PROBLEM 5.80

A gas mixture consisting of 15.0 mole% methane, 60.0% ethylene, and 25.0 mole% ethane is compressed to a pressure of 175 bar at 90°C. It flows through a process line in which the velocity should be no greater than 10 m/s. What flow rate (kmol/min) of the mixture can be handled by a 2-cm internal diameter pipe?

Strategy

The maximum velocity and internal diameter of the pipe allow us to determine a maximum volumetric flow rate (= velocity times cross-sectional area). Knowing the temperature and pressure, we can then calculate a maximum molar flow rate using an appropriate equation of state for the gas mixture.

At 175 bar, the mixture seems to be highly compressed; however, the 90°C temperature might be sufficiently high to mitigate the effect of pressure on the nonideality of the mixture. We will first apply the rule-of-thumb on p. 192 to decide whether or not to assume ideal gas behavior. If we cannot and we want to use a non-ideal equation of state from the text, we have no choice: the compressibility factor equation of state coupled with Kay's rule is the only correlation given that enables us to do *PVT* calculations for mixtures of gases.

Solution

Test of ideality

$$\hat{V} = \frac{RT}{P} = \frac{\_\_\_\_\_ \frac{\text{L}\cdot\text{bar}}{\text{mol}\cdot\text{K}} \times \_\_\_\_ \text{K}}{\_\_\_\_\_ \text{atm}} = \_\_\_\_\_ \frac{\text{L}}{\text{mol}} < \_\_\_\_\_ \frac{\text{L}}{\text{mol}} \Rightarrow \underline{\text{nonideal}} \qquad \textbf{(5.80-1)}$$

Maximum volumetric flow rate

$$\dot{V}_{\max} = u_{\max} A_{\text{pipe}} = \frac{\_\_\_ \text{m} \,\big|\, \_\_\_ \text{s} \,\big|\, \_\_\_\_\_ \text{cm}^2 \,\big|\, \_\_\_\_\_ \text{m}^2}{\text{s} \,\big|\, \_\_\_ \text{min} \,\big|\, \_\_\_\_\_ \text{cm}^2} = \_\_\_\_\_ \frac{\text{m}^3}{\text{min}} \qquad \textbf{(5.80-2)}$$

Calculation of pseudocritical temperature and pressure (Kay's rule) **(5.80-3)**

Critical Properties			
Component	Mol Fraction	T_c, K	P_c, atm
methane	.15	_____	_____
ethylene	.60	_____	_____
ethane	.25	_____	_____

Eq. (5.4-9) $\Rightarrow T_c' =$ 0.15(_____ K) + 0.60(_____ K) + 0.25(_____ K) = _____ K

Eq. (5.4-10) $\Rightarrow P_c' =$ 0.15(_____ atm) + 0.60(_____ atm) + 0.25(_____atm) = _____ atm