Homework 3 Solution

3.34

a) $T_c = 318.7\ K$ $T = 348.15\ K$ $T_r = \frac{T}{T_c} = 1.092$

$P_c = 37.6\ bar$ $P = 15\ bar$ $P_r = \frac{P}{P_c} = 0.399$

$\omega = 0.286$

$B = -194\ \frac{cm^3}{mol}$ $C = 15300\ \frac{cm^6}{mol^2}$

$$\frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2}$$

$$\boxed{V = 1722\ \frac{cm^3}{mol}}$$

$$Z = \frac{PV}{RT} = \boxed{0.893}$$

b) $B_0 = 0.083 - \frac{0.422}{T_r^{1.6}}$ $B_0 = -0.283$

$B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$ $B_1 = 0.02$

$$Z = 1 + (B_0 + \omega B_1)\frac{P_r}{T_r} \qquad \boxed{Z = 0.899}$$

$$V = \frac{ZRT}{P} \qquad \boxed{V = 1734\ \frac{cm^3}{mol}}$$

3.34 cont'   SRK EOS

d) $\sigma = 1$ $\varepsilon = 0$ $\Omega = 0.08664$ $\Psi = 0.42748$

(From Table 3.1)

$$\alpha(T_r, \omega) = \left[1 + (0.480 + 1.574\,\omega - 0.176\,\omega^2)\left(1 - T_r^{1/2}\right)\right]^2$$

$$q(T_r) = \frac{\Psi\,\alpha(T_r, \omega)}{\Omega\,T_r}$$ (equation 3.51)

$$\beta(T_r, P_r) = \frac{\Omega\,P_r}{T_r}$$ (equation 3.50)

$$Z = 1 + \beta(T_r, P_r) - q(T_r)\,\beta(T_r, P_r)\,\frac{Z - \beta(T_r, P_r)}{(Z + \varepsilon \cdot \beta(T_r, P_r)) \cdot (Z + \sigma\beta(T_r, P_r))}$$

$$\boxed{Z = 0.895}$$

$$V = \frac{ZRT}{P}$$ $$\boxed{V = 1726.9\ \frac{cm^3}{mol}}$$

3.34 cont

e) Peng / Robinson EOS

$\sigma = 1 + \sqrt{2}$ $\varepsilon = 1 - \sqrt{2}$ $\Omega = 0.07779$ $\Psi = 0.45724$ (Table 3.1)

$$\alpha(T_r, \omega) = \left[1 + (0.37464 + 1.54226\omega - 0.26992\omega^2)\left(1 - T_r^{1/2}\right)\right]^2$$ (Table 3.1)

$$q(T_r) = \frac{\Psi \alpha(T_r, \omega)}{\Omega \cdot T_r}$$ (Equation 3.51)

$$\beta(T_r, P_r) = \frac{\Omega P_r}{T_r}$$ (equation 3.50)

$$Z = 1 + \beta(T_r, P_r) - q(T_r)\beta(T_r, P_r)\frac{Z - \beta(T_r, P_r)}{(Z + \varepsilon\beta(T_r, P_r)) \cdot (Z + \sigma\beta(T_r, P_r))}$$

$$\boxed{Z = 0.882}$$

$$V = \frac{ZRT}{P}$$ $$\boxed{V = 1701.5 \frac{cm^3}{mol}}$$

3.53

For n-pentane

$T_c = 469.7\ K$ $\quad P_c = 33.7\ bar$ $\quad \rho_1 = 0.63\ \frac{gm}{cm^3}$

$T_1 = 291.15\ K$ $\quad P_1 = 1\ bar$ $\quad T_2 = 413.15\ K$

$P_2 = 120\ bar$

$T_{r1} = \frac{T_1}{T_c}$ $\quad P_{r_1} = \frac{P_1}{P_c}$ $\quad T_{r_2} = \frac{T_2}{T_c}$ $\quad P_{r_2} = \frac{P_2}{P_c}$

$T_{r_1} = 0.62$ $\quad P_{r_1} = 0.03$ $\quad T_{r_2} = 0.88$ $\quad P_{r_2} = 3.561$

From Fig (3.17) $\quad \rho_{r_1} = 2.69$ $\quad \rho_{r_2} = 2.27$

By equation (3.65)

$$\rho_2 = \rho_1 \frac{\rho_{r_2}}{\rho_{r_1}}$$

$$\boxed{\rho_2 = 0.532\ \frac{gm}{cm^3}}$$

3.61

For Methane

$\omega = 0.012$ $\quad T_c = 190.6\ K$ $\quad P_c = 45.99\ bar$

at Standard Condition

$$T = \left[(60-32)\frac{5}{9} + 273.15\right] K \qquad T = 288.706\ K$$

$P = 1\ atm$

$T_r = \frac{T}{T_c}$ $\quad T_r = 1.515$ $\qquad P_r = \frac{P}{P_c}$ $\quad P_r = 0.022$

$B_0 = 0.083 - \frac{0.422}{T_r^{1.6}}$ $\qquad B_0 = -0.134$

$B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$ $\qquad B_1 = 0.109$

$Z_0 = 1 + B_0 \frac{P_r}{T_r}$ $\qquad Z_0 = 0.998$

$Z_1 = B_1 \frac{P_r}{T_r}$ $\qquad Z_1 = 0.00158$

$Z = Z_0 + \omega Z_1$ $\qquad Z = 0.998$

$V_1 = \frac{ZRT}{P}$ $\qquad V_1 = 0.024 \frac{m^3}{mol}$

3.01 cont.

a) At actual condition $T = \left[(50-32)\frac{5}{9} + 273.15\right] K$

$T = 283.15\ K$

$P = 300\ psi$

$T_r = \frac{T}{T_c}$ $T_r = 1.486$ $P_r = \frac{P}{P_c}$ $P_r = 0.45$

$B_0 = 0.083 - \frac{0.422}{T_r^{1.6}}$ $B_0 = -0.141$

$B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$ $B_1 = 0.106$

$Z_0 = 1 + B_0 \frac{P_r}{T_r}$ $Z_0 = 0.957$

$Z_1 = B_1 \frac{P_r}{T_r}$ $Z_1 = 0.0322$

$Z = Z_0 + \omega Z_1$ $Z = 0.958$

$V_2 = \frac{ZRT}{P}$ $V_2 = 0.0322$

$q_1 = 150 \times 10^6 \frac{ft^3}{day}$ $q_2 = q_1 \frac{V_2}{V_1}$ $\boxed{q_2 = 6.915 \times 10^6 \frac{ft^3}{day}}$

b) $n_1 = \frac{q_1}{V_1}$ $\boxed{n_1 = 7.485 \times 10^3 \frac{kmol}{hr}}$

c) $D = 22.624$ $A = \frac{\pi}{4} D^2$ $A = 0.259 m^2$

$u = \frac{q_2}{A}$ $\boxed{u = 8.738 \frac{m}{s}}$

4.13

let P represent the vapor pressure

$$\ln\left(\frac{P}{kPa}\right) = 48.157543 - \frac{5622.7\,K}{T} - 4.70504\ln\left(\frac{T}{K}\right)$$

$$\frac{dP}{dT} = P\left(\frac{5622.7\,K}{T^2} - \frac{4.70504}{T}\right)$$

$$\frac{dP}{dT} = 0.029\ \frac{bar}{K}$$

$$P = 87.396\ kPa$$

$$\Delta H = 31600\ \frac{J}{mol} \qquad V_{liq} = 96.49\ \frac{cm^3}{mol}$$

Clapeyron equation : $\frac{dP}{dT} = \frac{\Delta H}{T(V - V_{liq})}$

V = vapor molar volume $\qquad V = V_{liq} + \frac{\Delta H}{T \cdot dP/dT}$

(Eq. 3.38) $\qquad B = V\left(\frac{PV}{RT} - 1\right)$

$$\boxed{B = -1369.5\ \frac{cm^3}{mol}}$$