PROBLEM 11.7

KNOWN: A vessel whose volume is 1 m³ contains 4 mol of CH₄ at 1000°C. Find: Estimate the pressure using (a) the ideal gas model, (b) the Redlich-Kwong equation, (c) the Benedict-Webb-Rubin equation.

Analysis:
(a) Ideal Gas Model

\[ p = \frac{RT}{V} = \frac{\left(\frac{8314 \text{ N·m·K}}{\text{mol·K}}\right)(373\text{K})}{1 \text{ m}^3/4 \text{ mol}} = \frac{1 \text{ bar}}{10^5 \text{ N·m}^2/\text{m}^2} = 124.04 \text{ bar} \]

(b) Redlich-Kwong, with data from Table A-24

\[ p = \frac{RT}{V - b} - \frac{a}{V(V + b)(T/2)} = \frac{\left(\frac{8314 \text{ N·m·K}}{\text{mol·K}}\right)(373\text{K})}{0.25 - 0.02965 \text{ m}^3/\text{mol}} - \frac{1 \text{ bar}}{10^5 \text{ N·m}^2} \]

\[ = 140.74 - 23.78 = 116.96 \text{ bar} \]

(c) Benedict-Webb-Rubin, with data from Table A-24

\[ p = \frac{RT}{V} + \frac{[BR - A - \frac{C}{T^2}]}{V^2} = \frac{\left(\frac{8314 \text{ N·m·K}}{\text{mol·K}}\right)(373\text{K})}{0.035 \text{ m}^3/\text{mol}} \]

\[ + \left[ \left(0.04260 \times 0.08314 \times (373) - 1.8796 - 2.277 \times 10^{-4} \right) \frac{1}{(373)^2} \right] + \left(0.00612 \times 0.08314 \times (373) - 0.0501 \right) \]

\[ + \left( \frac{2.679 \times 10^{-4}}{(0.25)^3 (373)^2} \right) \left(1 + 0.0062 \right) \exp \left(-\frac{0.0062}{(0.25)^2}\right) \]

\[ = 124.04 - 11.57 + 3.50 + 0.03 + 1.18 = 117.18 \text{ bar} \]

Discussion: The Redlich-Kwong and Benedict-Webb-Rubin equations suggest that the pressure is in the safe range. Using \( P_c \) and \( T_c \) from Table A-1,

\[ \frac{P_c}{46.7 \text{ bar}} = 2.59, \quad \frac{T_c}{1910 \text{ K}} = 1.95 \]

Figure A-2 gives \( Z = 0.96 \), and so \( p = \frac{ZRT}{V} = (0.96)(124.04) \text{ bar} = 119.1 \text{ bar} \), which is also in the safe range.