PROBLEM 10.15

A mixture of 40% water and 60% carbon dioxide by mass is heated from 400K to 1000K at a constant pressure of 120 kPa. Find the total change in enthalpy and entropy using Table A.5 values.

ASSUMPTIONS
(1) STEADY FLOW
(2) CONSTANT PRESSURE
(3) NO CHEMICAL REACTIONS
(4) NEGLECTIBLE ΔKE AND ΔPE
(5) USE TABLE A.5 - CONSTANT SPECIFIC HEATS
(6) DALTON MODEL FOR MIXTURES APPLIES.

SOLUTION

FROM TABLE A.5

\[ C_{p0\text{H}_2O} = 1.872 \text{ kJ/kg K} \]
\[ C_{p0\text{CO}_2} = 0.842 \text{ kJ/kg K} \]
\[ R_w = 0.4615 \text{ kJ/kg K} \]
\[ R_{CO_2} = 0.1889 \text{ kJ/kg K} \]

SO THE CHANGE IN ENTHALPY IS

\[ \Delta h = h_2 - h_1 = C_{p0}(T_2 - T_1) \]

BUT SINCE WE HAVE A BINARY MIXTURE

\[ C_{p0} = C_{w}C_{p0\text{H}_2O} + C_{CO_2}C_{p0\text{CO}_2} \]
\[ = (0.4)(1.872 \frac{\text{kJ}}{\text{kg K}}) + (0.6)(0.842 \frac{\text{kJ}}{\text{kg K}}) \]
\[ C_{p0} = 1.254 \text{ kJ/kg K} \]

THUS,

\[ \Delta h = 752.4 \text{ kJ/kg} \]
Problem 10.15 cont’d

Now, for constant specific heats, the entropy change is:

\[ \Delta S = S_2 - S_1 = C_p \ln \left( \frac{T_2}{T_1} \right) - R \ln \left( \frac{p_2}{p_1} \right) \]

The gas const for the mixture is

\[ R_{\text{mix}} = \sum C_i R_i \]

\[ R_{\text{mix}} = 0.4 \left( 0.4615 \frac{\text{kJ}}{\text{K} \cdot \text{kg}} \right) + 0.6 \left( 0.1889 \frac{\text{kJ}}{\text{K} \cdot \text{kg}} \right) \]

\[ R_{\text{mix}} = 0.2979 \frac{\text{kJ}}{\text{K} \cdot \text{kg}} \]

So the entropy change is:

\[ \Delta S = 1.254 \frac{\text{kJ}}{\text{K} \cdot \text{kg}} \ln \left( \frac{1000}{400} \right) + 0.2979 \frac{\text{kJ}}{\text{K} \cdot \text{kg}} \ln \left( \frac{120}{120} \right) \]

\[ \Delta S = 1.149 \frac{\text{kJ}}{\text{K} \cdot \text{kg}} \]
PROBLEM 10.16

A MIXTURE OF 40% WATER AND 60% CARBON DIOXIDE BY MASS IS HEATED FROM 400K TO 1000K AT A CONSTANT PRESSURE OF 120 kPa. FIND THE TOTAL CHANGE IN ENTHALPY AND ENTROPY USING VARIABLE HEAT CAPACITY VALUES FROM TABLE A.8.

ASSUMPTIONS

(1) STEADY FLOW
(2) CONSTANT PRESSURE
(3) NO CHEMICAL REACTIONS
(4) NEGLECTIBLE ΔKE AND ΔPE
(5) VARIABLE HEAT CAPACITIES
(6) DALTON MODEL FOR MIXTURES APPLIES.

SOLUTION

FROM TABLE A.8

\[
\begin{align*}
 h_1 |_{CO_2} &= 303.76 \text{ kJ/kg} & h_2 |_{CO_2} &= 971.67 \text{ kJ/kg} \\
 S_0 |_{T_1} |_{CO_2} &= 5.119 \text{ kJ/kgK} & S_0 |_{T_2} |_{CO_2} &= 6.1190 \text{ kJ/kgK} \\
 h_1 |_{H_2O} &= 747.40 \text{ kJ/kg} & h_2 |_{H_2O} &= 1994.13 \text{ kJ/kg} \\
 S_0 |_{T_1} |_{H_2O} &= 11.0345 \text{ kJ/kgK} & S_0 |_{T_2} |_{H_2O} &= 12.9172 \text{ kJ/kgK}
\end{align*}
\]

THE ENTHALPY CHANGE IS

\[
\Delta h = \chi^{0.4} (h_2 |_{H_2O} - h_1 |_{H_2O}) + \chi^{0.6} (h_2 |_{CO_2} - h_1 |_{CO_2})
\]

THUS,

\[
\Delta h = 901.4 \text{ kJ/kg }
\]
THE ENTRPY CHANCE IS

\[ \Delta S = \frac{0.4}{\text{H}_2\text{O}} \left( S^{0}_{\text{H}_2\text{O}} - S^{0}_{\text{H}_2\text{O}} \right) \]

\[ + \frac{0.6}{\text{CO}_2} \left( S^{0}_{\text{CO}_2} - S^{0}_{\text{CO}_2} \right) \]

\[ = 0.4 \left( S^{0}_{T_2|\text{H}_2\text{O}} - S^{0}_{T_1|\text{H}_2\text{O}} - R_{\text{H}_2\text{O}} \ln \frac{P_{\text{H}_2\text{O}}}{P_{\text{i,\text{H}_2\text{O}}}} \right) \]

\[ + 0.6 \left( S^{0}_{T_2|\text{CO}_2} - S^{0}_{T_1|\text{CO}_2} - R_{\text{CO}_2} \ln \frac{P_{\text{CO}_2}}{P_{\text{i,\text{CO}_2}}} \right) \]

\[ \Delta S = 1.3535 \frac{\text{KJ}}{\text{kg-K}} \]

NOTICE THESE VALUES ARE OVER 15\% DIFFERENT (HIGHER) THAN THOSE CALCULATED IN PROBLEM 10.15!