

Chapter 08 Solved Problems

Problem 8.23

a) Table B.1.2 $s_f < s < s_g$ so two-phase and $T = T_{\text{sat}}(P) = 64.97^\circ\text{C}$

$$x = (s - s_f)/s_{fg} = \frac{7.70 - 0.893}{6.9383} = 0.981$$

$$h = 271.9 + 0.981 \times 2346.3 = 2573.8 \text{ kJ/kg}$$

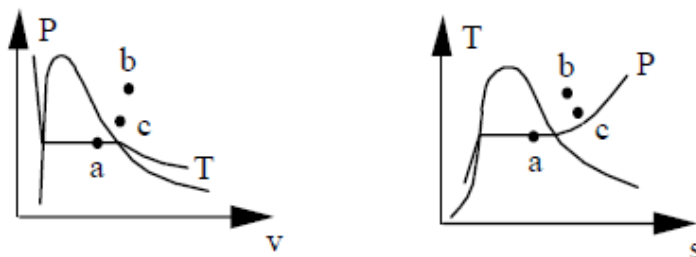
b) Table B.1.2 $u > u_g \Rightarrow$ Superheated vapor Table B.1.3, $x = \text{undefined}$

$$T \cong 682^\circ\text{C}, \quad s \cong 7.1223 \text{ kJ/kg K}$$

c) Table B.1.1 $s > s_g$ so superheated vapor. Table B.1.3, $x = \text{undefined}$

State is located between 100 and 200 kPa, so interpolate

$$P = 100 \text{ kPa} + 100 \text{ kPa} \times \frac{7.40 - 7.6133}{7.2795 - 7.6133} = 163.9 \text{ kPa}$$



Problem 8.25

a) B.2.2 average between 60°C and 70°C

$$v = (0.25981 + 0.26999)/2 = 0.26435 \text{ m}^3/\text{kg}$$

$$s = (5.6383 + 5.7094)/2 = 5.6739 \text{ kJ/kgK}$$

b) B.2.1: $P < P_{\text{sat}} = 857.5 \text{ kPa} \Rightarrow$

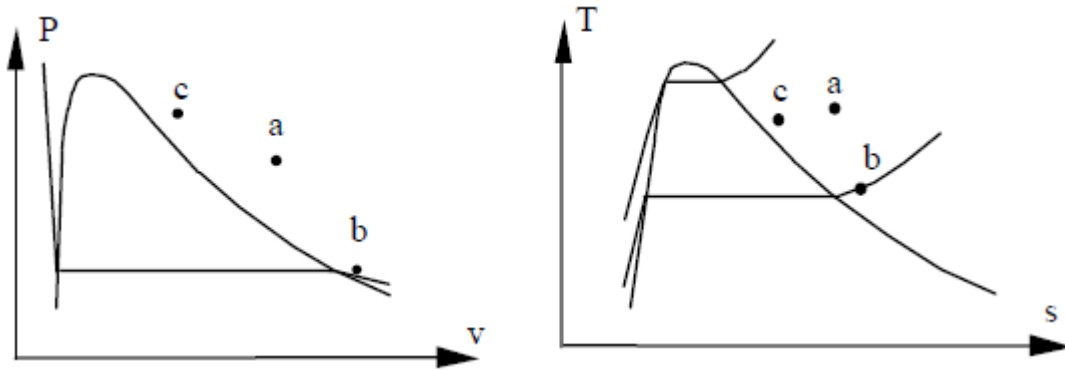
B.2.2 superheated vapor so x is undefined

$$v = 1.4153 \text{ m}^3/\text{kg}, \quad s = 6.2826 \text{ kJ/kgK}$$

c) B.2.1: $v > v_g = 0.06337 \text{ m}^3/\text{kg} \Rightarrow$

B.2.2 superheated vapor so x is undefined

$$\text{very close to } 1200 \text{ kPa}, \quad s = 5.1497 \text{ kJ/kgK}$$



Problem 8.29

State 1 from Table B.1.2 at 200 kPa

$$s = s_f + x s_{fg} = 1.53 + 0.25 \times 5.597 = 2.9293 \text{ kJ/kg}$$

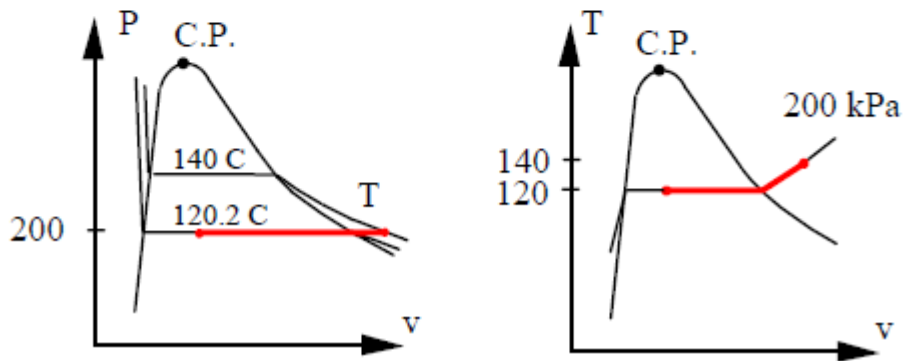
State 2 has same P from Table B.1.2 at 200 kPa

$$T_2 = T_{\text{sat}} + 20 = 120.23 + 20 = 140.23^\circ\text{C}$$

so state 2 is superheated vapor ($x = \text{undefined}$) from Table B.1.3

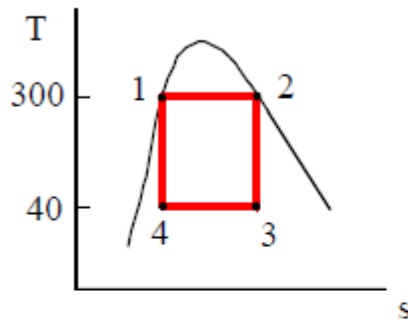
$$s_2 = 7.1271 + (7.2795 - 7.1271) \frac{20}{150 - 120.23} = 7.2295 \text{ kJ/kgK}$$

$$s_2 - s_1 = 7.2295 - 2.9293 = 4.3002 \text{ kJ/kgK}$$



Problem 8.32

From the definition of the Carnot cycle, two constant s and two constant T processes.



From table B.1.1

State 2 is saturated vapor so

$$s_3 = s_2 = 5.7044 \text{ kJ/kg K} \\ = 0.5724 + x_3(7.6845)$$

$$x_3 = \mathbf{0.6678}$$

State 1 is saturated liquid so

$$s_4 = s_1 = 3.2533 \text{ kJ/kg K} = 0.5724 + x_4(7.6845)$$

$$x_4 = \mathbf{0.3489}$$

$$\eta_{TH} = \frac{w_{NET}}{q_H} = \frac{T_H - T_L}{T_H} = \frac{260}{573.2} = \mathbf{0.4536}$$

$$q_H = T_H(s_2 - s_1) = 573.2 \text{ K} (5.7044 - 3.2533) \text{ kJ/kg K} = 1405.0 \text{ kJ/kg}$$

$$w_{NET} = \eta_{TH} \times q_H = \mathbf{637.3 \text{ kJ/kg}}$$

Problem 8.33

C.V. The R-410a

$$\text{Energy Eq.: } u_2 - u_1 = {}_1q_2 - {}_1w_2 = -{}_1w_2$$

$$\text{Entropy Eq.: } s_2 - s_1 = \int dq/T + 0 = 0 \quad \Rightarrow \quad s_2 = s_1$$

State 1: Sup. vapor $u_1 = 251.18 \text{ kJ/kg}$, $s_1 = 1.1783 \text{ kJ/kgK}$

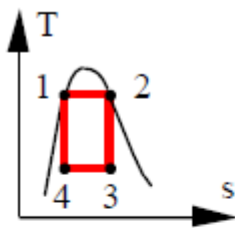
State 2: (P_2, s_2) $u_2 = 300.05 \text{ kJ/kg}$ (same interpolation as for T),

$$T_2 = 60 + 20 \frac{1.1783 - 1.1747}{1.2331 - 1.1747} = \mathbf{61.2^\circ\text{C}}$$

$${}_1w_2 = u_1 - u_2 = 251.18 - 300.05 = \mathbf{-48.87 \text{ kJ/kg}}$$

Problem 8.35

Carnot cycle heat engine:



Constant $T \Rightarrow$ constant P from 1 to 2, Table B.2.1

$$q_H = \int T ds = T (s_2 - s_1) = T s_{fg} = h_{fg} \\ = 473.15 (4.1014) = \mathbf{1940 \text{ kJ/kg}}$$

States 3 & 4 are two-phase, Table B.2.1

$$\Rightarrow T_L = T_3 = T_4 = T_{\text{sat}}(P) = 60.06^\circ\text{C}$$

Carnot cycle refrigerator (T_L and T_H are different from above):

$$\beta_{\text{ref}} = \frac{Q_L}{W} = \frac{T_L}{T_H - T_L} = \frac{273 - 15}{20 - (-15)} = \frac{258}{35} = 7.37$$

$$W = \frac{Q_L}{\beta} = \frac{1}{7.37} = 0.136 \text{ kJ}$$

The needed work comes from the heat engine

$$W = \eta_{\text{HE}} Q_{\text{H H}_2\text{O}} ; \quad \eta_{\text{HE}} = 1 - \frac{T_L}{T_H} = 1 - \frac{333}{473} = 0.296$$

$$Q_{\text{H H}_2\text{O}} = \frac{W}{\eta_{\text{HE}}} = \frac{0.136}{0.296} = \mathbf{0.46 \text{ kJ}}$$

Problem 8.43

C.V. Ammonia in the cylinder.

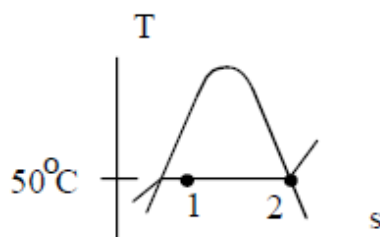
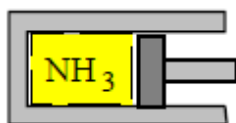


Table B.2.1: $T_1 = 50^\circ\text{C}$, $x_1 = 0.20$, $V_1 = 1 \text{ L}$

$$v_1 = 0.001777 + 0.2 \times 0.06159 = 0.014095 \text{ m}^3/\text{kg}$$

$$s_1 = 1.5121 + 0.2 \times 3.2493 = 2.1620 \text{ kJ/kg K}$$

$$m = V_1/v_1 = 0.001/0.014095 = 0.071 \text{ kg}$$

$$v_2 = v_g = 0.06336 \text{ m}^3/\text{kg},$$

$$s_2 = s_g = 4.7613 \text{ kJ/kg K}$$

Process: $T = \text{constant to } x_2 = 1.0, \quad P = \text{constant} = 2.033 \text{ MPa}$

From the constant pressure process

$${}_1W_2 = \int PdV = Pm(v_2 - v_1) = 2033 \times 0.071 \times (0.06336 - 0.014095) = 7.11 \text{ kJ}$$

From the second law Eq.8.3 with constant T

$${}_1Q_2 = \int Tds = Tm(s_2 - s_1) = 323.2 \times 0.071(4.7613 - 2.1620) = 59.65 \text{ kJ}$$

or ${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = m(h_2 - h_1)$

$$h_1 = 421.48 + 0.2 \times 1050.01 = 631.48 \text{ kJ/kg}, \quad h_2 = 1471.49 \text{ kJ/kg}$$

$${}_1Q_2 = 0.071(1471.49 - 631.48) = 59.65 \text{ kJ}$$

Problem 8.55

C.V. R-134a.

Cont.Eq.: $m_2 = m_1 = m$;

Energy Eq.:5.11 $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Entropy Eq.8.3: $m(s_2 - s_1) = \int dQ/T$

Process: $T = \text{constant}$, reversible

State 1: (T, P) Table B.5.2 $u_1 = 388.36 \text{ kJ/kg}$, $s_1 = 1.822 \text{ kJ/kg K}$

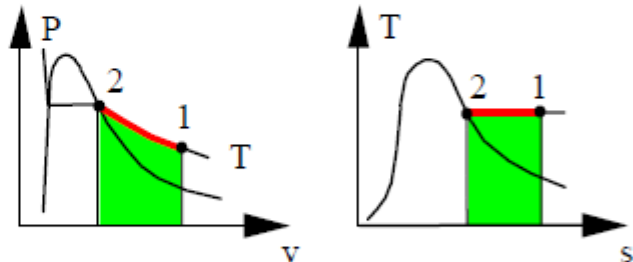
$$m = V/v_1 = 0.02/0.148283 = 0.1349 \text{ kg}$$

State 2: $(10^\circ\text{C}$, sat. vapor)

Table B.5.1

$$u_2 = 383.67 \text{ kJ/kg},$$

$$s_2 = 1.7218 \text{ kJ/kg K}$$



As T is constant we can find Q by integration as

$${}_1Q_2 = \int Tds = mT(s_2 - s_1) = 0.1349 \times 283.15 \times (1.7218 - 1.822) = -3.83 \text{ kJ}$$

The work is then from the energy equation

$${}_1W_2 = m(u_1 - u_2) + {}_1Q_2 = 0.1349 \times (388.36 - 383.67) - 3.83 = -3.197 \text{ kJ}$$

Problem 8.57

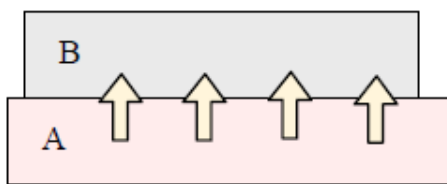
C.V. Both blocks, no external heat transfer, C from Table A.3.

$$\begin{aligned}\text{Energy Eq.: } U_2 - U_1 &= m_A(u_2 - u_1)_A + m_B(u_2 - u_1)_B = 0 - 0 \\ &= m_A C(T_2 - T_{A1}) + m_B C(T_2 - T_{B1})\end{aligned}$$

$$T_2 = \frac{m_A T_{A1} + m_B T_{B1}}{m_A + m_B} = \frac{1}{2} T_{A1} + \frac{1}{2} T_{B1} = 137.5^\circ\text{C}$$

$$\text{Entropy Eq. 8.39: } S_2 - S_1 = m_A(s_2 - s_1)_A + m_B(s_2 - s_1)_B = {}_1S_2 \text{ gen}$$

$$\begin{aligned}S_2 - S_1 &= m_A C \ln \frac{T_2}{T_{A1}} + m_B C \ln \frac{T_2}{T_{B1}} \\ &= 5 \times 0.46 \ln \frac{137.5 + 273.15}{250 + 273.15} + 5 \times 0.46 \ln \frac{137.5 + 273.15}{298.15} \\ &= -0.5569 + 0.7363 = \mathbf{0.1794 \text{ kJ/K}}\end{aligned}$$



Heat transfer over a finite temperature difference is an irreversible process

Problem 8.65

C.V.: Steel and the water, control mass of constant volume.

Energy Eq.5.11: $U_2 - U_1 = {}_1Q_2 - {}_1W_2$

Process: $V = \text{constant} \Rightarrow {}_1W_2 = 0$

State 1: H_2O Table B.1.3: $u_1 = 2621.9 \text{ kJ/kg}$, $v_1 = 0.20596 \text{ m}^3/\text{kg}$,
 $s_1 = 6.6939 \text{ kJ/kg K}$

State 2: H_2O : $T_2, v_2 = v_1 \Rightarrow$ from Table B.1.1

$$x_2 = \frac{v - v_f}{v_{fg}} = \frac{0.20596 - 0.001004}{32.8922} = 0.006231$$

$$u_2 = 125.77 + x_2 \times 2290.81 = 140.04 \text{ kJ/kg}$$

$$s_2 = 0.4369 + x_2 \times 8.0164 = 0.48685 \text{ kJ/kg K}$$

$$\begin{aligned} {}_1Q_2 &= m(u_2 - u_1) = m_{\text{steel}}C_{\text{steel}}(T_2 - T_1) + m_{H_2O}(u_2 - u_1)_{H_2O} \\ &= 12 \times 0.46(30 - 200) + 0.2(140.04 - 2621.9) \\ &= \mathbf{-1434.8 \text{ kJ}} \end{aligned}$$

Entropy changes from Eq.8.11 and the water tables

$$\begin{aligned} S_2 - S_1 &= m_2 s_2 - m_1 s_1 = m_{\text{steel}}C_{\text{steel}} \ln\left(\frac{T_2}{T_1}\right) + m_{H_2O}(s_2 - s_1)_{H_2O} \\ &= 12 \times 0.46 \ln\left(\frac{303.15}{473.15}\right) + 0.2(0.48685 - 6.6939) \\ &= -2.4574 - 1.2414 \\ &= \mathbf{-3.699 \text{ kJ/K}} \end{aligned}$$

Problem 8.77

C.V. Air. Assume a reversible, adiabatic process.

Energy Eq.5.11: $u_2 - u_1 = 0 - {}_1w_2$;

Entropy Eq.8.37: $s_2 - s_1 = \int dq/T + {}_1s_2_{gen} = 0$

Process: Adiabatic ${}_1q_2 = 0$ Reversible ${}_1s_2_{gen} = 0$

With these two terms zero we have a zero for the entropy change. So this is a constant s (isentropic) expansion process. From Eq.8.19

$$s_{T2}^o - s_{T1}^o = R \ln \frac{P_2}{P_1}$$

Properties: Table A.8: $s_{T1}^o = 6.4168$, $s_{T2}^o = 7.2336$ kJ/kg K

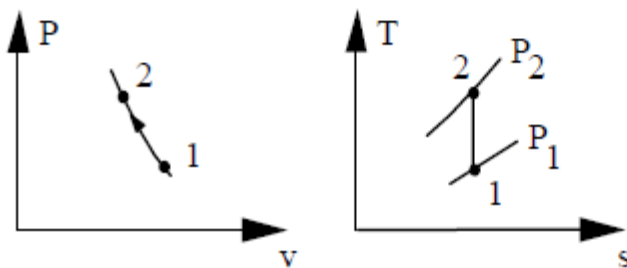
$$\frac{P_2}{P_1} = \exp [(s_{T2}^o - s_{T1}^o)/R] = \exp\left(\frac{7.2336 - 6.4168}{0.2598}\right) = 23.1955$$

$$P_2 = 100 \times 23.1955 = \mathbf{2320 \text{ kPa}}$$

Ideal gas law: $P_1V_1 = mRT_1$ and $P_2V_2 = mRT_2$

Take the ratio of these so mR drops out to give

$$V_2 = V_1 \times (T_2 / T_1) \times (P_1 / P_2) = 0.1 \times \left(\frac{700}{300}\right) \times \left(\frac{100}{2320}\right) = \mathbf{0.01 \text{ m}^3}$$



Problem 8.81

C.V. CO₂, a control mass undergoing a reversible, adiabatic process.

Energy Eq.5.11: $u_2 - u_1 = 0 - {}_1w_2$;

Entropy Eq.8.37: $s_2 - s_1 = \int dq/T + {}_1s_2_{gen} = 0$

Process: Adiabatic ${}_1q_2 = 0$ Reversible ${}_1s_2_{gen} = 0$

State 1: (300 K, 400 kPa) State 2: (3000 kPa, ?)

With two terms zero in the entropy equation we have a zero for the entropy change. So this is a constant s (isentropic) expansion process, $s_2 = s_1$.

a) Table A.8 for CO₂ and Eq.8.19

$$s_2 - s_1 = 0 = s_{T2}^{\circ} - s_{T1}^{\circ} - R \ln(P_2/P_1)$$

$$s_{T2}^{\circ} = s_{T1}^{\circ} + R \ln \frac{P_2}{P_1} = 4.8631 + 0.1889 \ln \frac{3000}{400} = 5.2437 \text{ kJ/kg-K}$$

Now interpolate in A.8 to find T₂

$$T_2 = 450 + 50 (5.2437 - 5.2325)/(5.3375 - 5.2325) = \mathbf{455.3 \text{ K}}$$

$${}_1w_2 = -(u_2 - u_1) = -(271 - 157.7) = \mathbf{-113.3 \text{ kJ/kg}}$$

b) Table A.5: $k = 1.289$, $C_{V0} = 0.653 \text{ kJ/kg K}$ and now Eq.8.23

$$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{\frac{k-1}{k}} = 300 \left(\frac{3000}{400} \right)^{0.224} = \mathbf{471.1 \text{ K}}$$

$${}_1w_2 = -C_{V0}(T_2 - T_1) = -0.653 (471.1 - 300) = \mathbf{-111.7 \text{ kJ/kg}}$$

Find a heat capacity at an average temperature from Table A.6.

Estimate $T_2 \sim 500 \text{ K}$ giving $T_{AVE} \sim 400 \text{ K} \Rightarrow \theta = 0.4$

$$C_{P0} = 0.45 + 1.67 \times 0.4 - 1.27 \times 0.4^2 + 0.39 \times 0.4^3 = 0.9398 \text{ kJ/kg K}$$

$$C_{V0} = C_{P0} - R = 0.9398 - 0.1889 = 0.7509, \quad k = C_{P0}/C_{V0} = 1.2516$$

Eq.8.32:
$$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{\frac{k-1}{k}} = 300 \left(\frac{3000}{400} \right)^{0.201} = \mathbf{449.8 \text{ K}}$$

$${}_1w_2 = -C_{V0}(T_2 - T_1) = -0.7509 (449.8 - 300) = \mathbf{-112.5 \text{ kJ/kg}}$$

From Table B.3.2: $s_1 = 1.8102 \text{ kJ/kg-K}$, $u_1 = 336.2 \text{ kJ/kg}$

$$T_2 = 186.7^{\circ}\text{C} = \mathbf{459.8 \text{ K}}, \quad u_2 = 446.9 \text{ kJ/kg}$$

$${}_1w_2 = -(u_2 - u_1) = -(446.9 - 336.2) = \mathbf{-110.7 \text{ kJ/kg}}$$

Problem 8.83

C.V. Air, Cylinder is insulated so adiabatic, $Q = 0$.

Continuity Eq.: $m_2 = m_1 = m$,

Energy Eq.5.11: $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2 = -{}_1W_2$

Entropy Eq.8.37: $m(s_2 - s_1) = \int dQ/T + {}_1S_2 \text{ gen} = 0 + {}_1S_2 \text{ gen}$

State 1: (T_1, P_1) State 2: $(P_2, ?)$

So one piece of information is needed for the ?, assume reversible process.

$${}_1S_2 \text{ gen} = 0 \Rightarrow s_2 - s_1 = 0$$

State 1: Table A.7: $u_1 = 1095.2 \text{ kJ/kg}$, $s_{T1}^{\circ} = 8.5115 \text{ kJ/kg K}$

$$m = P_1 V_1 / RT_1 = \frac{15000 \times 10 \times 10^{-6}}{0.287 \times 1380} = 0.000379 \text{ kg}$$

State 2: P_2 and from Entropy eq.: $s_2 = s_1$ so from Eq.8.19

$$s_{T2}^{\circ} = s_{T1}^{\circ} + R \ln \frac{P_2}{P_1} = 8.5115 + 0.287 \ln \left(\frac{200}{15000} \right) = 7.2724 \text{ kJ/kg K}$$

Now interpolate in Table A.7 to get T_2

$$T_2 = 440 + 20 (7.2724 - 7.25607) / (7.30142 - 7.25607) = 447.2 \text{ K}$$

$$u_2 = 315.64 + (330.31 - 315.64) 0.36 = 320.92 \text{ kJ/kg}$$

$$V_2 = V_1 \frac{T_2 P_1}{T_1 P_2} = \frac{10 \times 447.2 \times 15000}{1380 \times 200} = 243 \text{ cm}^3$$

$$\Rightarrow L_2 = V_2 / A_{\text{cyl}} = 243/5 = \mathbf{48.6 \text{ cm}}$$

$${}_1w_2 = u_1 - u_2 = 774.3 \text{ kJ/kg}, \quad {}_1W_2 = m_1 w_2 = \mathbf{0.2935 \text{ kJ}}$$

Problem 8.101

Continuity Eq.: $m_2 - m_A - m_B = 0$

Energy Eq.5.11: $m_2 u_2 - m_A u_A - m_B u_B = -{}_1W_2$

Entropy Eq.8.37: $m_2 s_2 - m_A s_A - m_B s_B = \int dQ/T + {}_1S_2 \text{ gen}$

Process: $P = \text{Constant} \Rightarrow {}_1W_2 = \int PdV = P(V_2 - V_1)$

$$Q = 0$$

Substitute the work term into the energy equation and rearrange to get

$$m_2 u_2 + P_2 V_2 = m_2 h_2 = m_A u_A + m_B u_B + P V_1 = m_A h_A + m_B h_B$$

where the last rewrite used $P V_1 = P V_A + P V_B$.

State A1: Table B.1.3 $h_A = 3487.03$ kJ/kg, $s_A = 8.5132$ kJ/kg K

State B1: Table B.1.2 $h_B = 2706.63$ kJ/kg, $s_B = 7.1271$ kJ/kg K

Energy equation gives:

$$h_2 = \frac{m_A}{m_2} h_A + \frac{m_B}{m_2} h_B = \frac{1}{2} 3487.03 + \frac{1}{2} 2706.63 = 3096.83 \text{ kJ/kg}$$

State 2: $P_2, h_2 = 3096.83$ kJ/kg $\Rightarrow s_2 = 7.9328$ kJ/kg K; $T_2 = 312.2^\circ\text{C}$

With the zero heat transfer we have

$$\begin{aligned} {}_1S_2 \text{ gen} &= m_2 s_2 - m_A s_A - m_B s_B \\ &= 2 \times 7.9328 - 1 \times 8.5132 - 1 \times 7.1271 = \mathbf{0.225 \text{ kJ/K}} \end{aligned}$$

Problem 8.108

Energy Eq.5.11: $U_2 - U_1 = {}_1Q_2 - {}_1W_2$

Entropy Eq.8.37: $m(s_2 - s_1) = \int dQ/T + {}_1S_2 \text{ gen} = {}_1Q_2/T_{\text{res}} + {}_1S_2 \text{ gen}$

Process: $P = \text{constant}$ so ${}_1W_2 = P(V_2 - V_1) = mP(v_2 - v_1)$

State 1: Table B.1.4: $h_1 = 422.72$ kJ/kg, $u_1 = 417.52$ kJ/kg,

$$s_1 = 1.303 \text{ kJ/kg K}, \quad v_1 = 0.00104 \text{ m}^3/\text{kg}$$

State 2: Table B.1.3: $h_2 = 3900.1$ kJ/kg, $u_2 = 3457.6$ kJ/kg,

$$s_2 = 7.5122 \text{ kJ/kg K}, \quad v_2 = 0.08849 \text{ m}^3/\text{kg}$$

Work is found from the process (area in P-V diagram)

$${}_1W_2 = mP(v_2 - v_1) = 2 \times 5000(0.08849 - 0.00104) = \mathbf{874.6 \text{ kJ}}$$

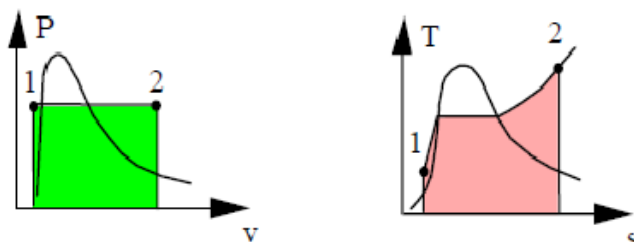
The heat transfer from the energy equation is

$${}_1Q_2 = U_2 - U_1 + {}_1W_2 = m(u_2 - u_1) + mP(v_2 - v_1) = m(h_2 - h_1)$$

$${}_1Q_2 = 2(3900.1 - 422.72) = \mathbf{6954.76 \text{ kJ}}$$

Entropy generation from entropy equation (or Eq.8.39)

$${}_1S_2 \text{ gen} = m(s_2 - s_1) - {}_1Q_2/T_{\text{res}} = 2(7.5122 - 1.303) - 6954/973 = \mathbf{5.27 \text{ kJ/K}}$$



Problem 8.119

$$1 : v_1 = 0.11265 \text{ m}^3/\text{kg}, \quad u_1 = 1516.6 \text{ kJ/kg}, \quad s_1 = 5.5018 \text{ kJ/kg K}$$

$$V_1 = mv_1 = 0.05634 \text{ m}^3$$

$$\text{Stop 1a: } v_{\text{stop}} = V/m = 0.02/0.5 = 0.04 \text{ m}^3/\text{kg}$$

$$P_{\text{stop}} = P_1 \Rightarrow T \sim 42^\circ\text{C (saturated)}$$

$$2 : 30^\circ\text{C} < T_{\text{stop}} \text{ so } v_2 = v_{\text{stop}} = 0.04 \text{ m}^3/\text{kg}$$

$$x_2 = \left(\frac{v_2 - v_f}{v_{fg}} \right) = \frac{0.04 - 0.00168}{0.10881} = 0.35217$$

$$u_2 = 320.46 + x_2 \times 1016.9 = 678.58 \text{ kJ/kg}$$

$$s_2 = 1.2005 + x_2 \times 3.7734 = 2.5294 \text{ kJ/kg K}$$

$${}_1W_2 = \int P \, dV = P_1 m (v_2 - v_1) = 1600 \times 0.5 (0.004 - 0.11268) = -58.14 \text{ kJ}$$

$$\begin{aligned} {}_1Q_2 &= m(u_2 - u_1) + m_{\text{st}}(u_2 - u_1) + {}_1W_2 \\ &= 0.5(678.58 - 1516.6) + 1 \times 0.46(30 - 120) - 58.14 \\ &= -419.01 - 41.4 - 58.14 = \mathbf{-518.55 \text{ kJ}} \end{aligned}$$

$$\begin{aligned} {}_1S_2 \text{ gen} &= m(s_2 - s_1) + m_{\text{st}}(s_2 - s_1) - {}_1Q_2/T_{\text{amb}} \\ &= 0.5(2.5294 - 5.5018) + 1 \times 0.46 \ln \frac{273+30}{273+120} - \frac{-518.5}{293.15} \\ &= -1.4862 - 0.1196 + 1.6277 \\ &= \mathbf{0.02186 \text{ kJ/K}} \end{aligned}$$

Problem 8.127

C.V. Nitrogen gas.

$$\text{Energy Eq. 5.11: } m(u_2 - u_1) = {}_1Q_2 - {}_1W_2 = - \int P_{\text{eq}} \, dV = -P_2 (V_2 - V_1)$$

$$\text{Entropy Eq. 8.14: } m(s_2 - s_1) = 0 + {}_1S_2 \text{ gen}$$

Process: ${}_1Q_2 = 0$ (already used), $P = P_{\text{eq}}$ after pin is out.

State 1: 200°C , 300 kPa State 2: $P_2 = P_{\text{eq}} = 200 \text{ kPa}$

$$m = P_1 V_1 / RT_1 = 300 \times 0.005 / 0.2968 \times 473.15 = 0.01068 \text{ kg}$$

The energy equation becomes

$$mu_2 + P_2 V_2 = mu_1 + P_2 V_1 = mh_2 \Rightarrow$$

$$h_2 = u_1 + P_2 V_1 / m = u_1 + P_2 V_1 / P_1 V_1 \times RT_1 = u_1 + (P_2 / P_1) RT_1$$

Solve using constant C_p , C_v

$$C_p T_2 = C_v T_1 + (P_2/P_1) RT_1$$

$$T_2 = T_1 [C_v + (P_2/P_1) R] / C_p$$

$$= 473.15 [0.745 + (200 / 300) \times 0.2368] / 1.042$$

$$= \mathbf{428.13 \text{ K}}$$

$$V_2 = V_1 (T_2 / T_1) \times (P_1/P_2) = 0.005 \times \frac{428.13}{473.15} \times \frac{300}{200}$$

$$= 0.00679 \text{ m}^3$$

$${}_1S_2 \text{ gen} = m(s_2 - s_1) \cong m[C_p \ln (T_2/T_1) - R \ln (P_2/P_1)]$$

$$= P_1 V_1 / RT_1 [C_p \ln (T_2/T_1) - R \ln (P_2/P_1)]$$

$$= 0.01068 [1.042 \times \ln (428.13/473.15) - 0.2968 \times \ln (200 / 300)]$$

$$= \mathbf{0.000173 \text{ kJ/K}}$$

Problem 8.134

C.V. Ethane gas of constant mass $m_2 = m_1 = m$ out to ambient.

$$\text{Energy Eq.5.11: } m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$$

$$\text{Entropy Eq.8.37: } m(s_2 - s_1) = \int dQ/T + {}_1S_2 \text{ gen} = {}_1Q_2/T_{\text{amb}} + {}_1S_2 \text{ gen}$$

$$\text{Process: } P v_1^n = P_2 v_2^n$$

State 1: (T_1, P_1) State 2: $(T_2, ?)$ on process curve

$$P_2 = P_1 (T_2/T_1)^{\frac{n}{n-1}} = 500 \left(\frac{293.2}{373.2} \right)^{4.333} = 175.8 \text{ kPa}$$

Work is integrated in Eq.8.29

$${}_1w_2 = \int_1^2 P dv = \frac{P_2 v_2 - P_1 v_1}{1-n} = \frac{R(T_2 - T_1)}{1-n} = \frac{0.2765(293.2 - 373.2)}{1-1.30} = \mathbf{+73.7 \text{ kJ/kg}}$$

Heat transfer is from the energy equation

$${}_1q_2 = C_{v0}(T_2 - T_1) + {}_1w_2 = 1.49(293.2 - 373.2) + 73.7 = \mathbf{-45.5 \text{ kJ/kg}}$$

Entropy change from Eq.8.16

$$\begin{aligned} s_2 - s_1 &= C_{p0} \ln(T_2/T_1) - R \ln(P_2/P_1) \\ &= 1.766 \ln \frac{293.2}{373.2} - 0.2765 \ln \frac{175.8}{500} = -0.1371 \text{ kJ/kg K} \end{aligned}$$

$$m(s_2 - s_1) = \Delta S_{\text{SYSTEM}} = 2(-0.1371) = -0.2742 \text{ kJ/K}$$

$$\Delta S_{\text{SURR}} = -{}_1Q_2/T_0 = + 2 \times 45.5/293.2 = +0.3104 \text{ kJ/K}$$

Generation from entropy equation or Eq.8.37 or 39

$$\begin{aligned} {}_1S_2 \text{ gen} &= m(s_2 - s_1) - {}_1Q_2/T_{\text{amb}} = \Delta S_{\text{NET}} = \Delta S_{\text{SYSTEM}} + \Delta S_{\text{SURR}} \\ &= -0.2742 + 0.3104 = +0.0362 \text{ kJ/K} \end{aligned}$$