ME 24-221
Thermodynamics I

Solution to Assignment No: 4
Due Date: 29 September 2000
Fall 2000
Instructor: J.Murthy

Pb # 5.7

Solution:

a) Table B.1.1: $u_f < u < u_g$ => 2-phase mixture of liquid and vapor

$x = (u - u_f)/ u_{fg} = (2390 - 376.82)/2117.7 = \mathbf{0.9506}$

$v = v_f + x\, v_{fg} = 0.001036 + 0.9506 \times 2.35953 = \mathbf{2.244\ m^3/kg}$

$h = h_f + x\, h_{fg} = 376.96 + 0.9506 \times 2283.19 = \mathbf{2547.4\ kJ/kg}$

b) Table B.1.2: $u < u_f$ so compressed liquid B.1.4, x = **undefined**

$$T \cong 260 + (280 - 260) \times \frac{1200\text{-}1121.03}{1220.9\text{-}1121.03} = \mathbf{275.8°C}$$

$$v = 0.001265 + 0.000057 \times \frac{1200\text{-}1121.03}{1220.9\text{-}1121.03} = \mathbf{0.0013096\ m^3/kg}$$

c) Table B.3.1: P > Psat => x = **undef**, **compr. liquid**

Approximate as saturated liquid at same T, $h = h_f = \mathbf{31.45\ kJ/kg}$

d) Table B.5.1: h > hg => x = **undef**, **superheated vapor** B.5.2,

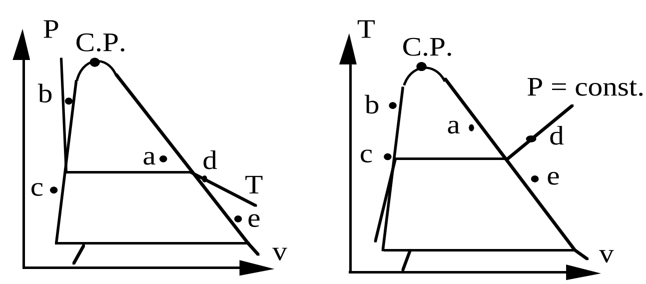
find it at given T between 1400 kPa and 1600 kPa to match h:

$$v \cong 0.01503 + (0.01239\text{-}0.01503) \times \frac{430\text{-}434.08}{429.32\text{-}434.08} = \mathbf{0.01269\ m^3/kg}$$

e) Table B.2.1: P < Psat => x = **undef**, **superheated vapor**, from B.2.2:

$v = \mathbf{1.4153\ m^3/kg}$; $u = h - Pv = 1516.1 - 100 \times 1.4153 = \mathbf{1374.6\ kJ/kg}$

States shown are placed relative to the two-phase region, not to each other.



Pb # 5.10

C.V.: Nitrogen in tank. $m_2 = m_1$; $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Process: V = constant, $v_2 = v_1 = V/m$ => $\mathbf{{}_1W_2 = \emptyset}$

Table B.6.2: State 1: $v_1 = 0.045514$ => $m = V/v_1 = 2.197$ kg

$u_1 = h_1 - P_1v_1 = 963.59 – 6000 \text{ x } 0.045514 = 690.506$

State 2: 100 K, $v_2 = v_1 = V/m$, look in table B.6.2 at 100 K

500 kPa: v= 0.05306 ; h = 94.46, 600 kPa: v = 0.042709, h = 91.4

so a linear interpolation gives: $P_2 = 572.9$ kPa, $h_2 = 92.265$ kJ/kg,

$u_2 = h_2 - P_2v_2 = 92.265 - 572.9 \times 0.04551 = 66.19$ kJ/kg

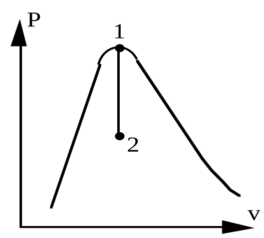
${}_1Q_2 = m(u_2 - u_1) = 2.197 (66.19 – 690.506) =$ **-1372 kJ**

Pb # 5.13

Solution:

C.V.: Water

$m_2 = m_1 = m$; $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$



Process: Constant volume $\Rightarrow v_2 = v_1$

Properties from Table B.1.1

State 1: $v_1 = v_c = 0.003155$ $u_1 = 2029.6$

$m = V/v_1 = 0.0317$ kg

State 2: T_2, $v_2 = v_1 = 0.001002 + x_2 \text{ x } 57.79$

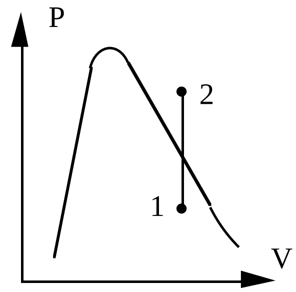
$x_2 = 3.7\text{x}10^{-5}$, $u_2 = 83.95 + x_2 \text{ x } 2319 = 84.04$

Constant volume => ${}_1W_2 = \emptyset$

${}_1Q_2 = m(u_2 - u_1) = 0.0317(84.04 - 2029.6) =$ **-61.7 kJ**

Pb # 5.17

C.V.: NH_3 : $m_2 = m_1 = m$; $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$



Process: constant volume process $\Rightarrow {}_1W_2 = 0$

State 1: $v_1 = 0.001504 + 0.2 \times 0.62184 = 0.1259$

=> $m = V/v_1 = 0.05/0.1259 = 0.397$ kg

$u_1 = 88.76 + 0.2 \times 1210.7 = 330.9$ kJ/kg

State 2: P_2 , $v_2 = v_1$ => superheated vapor

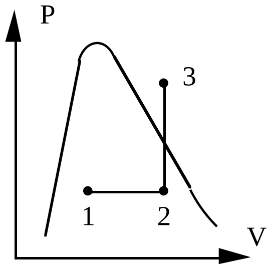
T ≅ 110°C, $u_2 = h_2 - P_2v_2 = 1677.6 - 1400 \text{ x } 0.1259 = 1501.34$

${}_1Q_2 = m(u_2 - u_1) = 0.397(1501.34 - 330.9) =$ **464.7 kJ**

Pb # 5.20

Solution:

C.V. R-22. Control mass goes through process: 1 -> 2 -> 3



As piston floats pressure is constant (1 -> 2) and the volume is constant for the second part (2 -> 3)

So we have: $v_3 = v_2 = 2 \text{ x } v_1$

State 3: Table B.4.2 (P,T) $v_3 = 0.02015$

$u_3 = h - Pv = 274.39 - 1300 \times 0.02015 = 248.2$ kJ/kg

So we can then determine state 1 and 2 Table B.4.1:

$v_1 = 0.010075 = 0.0008 + x_1 \times 0.03391 \quad \Rightarrow \quad x_1 = \mathbf{0.2735}$

b) $u_1 = 55.92 + 0.271 \times 173.87 = 103.5$

State 2: $v_2 = 0.02015$, $P_2 = P_1 = 681$ kPa this is still 2-phase.

$${}_1W_3 = {}_1W_2 = \int_1^2 PdV = P_1(V_2 - V_1) = 681 \text{ x } 5\ (0.02 - 0.01) = \mathbf{34.1\ kJ}$$

$${}_1Q_3 = m(u_3 - u_1) + {}_1W_3 = 5(248.2-103.5) + 34.1 = \mathbf{757.6\ kJ}$$

Pb # 5.27

Solution:

Take CV as the nitrogen.

$m_2 = m_1 = m$; $\quad m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

State 1: Table B.6.1

$v_1 = 0.001452 + 0.5 \times 0.02975 = 0.01633$ m^3/kg, $V_1 = \mathbf{0.0327\ m^3}$

$h_1 = -73.20 + 0.5 \times 160.68 = 7.14$ kJ/kg

State 2: P = 779.2 kPa , 300 K => sup. vapor interpolate in Table B.6.2

$v_2 = 0.14824 + (0.11115-0.14824) \times 179.2/200 = 0.115$ m^3/kg, $V_2 = \mathbf{0.23\ m^3}$

$h_2 = 310.06 + (309.62-310.06) \times 179.2/200 = 309.66$ kJ/kg

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

$${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = m(h_2 - h_1) = 2 \text{ x } (309.66 - 7.14) = \mathbf{605\ kJ}$$