma = \epsilon \end{cases}$$

$$= \ln \frac{z + \beta}{z} = 0.0301$$

$$\ln\phi = z - 1 - \ln(z - \beta) - qI$$

$$= -0.1055$$

$$\boxed{\begin{aligned} \phi &= 0.8999 \\ f = \phi P &= 8.999 \text{ bar} \end{aligned}}$$

$T_r = 1.0343 \quad P_r = 0.3306$

From Table E13 (2D interpolate)

$\phi^0 \big|_{T_r, P_r} = 0.9023$

From Table E14 (2D interpolate)

$\phi^1 \big|_{T_r, P_r} = 0.9870$

$\omega = 0.301$

$\phi = \phi^0 (\phi^1)^{\omega}$

$= \underline{0.8987}$

$f = \phi P = \underline{8.987 \text{ bar}}$