ORIGIN := 1

$T := 366.4$ $P := 138.76$

$$T_c := \begin{pmatrix} 126.2 \\ 554 \end{pmatrix} \qquad P_c := \begin{pmatrix} 34 \\ 40.7 \end{pmatrix} \qquad \omega := \begin{pmatrix} 0.039 \\ 0.212 \end{pmatrix}$$

$i := 1 .. 2$ $j := 1 .. 2$

$$T_{r_i} := \frac{T}{T_{c_i}} \qquad P_{r_i} := \frac{P}{P_{c_i}} \qquad k := \begin{pmatrix} 0 & 0.109 \\ 0.109 & 0 \end{pmatrix}$$

$$\alpha_i := \left[1 + \left[0.37464 + 1.54226 \cdot \omega_i - 0.26992 \cdot \left(\omega_i\right)^2\right] \cdot \left(1 - \sqrt{T_{r_i}}\right)\right]^2$$

$$A_{i,\,i} := 0.45724 \frac{P_{r_i} \cdot \alpha_i}{\left(T_{r_i}\right)^2} \qquad B_i := 0.07780 \cdot \frac{P_{r_i}}{T_{r_i}}$$

$$A_{i,\,j} := \left(1 - k_{i,\,j}\right) \cdot \sqrt{A_{i,\,i} \cdot A_{j,\,j}}$$

LIQUID PHASE

$x_1 := 0.1286$

$x_2 := 1 - x_1$

$$A_{mix} := \sum_i \left[\sum_j \left(x_i \cdot x_j \cdot A_{i,\,j}\right)\right] = 3.589 \qquad B_{mix} := \sum_i \left(x_i \cdot B_i\right) = 0.364$$

$$p := -1 + B_{mix} \qquad q := A_{mix} - 2B_{mix} - 3B_{mix}^2 \qquad r := -A_{mix} \cdot B_{mix} + B_{mix}^2 + B_{mix}^3$$

$$S := X^3 + p \cdot X^2 + q \cdot X + r \;\Big|\; \begin{array}{l} \text{solve} \\ \text{assume , } X = \text{real} \end{array} \rightarrow 0.4710268846697319345$$

$Z_L := \min(S) = 0.471$

$$CL := \frac{Z_L + \left(1 + \sqrt{2}\right) \cdot B_{mix}}{Z_L + \left(1 - \sqrt{2}\right) \cdot B_{mix}}$$

$$\phi L_i := \exp\left[\frac{B_i\cdot(Z_L-1)}{B_{mix}} - \ln(Z_L - B_{mix}) - \frac{A_{mix}}{\sqrt{8}\cdot B_{mix}}\cdot\left[\frac{2\cdot\sum_j (x_j\cdot A_{i,j})}{A_{mix}} - \frac{B_i}{B_{mix}}\right]\cdot\ln(CL)\right]$$

$$\phi L = \begin{pmatrix} 7.623 \\ 0.017 \end{pmatrix}$$

VAPOR PHASE

$y_1 := 0.9721$

$y_2 := 1 - y_1$

$A_{mix} := \sum_i\left[\sum_j (y_i\cdot y_j\cdot A_{i,j})\right] = 0.138$ $\quad$ $B_{mix} := \sum_i (y_i\cdot B_i) = 0.118$

$p := -1 + B_{mix}$ $\quad$ $q := A_{mix} - 2B_{mix} - 3B_{mix}^2$ $\quad$ $r := -A_{mix}\cdot B_{mix} + B_{mix}^2 + B_{mix}^3$

$$S := X^3 + p\cdot X^2 + q\cdot X + r \;\Big|\; \begin{matrix}\text{solve}\\ \text{assume , } X = \text{real}\end{matrix} \rightarrow \begin{pmatrix} 1.0190844439961380924 \\ -0.13067944202477040138 \\ -0.005905824315710861008 4 \end{pmatrix}$$

$Z_V := \max(S) = 1.019$

$$CV := \frac{Z_V + (1+\sqrt{2})\cdot B_{mix}}{Z_V + (1-\sqrt{2})\cdot B_{mix}}$$

$$\phi V_i := \exp\left[\frac{B_i\cdot(Z_V-1)}{B_{mix}} - \ln(Z_V - B_{mix}) - \frac{A_{mix}}{\sqrt{8}\cdot B_{mix}}\cdot\left[\frac{2\cdot\sum_j (y_j\cdot A_{i,j})}{A_{mix}} - \frac{B_i}{B_{mix}}\right]\cdot\ln(CV)\right]$$

$$\phi V = \begin{pmatrix} 1.021 \\ 0.493 \end{pmatrix}$$

$y_i \cdot \phi_{V_i} =$

0.992
0.014

Part (b)

$$V_V := \frac{Z_V \cdot 83.14 \cdot T}{P} = 223.723 \qquad V_L := \frac{Z_L \cdot 83.14 \cdot T}{P} = 103.406$$

$$M_V := y_1 \cdot 28.01 + y_2 \cdot 84.16 = 29.577 \qquad M_L := x_1 \cdot 28.01 + x_2 \cdot 84.16 = 76.939$$

$$\rho_V := \frac{M_V}{V_V} = 0.132 \qquad \rho_L := \frac{M_L}{V_L} = 0.744$$

Alternative Solution

ORIGIN := 1

$$\text{root}(p, q, r) := \left| \begin{array}{l} v \leftarrow \begin{pmatrix} r \\ q \\ p \\ 1 \end{pmatrix} \\ x \leftarrow \text{polyroots}(v) \\ \text{for } i \in 1 .. 3 \\ \quad x_i \leftarrow 0 \text{ if } \text{Im}(x_i) \neq 0 \\ x1 \leftarrow \max(x) \\ y \leftarrow \min(x) \\ x2 \leftarrow \left| \begin{array}{ll} \max(x) & \text{if } y = 0 \\ y & \text{otherwise} \end{array} \right. \\ \begin{pmatrix} x1 \\ x2 \end{pmatrix} \end{array} \right.$$

$$T_c := \begin{pmatrix} 126.2 \\ 554 \end{pmatrix} \qquad P_c := \begin{pmatrix} 34 \\ 40.7 \end{pmatrix} \qquad \omega := \begin{pmatrix} 0.039 \\ 0.212 \end{pmatrix} \qquad k := \begin{pmatrix} 0 & 0.109 \\ 0.109 & 0 \end{pmatrix}$$

$i := 1 .. 2 \qquad j := 1 .. 2$

$$T_{r_i} := \frac{T}{T_{c_i}} \qquad P_{r_i} := \frac{P}{P_{c_i}} \qquad x := \begin{pmatrix} 0.1286 \\ 1 - 0.1286 \end{pmatrix} \qquad y := \begin{pmatrix} 0.9721 \\ 1 - 0.9721 \end{pmatrix}$$

$\phi_V(T, P) :=$

$n \leftarrow 2$

for $i \in 1 .. n$

$T_{r_i} \leftarrow \frac{T}{T_{c_i}}$

$P_{r_i} \leftarrow \frac{P}{P_{c_i}}$

$\alpha_i \leftarrow \left[1 + \left[0.37464 + 1.54226 \cdot \omega_i - 0.26992 \cdot (\omega_i)^2\right] \cdot \left(1 - \sqrt{T_{r_i}}\right)\right]^2$

$A_{i,i} \leftarrow 0.45724 \cdot \left[\frac{P_{r_i}}{(T_{r_i})^2}\right] \cdot \alpha_i$

$B_i \leftarrow 0.07780 \cdot \left(\frac{P_{r_i}}{T_{r_i}}\right)$

for $i \in 1 .. n$

for $j \in 1 .. n$

$A_{i,j} \leftarrow (1 - k_{i,j}) \cdot \sqrt{A_{i,i} \cdot A_{j,j}}$

$A_{mix} \leftarrow \sum_{i=1}^{n} \sum_{j=1}^{n} (y_i \cdot y_j \cdot A_{i,j})$

$B_{mix} \leftarrow \sum_{i=1}^{n} (y_i \cdot B_i)$

$p \leftarrow -1 + B_{mix}$

$q \leftarrow A_{mix} - 3 \cdot B_{mix}^2 - 2 \cdot B_{mix}$

$r \leftarrow -A_{mix} \cdot B_{mix} + B_{mix}^2 + B_{mix}^3$

$Z \leftarrow \text{root}(p, q, r)_1$

$C \leftarrow \ln\left[\frac{Z + (1 + \sqrt{2}) \cdot B_{mix}}{Z + (1 - \sqrt{2}) \cdot B_{mix}}\right]$

for $i \in 1 .. 2$

$$\phi_i \leftarrow \exp\left[\frac{B_i\cdot(Z-1)}{B_{mix}} - \ln\left(Z - B_{mix}\right) - \frac{A_{mix}\cdot C}{2\sqrt{2}\cdot B_{mix}}\cdot\left[\frac{2\cdot\sum_{j=1}^{n}\left(y_j\cdot A_{i,j}\right)}{A_{mix}} - \frac{B_i}{B_{mix}}\right]\right]$$

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$\phi_L(T,P) :=$

$n \leftarrow 2$

for $i \in 1..n$

$T_{r_i} \leftarrow \frac{T}{T_{c_i}}$

$P_{r_i} \leftarrow \frac{P}{P_{c_i}}$

$\alpha_i \leftarrow \left[1 + \left[0.37464 + 1.54226\cdot\omega_i - 0.26992\cdot\left(\omega_i\right)^2\right]\cdot\left(1 - \sqrt{T_{r_i}}\right)\right]^2$

$A_{i,i} \leftarrow 0.45724\cdot\left[\frac{P_{r_i}}{\left(T_{r_i}\right)^2}\right]\cdot\alpha_i$

$B_i \leftarrow 0.07780\cdot\left(\frac{P_{r_i}}{T_{r_i}}\right)$

for $i \in 1..n$

for $j \in 1..n$

$A_{i,j} \leftarrow \left(1 - k_{i,j}\right)\cdot\sqrt{A_{i,i}\cdot A_{j,j}}$

$A_{mix} \leftarrow \sum_{i=1}^{n}\sum_{j=1}^{n}\left(x_i\cdot x_j\cdot A_{i,j}\right)$

$B_{mix} \leftarrow \sum_{i=1}^{n}\left(x_i\cdot B_i\right)$

$p \leftarrow -1 + B_{mix}$

$q \leftarrow A_{mix} - 3\cdot B_{mix}^2 - 2\cdot B_{mix}$

$r \leftarrow -A_{mix}\cdot B_{mix} + B_{mix}^2 + B_{mix}^3$

$Z \leftarrow \text{root}(p, q, r)_2$

$C \leftarrow \ln\left[\frac{Z + \left(1+\sqrt{2}\right)\cdot B_{mix}}{Z + \left(1-\sqrt{2}\right)\cdot B_{mix}}\right]$

$$\left[Z \cdot (1 - \sqrt{2}) \cdot B_{mix} \right]$$

for $i \in 1 .. n$

$$\phi_i \leftarrow \exp\left[\frac{B_i \cdot (Z - 1)}{B_{mix}} - \ln(Z - B_{mix}) - \frac{A_{mix} \cdot C}{2\sqrt{2} \cdot B_{mix}} \cdot \left[\frac{2 \cdot \sum_{j=1}^{2} (x_j \cdot A_{i,j})}{A_{mix}} - \frac{B_i}{B_{mix}} \right] \right]$$

ϕ

$$\phi_L(T, P) = \begin{pmatrix} 7.623 \\ 0.017 \end{pmatrix}$$

$$\phi_V(T, P) = \begin{pmatrix} 1.021 \\ 0.493 \end{pmatrix}$$