열역학(다) Report #2

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[R2 - 1]

$$\mathrm{H_2O},\quad \text{steady flow}(\dot{m}=12\,\mathrm{kg/s}),\quad Q=0$$
$$P_1=4\,\mathrm{MPa},\quad T_1=500^\circ\mathrm{C},\quad V_1=80\,\mathrm{m/s}$$
$$P_2=30\,\mathrm{kPa},\quad x_2=0.92,\quad V_2=50\,\mathrm{m/s}$$

(a) Find Δke.
(b) Find $\dot{W}$.
(c) Find A_1.

[Solution]

$$\Delta \mathrm{ke}=\Delta\left(\frac{V^2}{2}\right)=\frac{V_2^2-V_1^2}{2}=\frac{50^2}{2}-\frac{80^2}{2}$$
$$=-1950.000\approx-1.950\,\mathrm{kJ/kg}$$
$$T_{\mathrm{sat\,@\,4\,MPa}}=250.35^\circ\mathrm{C}<T_1\quad\Rightarrow\quad\text{superheated vapor}$$
$$h_1=h_{@\,4\,\mathrm{MPa},500^\circ\mathrm{C}}=3446.0\,\mathrm{kJ/kg}$$
$$0<x_2<1\quad\Rightarrow\quad\text{wet vapor}$$
$$h_{2f}=h_{f@30\,\mathrm{kPa}}=289.27\,\mathrm{kJ/kg}$$
$$h_{2fg}=h_{fg@30\,\mathrm{kPa}}=2335.3\,\mathrm{kJ/kg}$$
$$h_2=h_{2f}+xh_{2fg}=289.27+(0.92)(2335.4)$$
$$=2437.838000\approx2437.8\,\mathrm{kJ/kg}$$
$$\cancel{q}+\left(h_1+\frac{V_1^2}{2}\right)=\left(h_2+\frac{V_2^2}{2}\right)+w$$
$$\dot{W}=\dot{m}w=\dot{m}\left(h_1-h_2-\Delta\mathrm{ke}\right)$$
$$=(12)\left(3446.0-2437.8+1.950\right)$$
$$=12121.8000\approx12.122\,\mathrm{MW}$$
$$\mathsf{v}_1=\mathsf{v}_{@\,4\,\mathrm{MPa},500^\circ\mathrm{C}}=0.08644\,\mathrm{m^3/kg}$$
$$\dot{\mathsf{V}}=\dot{m}\mathsf{v}=AV$$
$$A_1=\frac{\dot{m}\mathsf{v}_1}{V_1}=\frac{(12)(0.08644)}{80}=0.012966000$$
$$\approx0.01297\,\mathrm{m^2}$$

[R2 - 2]

$$\text{R-134a},\quad \mathsf{V}=\mathsf{V}_1=\mathsf{V}_3=0.05\,\mathrm{m^3},\quad P_1=0.8\,\mathrm{MPa}$$
$$x_1=1,\quad P_2=1.2\,\mathrm{MPa},\quad T_2=40^\circ\mathrm{C},\quad P_3=1.2\,\mathrm{MPa}$$

(a) Find m_2.
(b) Find Q.

[Solution]

$$x_1=1\quad\Rightarrow\quad\text{saturated vapor}$$
$$\mathsf{v}_1=\mathsf{v}_{g@800\,\mathrm{kPa}}=0.025645\,\mathrm{m^3/kg}$$
$$m_1=\frac{\mathsf{V}}{\mathsf{v}_1}=\frac{0.05}{0.025645}=1.9496977968\approx1.9497\,\mathrm{kg}$$
$$h_1=h_{f@800\,\mathrm{kPa}}=95.48\,\mathrm{kJ/kg}$$
$$T_{\mathrm{sat\,@\,1.2\,MPa}}=46.29^\circ\mathrm{C}>T_2\quad\Rightarrow\quad\text{compressed liquid}$$
$$h_2\approx h_{f@40^\circ\mathrm{C}}=108.28\,\mathrm{kJ/kg}$$
saturated liquid at state 3
$$\Rightarrow\quad h_3=h_{f@1.2\,\mathrm{MPa}}=117.79\,\mathrm{kJ/kg}$$
$$\Rightarrow\quad \mathsf{v}_3=\mathsf{v}_{f@1.2\,\mathrm{MPa}}=0.0008935\,\mathrm{m^3/kg}$$
$$m_3=\frac{\mathsf{V}}{\mathsf{v}_3}=\frac{0.05}{0.0008935}=55.9597090\approx55.960\,\mathrm{kg}$$
$$m_3=m_1+m_2$$
$$m_2=m_3-m_1=55.960-1.9497=54.0103000$$
$$\approx54.010\,\mathrm{kg}$$
$$Q+m_1h_1+m_2h_2=m_3h_3$$
$$Q=m_3h_3-m_1h_1-m_2h_2$$
$$=(55.96)(117.79)-(1.9497)(95.48)-(54.01)(108.28)$$
$$=557.168244\approx557.168\,\mathrm{kJ}$$

[R2 - 3]

$$\dot{m}_1=2\dot{m}_2,\quad T_1=20^\circ\mathrm{C},\quad T_2=45^\circ\mathrm{C}$$
$$P=100\,\mathrm{kPa},\quad Q=0,\quad\text{steady flow}$$

(a) Find the eq. of conservation of energy and mass.
(b) Find T_3.

[Solution]

$$\sum_i\dot{m}=\sum_e\dot{m}\quad\Rightarrow\quad\dot{m}_1+\dot{m}_2=\dot{m}_3$$
$$\cancel{\dot{Q}}+\sum_i\dot{m}j=\sum_e\dot{m}j+\cancel{\dot{W}}\quad\Rightarrow\quad\dot{m}_1h_1+\dot{m}_2h_2=\dot{m}_3h_3$$
$$T_{\mathrm{sat\,@\,100\,kPa}}=99.61^\circ\mathrm{C}>T_2>T_1\quad\Rightarrow\quad\text{compressed liquid}$$
$$h_1\approx h_{f@20^\circ\mathrm{C}}=83.915\,\mathrm{kJ/kg}$$
$$h_2\approx h_{f@45^\circ\mathrm{C}}=188.44\,\mathrm{kJ/kg}$$

These equations can be combined to an equation;

$$2\dot{m}_2h_1+\dot{m}_2h_2=3\dot{m}_2h_3$$
$$2h_1+h_2=3h_3$$
$$h_3=\frac{2h_1+h_2}{3}=\frac{2(83.915)+(188.44)}{3}=118.7566667$$
$$\approx118.757\,\mathrm{kJ/kg}$$

@ $P = 100\,\mathrm{kPa}$

$T\,[^\circ\mathrm{C}]$	$h\,[\mathrm{kJ/kg}]$
25	104.830
T_3	118.753
30	125.730

$$T_3 = \frac{118.753 - 104.83}{125.73 - 104.83}(30-25) + 25 = 28.33086124$$
$$\approx 28.33^\circ\mathrm{C}$$

[R2 - 4]

Air, $\quad m = 3\,\mathrm{kg}, \quad P_1 = 100\,\mathrm{kPa}, \quad T_1 = 310\,\mathrm{K}$
$P_2 = 500\,\mathrm{kPa}, \quad T_2 = 490\,\mathrm{K}$

Determine ΔS
(a) when $\kappa = 1.4 = \text{const.}$
(b) using value from air table.
(c) using average specific heat.

[Solution]

$$Pv = RT, \quad T ds = \delta q, \quad \delta q = dh - v dP$$
$$\Rightarrow \quad ds = \frac{dh}{T} - \frac{v}{T}dP = \frac{c_p dT}{T} - \frac{R}{P}dP$$

(a) If $\kappa = 1.4 = \text{const.}$,

$$\begin{aligned}
\Delta S &= m\int_1^2 ds = m\left(c_p\int_1^2 \frac{1}{T}dT - R\int_1^2 \frac{1}{P}dP\right)\\
&= m\left(\frac{\kappa R}{\kappa - 1}\ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right)\\
&= mR\left(\frac{\kappa}{\kappa - 1}\ln\frac{T_2}{T_1} - \ln\frac{P_2}{P_1}\right)\\
&= (3)(0.2870)\left\{\frac{1.4}{1.4-1}\ln\frac{490}{310} - \ln\frac{500}{100}\right\}\\
&= -0.00604601 \approx -0.006046\,\mathrm{kJ/K}
\end{aligned}$$

(b) Using Table A-17, ΔS can be expressed to

$$\begin{aligned}
\Delta S &= m\left\{s^\circ(T_2) - s^\circ(T_1) - R\ln\frac{P_2}{P_1}\right\}\\
&= (3)\left\{2.19876 - 1.73498 - (0.2870)\ln\frac{500}{100}\right\}\\
&= 0.00561395 \approx 0.005614\,\mathrm{kJ/K}
\end{aligned}$$

(c) Using Table A-2,

$$\begin{aligned}
\bar{c}_p(T_1) &= 28.11 + 0.1967\times10^{-2}(310)\\
&+ 0.4802\times10^{-5}(310)^2 - 1.966\times10^{-9}(310)^3\\
&= 29.12267309 \approx 29.123\,\mathrm{kJ/kmol\cdot K}\\
\bar{c}_p(T_2) &= 28.11 + 0.1967\times10^{-2}(490)\\
&+ 0.4802\times10^{-5}(490)^2 - 1.966\times10^{-9}(490)^3\\
&= 29.99549227 \approx 29.995\,\mathrm{kJ/kmol\cdot K}\\
c_p &= \frac{\bar{c}_p(T_1) + \bar{c}_p(T_2)}{2M} = \frac{29.123 + 29.995}{2(28.97)}\\
&= 1.020331377 \approx 1.020\,\mathrm{kJ/kg\cdot K}\\
\Delta S &= m\left(c_p\ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right)\\
&= (3)\left\{(1.020)\ln\frac{490}{310} - (0.2870)\ln\frac{500}{100}\right\}\\
&= 0.0152432 \approx 0.01524\,\mathrm{kJ/K}
\end{aligned}$$