Chapter 05 Solved Problems

Problem 5.30

a. R-410a P = 500 kPa, h = 300 kJ/kg

Table B.4.1: h > hg = > **superheated vapor**, look in section 500 kPa and interpolate

T = 0 + 20 × (300 − 287.84)/(306.18 − 287.84) = 20 × 0.66303 = **13.26°C**,

v = 0.05651 + 0.66303 × (0.06231-0.05651) = **0.06036 m3/kg**,

u = 259.59 + 0.66303 × (275.02 – 259.59) = **269.82 kJ/kg**

b. R-410a T = 10°C, u = 200 kJ/kg

Table B.4.1: u < ug = 255.9 kJ/kg => L+V mixture, P = 1085.7 kPa

x = (u – uf)/ufg = (200 - 72.24)/183.66 = 0.6956,

v = 0.000886 + 0.6956 × 0.02295 = 0.01685 m3/kg,

h = 73.21 + 0.6956 × 208.57 = 218.3 kJ/kg

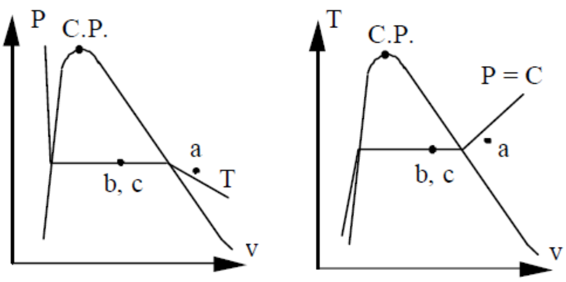
c. R-134a T = 40°C, h = 400 kJ/kg

Table B.5.1: h < hg => two-phase L + V, look in B.5.1 at 40°C:

x = (h – hf)/hfg = (400 − 256.5)/163.3 = 0.87875, P = Psat = 1017 kPa,

v = 0.000 873 + 0.87875 × 0.01915 = 0.0177 m3/kg

u = 255.7 + 0.87875 × 143.8 = 382.1 kJ/kg



Problem 5.36

C.V. Water. This is a control mass

Energy Eq.: m (u2 − u1) = $Q_{12} - W_{12}$

Process : V = constant

$W_{12} = \int P\, dV = 0$

State 1: T, x1 from Table B.1.1

v1 = vf + x1 vfg = 0.00106 + 0.25 × 0.8908 = 0.22376 m3/kg

u1 = uf + x1 ufg = 503.48 + 0.25 × 2025.76 = 1009.92 kJ/kg

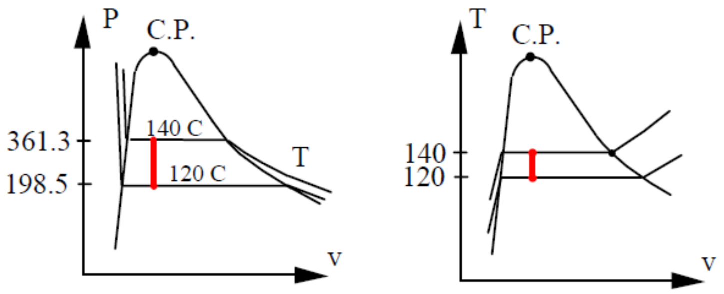
T2, v2 = v1< vg2 = 0.50885 m3/kg so two-phase

x2 = (v2 - vf2)/vfg2 = (0.22376 - 0.00108)/0.50777 = 0.43855

u2 = uf2 + x2 ufg2 = 588.72 + x2 ×1961.3 = 1448.84 kJ/kg

From the energy equation

Q_{12} = m(u_2 − u1) = 2 (1448.84 − 1009.92) = 877.8 kJ



Problem 5.37

$m_2 = m_1 = m$;

$m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Process: Constant volume $\Rightarrow$ $v_2 = v_1$ & ${}_1W_2 = 0$

State 1: Table B.2.1 two-phase state.

$v_1 = 0.001566 + x_1 \times 0.28783 = 0.17426 \text{ m}^3/\text{kg}$

$u_1 = 179.69 + 0.6 \times 1138.3 = 862.67 \text{ kJ/kg}$

$m = V/v_1 = 0.2/0.17426 = 1.148 \text{ kg}$

State 2: P_2 , $v_2 = v_1$ superheated vapor Table B.2.2

$\Rightarrow T_2 \cong 100°C, \quad u_2 \cong 1490.5 \text{ kJ/kg}$

So solve for heat transfer in the energy equation

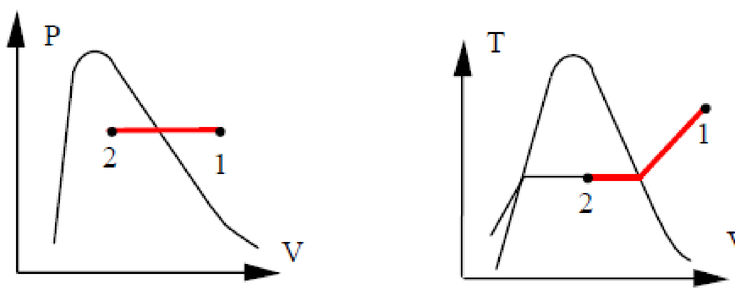
${}_1Q_2 = m(u_2 - u_1) = 1.148(1490.5 - 862.67) = \mathbf{720.75 \ kJ}$

Problem 5.39

C.V.: R-134a $m_2 = m_1 = m$;

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

Process: P = const. $\Rightarrow {}_1W_2 = \int PdV = P\Delta V = P(V_2 - V_1) = Pm(v_2 - v_1)$



State 1: Table B.5.2 $h_1 = (490.48 + 489.52)/2 = 490 \text{ kJ/kg}$

State 2: Table B.5.1 $h_2 = 206.75 + 0.75 \times 194.57 = 352.7 \text{ kJ/kg}$ (350.9 kPa)

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

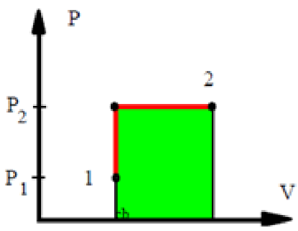
${}_1Q_2 = 2 \times (352.7 - 490) = \mathbf{-274.6 \ kJ}$

Problem 5.66

Take CV as the water.

$m_2 = m_1 = m$;

$m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$



Process: v = constant until $P = P_{lift}$, then P is constant.

State 1: Two-phase so look in Table B.1.2 at 100 kPa

$u_1 = 417.33 + 0.5 \times 2088.72 = 1461.7$ kJ/kg,

$v_1 = 0.001043 + 0.5 \times 1.69296 = 0.8475$ m^3/kg

State 2: v_2, $\mathbf{P_2 \leq P_{lift}}$ => $v_2 = 3 \times 0.8475 = 2.5425$ m^3/kg ;

Interpolate: $\mathbf{T_2 = 829°C}$, $u_2 = 3718.76$ kJ/kg

=> $V_2 = mv_2 = 25.425$ m^3

From the process equation (see P-V diagram) we get the work as

$${}_1W_2 = P_{lift}(V_2 - V_1) = 200 \times 10\ (2.5425 - 0.8475) = 3390 \text{ kJ}$$

From the energy equation we solve for the heat transfer

$${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = 10\times(3718.76 - 1461.7) + 3390 = \mathbf{25\ 961\ kJ}$$

Problem 5.67

Take the water in A and B as CV.

$$m_2 - m_{1A} - m_{1B} = 0$$

$$m_2u_2 - m_{1A}u_{1A} - m_{1B}u_{1B} = {}_1Q_2 - {}_1W_2$$

Process: $P = \text{constant} = P_{1A}$ if piston floats

(V_A positive) i.e. if $V_2 > V_B = 0.1\ m^3$

State A1: Sup. vap. Table B.1.3 $v = 0.95964\ m^3/kg$, $u = 2576.9\ kJ/kg$

=> $V = mv = 0.5 \times 0.95964 = 0.47982$

State B1: Table B.1.2 $v = (1\text{-}x) \times 0.001084 + x \times 0.4625 = 0.2318\ m^3/kg$

=> $m = V/v = 0.4314\ kg$

$u = 604.29 + 0.5 \times 1949.3 = 1578.9\ kJ/kg$

State 2: 200 kPa, $v_2 = V_2/m = 1.006/0.9314 = 1.0801\ m^3/kg$

Table B.1.3 => close to $T_2 = 200^oC$ and $u_2 = 2654.4\ kJ/kg$

So now

$V_1 = 0.47982 + 0.1 = \mathbf{0.5798\ m^3}$, $m_1 = 0.5 + 0.4314 = \mathbf{0.9314\ kg}$

Since volume at state 2 is larger than initial volume piston goes up and the pressure then is constant (200 kPa which floats piston).

$${}_1W_2 = \int P\,dV = P_{lift}(V_2 - V_1) = 200\ (1.006 - 0.57982) = \mathbf{85.24\ kJ}$$

$${}_1Q_2 = m_2u_2 - m_{1A}u_{1A} - m_{1B}u_{1B} + {}_1W_2$$
$$= 0.9314 \times 2654.4 - 0.5 \times 2576.9 - 0.4314 \times 1578.9 + 85.24 = \mathbf{588\ kJ}$$