Question Number II *(14 Marks ~ 25 minutes)*

A gas mixture is comprised of 22 mol% carbon dioxide (CO_2) with the remainder being nitrogen (N_2). A tank contains 1.0×10^4 moles of this mixture at 231.5 K and a pressure of 92.75 atm. Use the data in the following table to answer the questions below.

Gas	Molar Mass (kg/kmol)	T_c (K)	P_c (atm)	ω
CO_2	44.01	304.2	72.8	0.225
N_2	28.00	126.2	33.5	0.04

a) What is the average molecular mass of the gas in the tank? (/2)

$$\bar{M} = \sum y_i M_i = (0.22 \times 44.01) + (0.78 \times 28) = \boxed{31.52 \left(\frac{kg}{kmol}\right)}$$

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b) Use the ideal gas law to calculate the volume of the tank (m^3). (/2)

$$PV = nRT \Rightarrow V = \frac{nRT}{P} = \frac{(1 \times 10^4 \, mol)(8.314 \, \frac{Pa\,m^3}{mol\,K})(231.5\,K)}{(92.75\,atm)(101325\,Pa)}$$ 1

$$\Rightarrow \boxed{V = 2.048 \, (m^3)}$$ 1

c) Use the Pseudocritical point method and the Pitzer-Curl Tables to calculate the volume of the tank (m^3). (/4)

0.5 $T_{Pc} = \sum y_i T_{ci} = 0.22(304.2) + 0.78(126.2) = 165.36 \, (K)$

0.5 $P_{Pc} = \sum y_i P_{ci} = 0.22(72.8) + 0.78(33.5) = 42.146 \, (atm) = 4270.44 \, (kPa)$

0.5 $\bar{w} = 0.22(0.225) + 0.78(0.04) = 0.0807$

0.5 $T_{Pr} = \frac{T}{T_{Pc}} = \frac{231.5}{165.36} = 1.40$ 0.5 $P_{Pr} = \frac{P}{P_{Pc}} = \frac{92.75}{42.146} = 2.20$

From the Pitzer-curl Tables $\begin{cases} z^{(0)} = 0.759 \\ z^{(1)} = 0.20 \end{cases}$ 0.5 $\Rightarrow z_m = z^{(0)} + \omega_{Pc} z^{(1)}$

$z_m = 0.759 + (0.0807)(0.2)$

$\Rightarrow \boxed{z_m = 0.775}$ 0.5

$\Rightarrow PV = z_m nRT \Rightarrow V = \frac{z_m nRT}{P}$

$$\Rightarrow V = \frac{(0.775)(1 \times 10^4)(8.314)(231.5)}{(92.75\,atm)(101325)} = \boxed{1.587 (m^3)}$$ 0.5

d) Use the Pseudocritical point method and the generalized compressibility chart to determine the compressibility of the mixture. (/1)

$$\begin{cases} P_{Pr} = 2.2 \\ T_{Pr} = 1.4 \end{cases} \xrightarrow[\text{chart}]{\text{From Compressibility}} \boxed{Z = 0.785}$$

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e) Use the van der Waals equation of state to calculate the volume of the mixture (m^3). The van der Waals parameters for CO_2 are a=3.610 atm $(m^3/kmol)^2$, and b=0.0429 $m^3/kmol$). If you need to iterate, perform 2 iterations. (/5)

Van der Waals eq'n: $V_m^3 - \left[b + \frac{RT}{P}\right] V_m^2 + \frac{a}{P} V_m - \frac{ab}{P} = 0$

a&b for CO_2 Provided: $a = 3.610 \frac{atm(m^3)^2}{kmol^2}$, $b = 0.0429 \left(\frac{m^3}{kmol}\right)$

0.5

For N_2: $a_{N_2} = \frac{27 R^2 T^2}{64 P_c} = \frac{27}{64} \frac{(0.08205)^2 (126.2)^2}{33.5} = 1.35025\ (atm)\left(\frac{m^3}{kmol}\right)^2$

0.5 $b_{N_2} = \frac{RT_c}{8P_c} = \frac{(0.08205)(126.2)}{8 \times 33.5} = 0.038637 \frac{m^3}{kmol}$

0.5 $\Rightarrow \bar{a} = \left[\sum y_i \sqrt{a_i}\right]^2 = \left[(0.22)(1.90) + (0.78)(1.162)\right]^2 = 1.7539\ atm(m^3/kmol)^2$

0.5 $\Rightarrow \bar{b} = \sum y_i b_i = \left[(0.22)(0.04286) + (0.78)(0.038637)\right] = 0.03957 \left(\frac{m^3}{kmol}\right)$

0.5 $\Rightarrow V_m^3 - \left[0.03957 + \frac{0.08205 \times 231.5}{92.75}\right] V_m^2 + \frac{1.7539}{92.75} V_m - \frac{1.7539 \times 0.03957}{92.75} = 0$

0.5 $\Rightarrow V_m^3 - 0.24436 V_m^2 + 0.01891 V_m - 0.00074827 = 0$

0.5 $\Rightarrow V_m = 0.24436 - \frac{0.01891}{V_m} + \frac{0.00074827}{V_m^2}$

First guess $V_{m_1} = 0.2048 \left(\frac{m^3}{kmol}\right) \Rightarrow f(V_{m_1}) = 0.169866 = V_{m2} \left(\frac{m^3}{kmol}\right)$ 0.5

2^{nd} guess $V_{m2} = 0.1699 \Rightarrow f(V_{m_2}) = 0.1590 = V_{m3} \left(\frac{m^3}{kmol}\right)$ 0.5

$\xrightarrow[n(10\,kmol)]{\text{multiply by}} \boxed{V = 1.59\ m^3}$ $\left(\frac{m^3}{kmol}\right)$ 0.5