

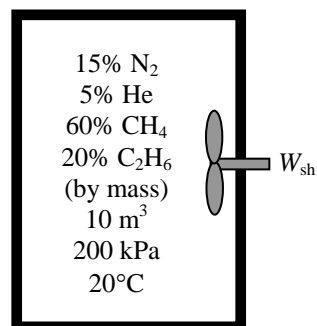
**13-56** The mass fractions of components of a gas mixture are given. This mixture is enclosed in a rigid, well-insulated vessel, and a paddle wheel in the vessel is turned until specified amount of work have been done on the mixture. The mixture's final pressure and temperature are to be determined.

**Assumptions** All gases will be modeled as ideal gases with constant specific heats.

**Properties** The molar masses of  $N_2$ , He,  $CH_4$ , and  $C_2H_6$  are 28.0, 4.0, 16.0, and 30.0 kg/kmol, respectively (Table A-1). The constant-pressure specific heats of these gases at room temperature are 1.039, 5.1926, 2.2537, and 1.7662 kJ/kg·K, respectively (Table A-2a).

**Analysis** We consider 100 kg of this mixture. The mole numbers of each component are

$$\begin{aligned} N_{N_2} &= \frac{m_{N_2}}{M_{N_2}} = \frac{15 \text{ kg}}{28 \text{ kg/kmol}} = 0.5357 \text{ kmol} \\ N_{He} &= \frac{m_{He}}{M_{He}} = \frac{5 \text{ kg}}{4 \text{ kg/kmol}} = 1.25 \text{ kmol} \\ N_{CH_4} &= \frac{m_{CH_4}}{M_{CH_4}} = \frac{60 \text{ kg}}{16 \text{ kg/kmol}} = 3.75 \text{ kmol} \\ N_{C_2H_6} &= \frac{m_{C_2H_6}}{M_{C_2H_6}} = \frac{20 \text{ kg}}{30 \text{ kg/kmol}} = 0.6667 \text{ kmol} \end{aligned}$$



The mole number of the mixture is

$$N_m = N_{N_2} + N_{He} + N_{CH_4} + N_{C_2H_6} = 0.5357 + 1.25 + 3.75 + 0.6667 = 6.2024 \text{ kmol}$$

The apparent molecular weight of the mixture is

$$M_m = \frac{m_m}{N_m} = \frac{100 \text{ kg}}{6.2024 \text{ kmol}} = 16.12 \text{ kg/kmol}$$

The constant-pressure specific heat of the mixture is determined from

$$\begin{aligned} c_p &= mf_{N_2} c_{p,N_2} + mf_{He} c_{p,He} + mf_{CH_4} c_{p,CH_4} + mf_{C_2H_6} c_{p,C_2H_6} \\ &= 0.15 \times 1.039 + 0.05 \times 5.1926 + 0.60 \times 2.2537 + 0.20 \times 1.7662 \\ &= 2.121 \text{ kJ/kg} \cdot \text{K} \end{aligned}$$

The apparent gas constant of the mixture is

$$R = \frac{R_u}{M_m} = \frac{8.134 \text{ kJ/kmol} \cdot \text{K}}{16.12 \text{ kg/kmol}} = 0.5158 \text{ kJ/kg} \cdot \text{K}$$

Then the constant-volume specific heat is

$$c_v = c_p - R = 2.121 - 0.5158 = 1.605 \text{ kJ/kg} \cdot \text{K}$$

The mass in the container is

$$m_m = \frac{P_1 V_m}{RT_1} = \frac{(200 \text{ kPa})(10 \text{ m}^3)}{(0.5158 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(293 \text{ K})} = 13.23 \text{ kg}$$

An energy balance on the system gives

$$W_{sh,in} = m_m c_v (T_2 - T_1) \longrightarrow T_2 = T_1 + \frac{W_{sh,in}}{m_m c_v} = (293 \text{ K}) + \frac{100 \text{ kJ}}{(13.23 \text{ kg})(1.605 \text{ kJ/kg} \cdot \text{K})} = \mathbf{297.7 \text{ K}}$$

Since the volume remains constant and this is an ideal gas,

$$P_2 = P_1 \frac{T_2}{T_1} = (200 \text{ kPa}) \frac{297.7 \text{ K}}{293 \text{ K}} = \mathbf{203.2 \text{ kPa}}$$