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## Question: A mixture of 60% methane and 40% propane, by volume, is c...

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A mixture of 60% methane and 40% propane, by volume, is compressed in an adiabatic compressor from 40°C,  $0.4 \times 10^6 \text{ N/m}^2$  to  $1.2 \times 10^6 \text{ N/m}^2$ . Determine the minimum work required per unit mass, the final temperature of the mixture, and the entropy change for each gas, assuming ideal gas behavior with constant specific heats. Explain the entropy changes determined for each gas and the total entropy change for the process.

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## Expert Answer



sundeeep answered this  
284 answers

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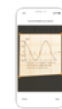


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Given

$$\text{initial temperature } (T_1) = 40^\circ\text{C} = 313\text{K}$$

$$\begin{aligned} \text{initial pressure } (P_1) &= 0.4 \times 10^6 \text{ N/m}^2 \\ &= 0.4 \text{ MPa} = 400 \text{ kPa} \end{aligned}$$

$$\text{final pressure } (P_2) = 1.2 \times 10^6 \text{ N/m}^2 = 1.2 \text{ MPa} = 1200 \text{ kPa}$$

$$\begin{aligned} \text{specific heat ratio } (\gamma) \\ \text{for methane (CH}_4) &= 1.304 \end{aligned}$$

$$\begin{aligned} \text{specific heat ratio } (\gamma) \\ \text{for propane} &= 1.13 \end{aligned}$$

$$\text{equivalent specific heat ratio} = 0.6(1.304) + 0.4(1.13)$$

$$\boxed{\gamma_{\text{mixture}} = 1.234}$$

from Ideal gas equation.

$$PV = mRT \quad (\text{freezing mass} = 1 \text{ kg})$$

$$PV = RT$$

$$V = \frac{RT}{P}$$

$$V_1 = \frac{0.287 \times 313}{400}$$

$$\boxed{V_1 = 0.2245 \text{ m}^3}$$

for Adiabatic process  $PV^\gamma = \text{constant}$ .

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$V_2^\gamma = \frac{P_1 V_1^\gamma}{P_2}$$

$$V_2 = V_1 \left( \frac{P_1}{P_2} \right)^{1/\gamma}$$

$$= 0.2245 \times \left( \frac{400}{1200} \right)^{1/1.234}$$

$$\boxed{V_2 = 0.092 \text{ m}^3}$$

work done in an Adiabatic process is given by

$$W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$$

$$= 1000 \times 0.2245 - 1000 \times 0.092$$



$$\boxed{W} = -88.024 \text{ KJ}$$

The minimum work required per unit mass is 88.024 KJ  
 here '-ve' sign indicates work is done on the system.

change in entropy of an ideal gas is given by

$$\Delta S_{\text{sys}} = C_v \ln\left(\frac{P_2}{P_1}\right) + C_p \ln\left(\frac{V_2}{V_1}\right)$$

specific heat at constant volume  $C_v = 0.45$   
 (methane)

specific heat at constant volume  $C_v = 0.24$   
 (propane)

specific heat at constant volume of the mixture.

$$= 0.6(0.45) + 0.4(0.24)$$

$$\boxed{C_{v \text{ mix}} = 0.406 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}}$$

$$\frac{C_p}{C_v} = \gamma$$

$$C_p = \gamma \cdot C_v$$

$$C_p = 1.234 \times 0.406$$

$$\boxed{C_{p \text{ mix}} = 0.501 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}}$$

$$\Delta S_{\text{sys}} = 0.406 \ln\left(\frac{1200}{400}\right) + 0.501 \ln\left(\frac{0.092}{0.2245}\right)$$

$$\boxed{\Delta S_{\text{sys}} = -8.99 \times 10^{-4} \frac{\text{kJ}}{\text{kg}\cdot\text{K}}}$$

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grams of krypton. What is the partial pressure of each gas in the mixture?  $P_{N_2} = \text{ mm Hg}$   $P_{Kr} = \text{ mm Hg}$  2) A mixture of hydrogen and nitrogen gases contains hydrogen at a partial pressure of 219mm Hg and nitrogen at a partial pressure of 685 mm Hg. What...

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