**15-51** The higher and lower heating values of liquid propane are to be determined and compared to the listed values.

Assumptions **1** Combustion is complete. **2** The combustion products contain CO_2, H_2O, and N_2. **3** Combustion gases are ideal gases.

Properties The molar masses of C, O_2, H_2, and air are 12, 32, 2, and 29 kg/kmol, respectively (Table A-1).

Analysis The combustion reaction with stoichiometric air is

$$C_3H_8(l) + 5(O_2 + 3.76N_2) \longrightarrow 3CO_2 + 4H_2O + 18.8N_2$$
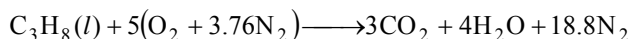
Both the reactants and the products are taken to be at the standard reference state of 25°C and 1 atm for the calculation of heating values. The heat transfer for this process is equal to enthalpy of combustion. Note that N_2 and O_2 are stable elements, and thus their enthalpy of formation is zero. Then,
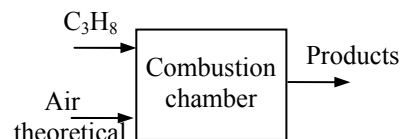
$$q = h_C = H_P - H_R = \sum N_P \bar{h}_{f,P}^\circ - \sum N_R \bar{h}_{f,R}^\circ = \left(N\bar{h}_f^\circ\right)_{CO2} + \left(N\bar{h}_f^\circ\right)_{H2O} - \left(N\bar{h}_f^\circ\right)_{C3H8}$$

The $\bar{h}_f^\circ$ of liquid propane is obtained by adding $\bar{h}_{fg}$ of propane at 25°C to $\bar{h}_f^\circ$ of gas propane ($103,850 + 44.097 \times 335 = 118,620$ kJ/kmol). For the HHV, the water in the products is taken to be liquid. Then,

$$h_C = (3 \text{ kmol})(-393,520 \text{ kJ/kmol}) + (4 \text{ kmol})(-285,830 \text{ kJ/kmol}) - (1 \text{ kmol})(-118,620 \text{ kJ/kmol})$$
$$= -2,205,260 \text{ kJ/kmol propane}$$

The HHV of the liquid propane is

$$HHV = \frac{-h_C}{M_m} = \frac{2,205,260 \text{ kJ/kmol } C_3H_8}{44.097 \text{ kg/kmol } C_3H_8} = \textbf{50,010 kJ/kg } \textbf{C}_3\textbf{H}_8$$

The listed value from Table A-27 is **50,330 kJ/kg**. For the LHV, the water in the products is taken to be vapor. Then,

$$h_C = (3 \text{ kmol})(-393,520 \text{ kJ/kmol}) + (4 \text{ kmol})(-241,820 \text{ kJ/kmol}) - (1 \text{ kmol})(-118,620 \text{ kJ/kmol})$$
$$= -2,029,220 \text{ kJ/kmol propane}$$

The LHV of the propane is then

$$LHV = \frac{-h_C}{M_m} = \frac{2,029,220 \text{ kJ/kmol } C_3H_8}{44.097 \text{ kg/kmol } C_3H_8} = \textbf{46,020 kJ/kg } \textbf{C}_3\textbf{H}_8$$

The listed value from Table A-27 is **46,340 kJ/kg**. The calculated and listed values are practically identical.