Question Number II *(15 Marks ~ 27 minutes)*

PART A

A mixture of gases is stored at 69 atm and 660 K in a cylindrical tank 10 m diameter. You know that there are 3 components in the mixture: methane (M=16 kg/kmol, Tc=190.4K, Pc=46atm, w=0.011), propane (M=44 kg/kmol, Tc=369.8K, Pc=42.5atm, w=0.153), and n-octane (M=114.23 kg/kmol, Tc=568.8K, Pc=24.9atm, w=0.398).

a) The methane was originally stored in a separate 6 m diameter spherical tank at 100 atm and 300 K before all of the contents were added to the cylindrical tank. Determine the moles of methane that was in this tank using the generalized compressibility chart. (/3)

$$Pv = ZnRT \rightarrow n = \frac{Pv}{ZRT}$$

$$T_r = \frac{T}{T_c} = \frac{300}{190.4} = 1.5756$$

$$P_r = \frac{P}{P_c} = \frac{100}{46\,atm} = 2.1739$$

$$Z = 0.87$$

$$v = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi (3m)^3$$

$$v = 113.1\ m^3$$

$$n = \frac{Pv}{ZRT} = \frac{(100\,atm)(113.1\,m^3)}{(0.87)(0.08205\,\frac{atm\,m^3}{kmol\,K})(300K)}$$

$$\boxed{n = 528.1\ \text{kmol methane}}$$

b) It is known that the pseudocritical temperature of the mixture in the cylindrical tank is 440 K and the pseudocritical pressure is 34.5 atm and that the mole fraction of methane is 0.4833. Determine the molar composition of the mixture. (/3)

$\rightarrow$ should have been octane

$\rightarrow$ no solution as written (see next page)

$$T_{pc} = 440K = y_1(190.4) + y_2(369.8) + y_3(568.8)$$

$$P_{pc} = 34.5\,atm = y_1(46) + y_2(42.5) + y_3(24.9)$$

should be ~~y_3 = ...~~ $y_3 = 0.4833$ (but told $y_1 = 0.4833$)

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(1) $y_3 = 0.4833 \longrightarrow 440 = 190.4y_1 + 369.8y_2 + 274.9$

$$34.5 = 46y_1 + 42.5y_2 + 12.034$$

$$165.1 = 190.4y_1 + 369.8y_2 \longrightarrow 0.86712 = y_1 + 1.94223y_2$$

$$22.466 = 46y_1 + 42.5y_2 \longrightarrow 0.48839 = y_1 + 0.9239y_2$$

$$0.37873 = 1.01833y_2$$

$$\boxed{y_1 = 0.1448} \longleftarrow \boxed{y_2 = 0.3719}$$

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(2) $y_1 = 0.4833 \longrightarrow 440 = 92.02 + 369.8y_2 + 568.8y_3$

$$34.5 = 22.2318 + 42.5y_2 + 24.9y_3$$

$$347.98 = 369.8y_2 + 568.8y_3 \longrightarrow 0.940995 = y_2 + 1.538y_3$$

$$12.2682 = 42.5y_2 + 24.9y_3 \longrightarrow 0.28866 = y_2 + 0.58588y_3$$

$$0.6523 = 0.95212y_3$$

also impossible $\boxed{y_2 = -0.113} \longleftarrow \boxed{y_3 = 0.6851}$ impossible!!

Question Number II *(Continued)*

c) Use the van der Waals Equation of State and mixing rules to determine the height of the cylindrical tank storing the mixture at 69 atm and 660 K. Van der Waals constants for methane are (a=2.253 atm $(m^3/kmol)^2$, b=0.0428 $m^3/kmol$) and propane are (a=9.2536 atm $(m^3/kmol)^2$, b=0.1338 $m^3/kmol$). If you need to iterate, only perform one iteration but state how you would continue. (/6)

[This solution uses $y_1 = 0.1448$ $y_2 = 0.3719$ $y_3 = 0.4833$]

need a, b for octane

$$a = \frac{27}{64}\frac{R^2 T_c^2}{P_c} = \frac{27}{64}\frac{(0.08205)^2(568.8)^2}{24.9} = 36.9 \text{ atm}(m^3/kmol)^2$$

$$b = \frac{RT_c}{8P_c} = \frac{0.08205 \times 568.8}{8 \times 24.9} = 0.2342 \text{ m}^3/\text{kmol}$$

$$b = \sum y_i b_i = 0.1448(0.0428) + 0.3719(0.1338) + 0.4833(0.2342) = 0.16395 \text{ m}^3/\text{kmol}$$

$$a = (\sum y_i \sqrt{a_i})^2 \qquad \sqrt{a_1} = 1.501 \qquad \sqrt{a_2} = 3.042 \qquad \sqrt{a_3} = 6.0745$$

$$a = [0.1448(1.501) + 0.3719(3.042) + 0.4833(6.0745)]^2 = 18.36 \text{ atm}\left(\frac{m^3}{kmol}\right)^2$$

$$V_m^3 - \left[b + \frac{RT}{P}\right]V_m^2 + \frac{a}{P}V_m - \frac{ab}{P} = 0$$

$$V_m^3 - \left[0.16395 + \frac{0.08205 \times 660}{69}\right]V_m^2 + \frac{18.36}{69}V_m - \frac{18.36 \times 0.16395}{69} = 0$$

$$V_m^3 - 0.948 V_m^2 + 0.266 V_m - 0.04362 = 0$$

$$V_m = 0.948 - \frac{0.266}{V_m} + \frac{0.04362}{V_m^2} \longrightarrow V_{m_1} = \frac{RT}{P} = 0.7848$$

$$V_{m_2} = 0.948 - \frac{0.266}{0.7848} + \frac{0.04362}{(0.7848)^2} = 0.6805$$

$$V_{m_3} = 0.6519 \quad , \quad V_{m_4} = 0.6426 \text{ m}^3/\text{kmol}$$

$$y_1 = 0.1448 = \frac{528.1 \text{ kmol}}{n_T}$$

$$n_T = 3647 \text{ kmol}$$

$$V_m = \frac{V}{n} \rightarrow V = V_m n = 2343.6 \text{ m}^3$$

$$V = \pi r^2 h \qquad 2343.6 m^3 = \pi(5m)^2 h$$

$$\boxed{h = 29.8 m^3}$$