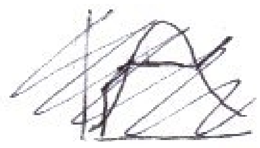
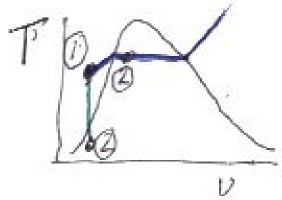


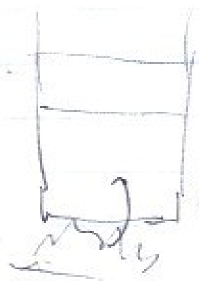


Chapter 5 [1st law = energy conservation]

Section 4.6 heat unit J (book kJ)

$1 kcal = 4.1868 kJ$
$1 BTU = 1.055056 kJ$ } Table A.1

Internal energy:

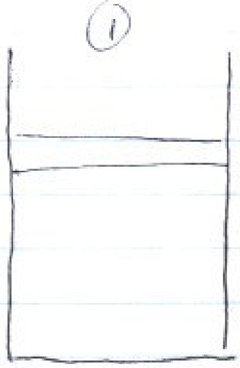


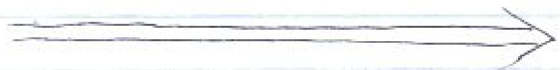
heat energy goes into kinetic and potential energy of the molecules

U: internal energy : [kJ] $u = \frac{U}{m}$: specific internal energy $\left[\frac{kJ}{kg}\right]$ → tables!

In 2 phase region $u = u_f + x(u_g - u_f)$

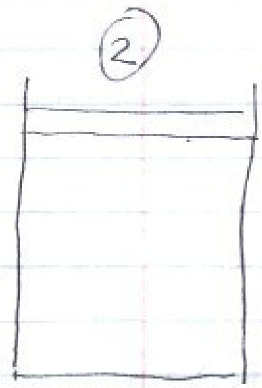
The first law = energy conservation





$$E_2 - E_1 = {}_1Q_2 - {}_1W_2$$

first law



$E_1 = m_1 u_1$
$[+ m_1 g Z_1$
$+ \frac{1}{2} m_1 Vel_1^2]$

$E_2 = m_2 u_2$
$[+ m_2 g Z_2$
$+ \frac{1}{2} m_2 Vel_2^2]$

${}_1Q_2$ is heat <u>added</u> to the substance

${}_1W_2$ is work <u>extracted</u> from the substance

Most of the time $E_2 - E_1 = U_2 - U_1 = {}_1Q_2 - {}_1W_2$

$= m(u_2 - u_1)$

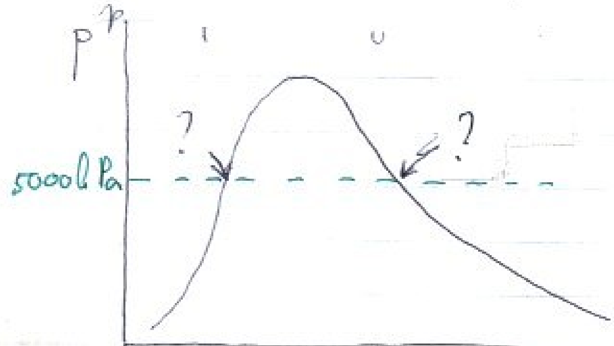
Chapter 3 type questions:

p 5.31 a H_2O 5000 kPa $u = 1000$ kJ/kg

Asked : p, T, v, u, x

Ans p = 5000 kPa u = 1000 kJ/kg

Need to find phase. Process for p,u is similar to p,v, (T,u is similar to T,v). p,u known, → p v is easiest. 5000 kPa line lined:



Now look up u_f and u_g in the saturated Tables

Table B.1.2 (A-5) p 680

(Saturated water, pressure entry)		Specific volume	Internal energy (kJ/kg)		
Press [kPa]	Temp [°C]		Sat liq u_f	Evap u_{fg}	Sat vap u_g
⋮	⋮		⋮	⋮	⋮
5000	263.99		1147.78		2597.12

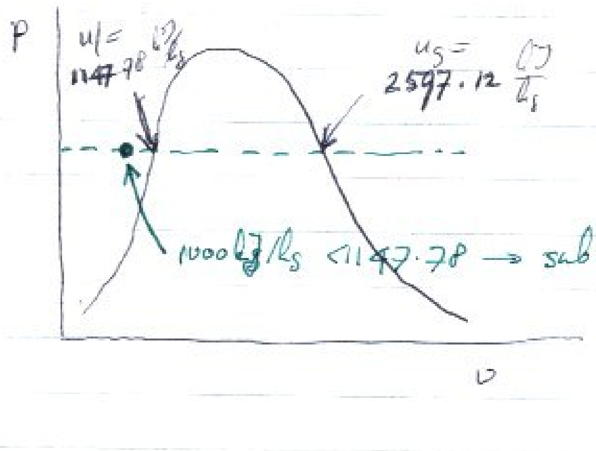


Table B.1.4 compressed liquid water p 608 @ 5000 kPa @ u = 1000 kJ/kg (A7, 5 MPa)

Temp °C	v m³/kg	u kJ/kg	- - -
		5000 kPa	
220°	0.001187	938.43 ✓ g_1	
240	0.001226	1031.34 ✓ g_2	

$g = 1000$

$$\frac{g - g_1}{g_2 - g_1} = \frac{1000 - 938.43 \ kJ/kg}{1031.34 - 938.43 \ kJ/kg} = 0.663$$

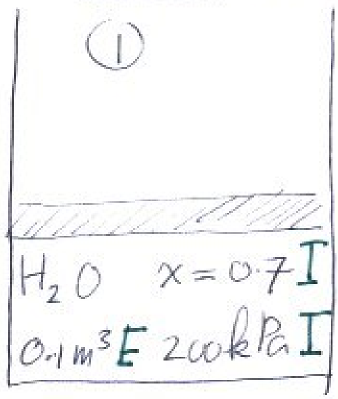
$$T = 220 + 0.663(240 - 220)°C = \underline{233°C}$$

$$v = 0.001187 \frac{m^3}{kg} + 0.663(0.001226 - 0.001187) \frac{m^3}{kg} = \underline{0.001213 \frac{m^3}{kg}}$$

x undefined (in 2 phase, you would have used $u = u_f + x u_{fg}$)

P5.49 | Abbreviated: only ask for ${}_1Q_2$

Given in black:

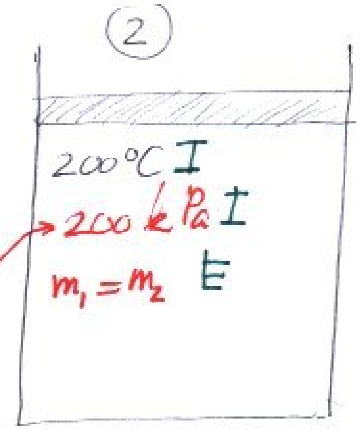


piston exerts constant pressure of 200 kPa

heated

isobaric → ${}_1W_2 = P(V_2 - V_1)$

$E_2 - E_1 = U_2 - U_1 = {}_1Q_2 - {}_1W_2$



Asked: ${}_1Q_2$

Solution: The only equation for ${}_1Q_2$ is the first law. To compute ${}_1Q_2$ from it, I need $U_1 = m u_1$, $U_2 = m u_2$, and ${}_1W_2 = P(V_2 - V_1)$, which in turn requires V_2.

B.1.2 @ 200 kPa

Start with 1:

$$v_1 = v_f + x v_{fg} = 0.001061 \frac{m^3}{kg} + 0.7\left(0.88467 \frac{m^3}{kg}\right) = 0.62033 \frac{m^3}{kg}$$

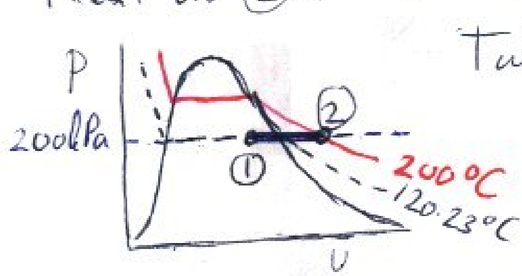
$$u_1 = u_f + x u_{fg} = 504.47 \frac{kJ}{kg} + 0.7\ 2025.02 \frac{kJ}{kg} = 1921.98 \frac{kJ}{kg}$$

$$m = m_1 = \frac{V_1}{v_1} = \frac{0.1\,m^3}{0.62033\,m^3/kg} = 0.1612\,kg$$

$$U_1 = m u_1 = 0.1612\,kg\ 1921.98 \frac{kJ}{kg} = 309.8\,kJ$$

Next do 2: Table B.1.2 @ 200 kPa: $T_s = 120.23\,°C$. ⇒ Superheated vapor

Table B.1.3 @ 200 °C and 200 kPa:



$$v_2 = 1.08034 \frac{m^3}{kg} \qquad u_2 = 2654.39 \frac{kJ}{kg}$$

$$V_2 = m v_2 = 0.1612\,kg\ 1.08034 \frac{m^3}{kg} = 0.17415\,m^3$$

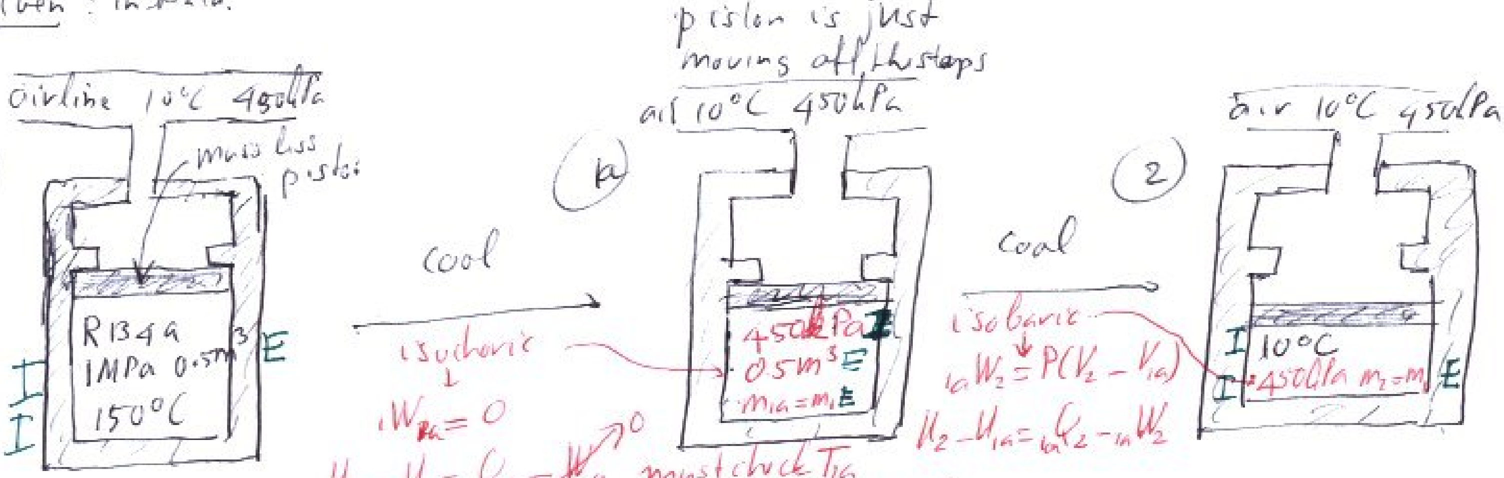
$$U_2 = m u_2 = 0.1612\,kg\ 2654.39 \frac{kJ}{kg} = 427.89\,kJ$$

$${}_1W_2 = P_1(V_2 - V_1) = 200\,kPa\,(0.17415 - 0.1)\,m^3 = 14.8\,kJ$$

$${}_1Q_2 = U_2 - U_1 + {}_1W_2 = 427.89\,kJ - 309.8\,kJ + 14.8\,kJ = \underline{133\,kJ}$$

Note: This could have done slightly quicker using enthalpy h instead of internal energy u: $U_2 - U_1 + {}_1W_2 = H_2 - H_1$ only if isobaric (see book for details)

Given: in black.



$_1W_{1a} = 0$

$U_{1a} - U_1 = {_1Q_{1a}} - {_1W_{1a}}$ (→ 0)

must check T_{1a} still greater than 10°C

$_{1a}W_2 = P(V_2 - V_{1a})$

$U_2 - U_{1a} = {_{1a}Q_2} - {_{1a}W_2}$

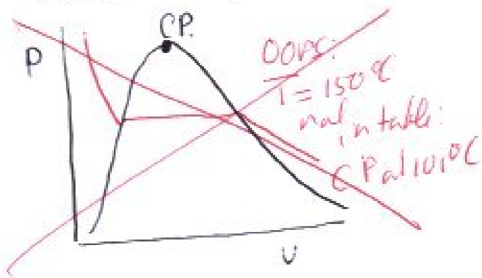
Quicker way: $U_2 - U_1 = {_1Q_2} - {_1W_2}$, $_1W_2 = {_{1a}W_2}$

Asked: $_1Q_2$ and Pv diagram

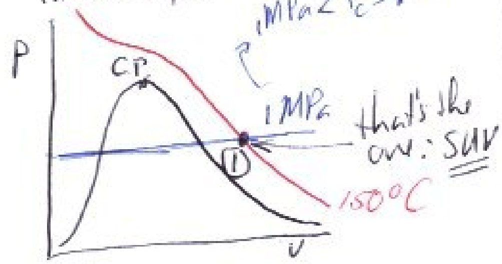
$\to {_1Q_{1a}} + {_{1a}Q_2}$

Solution

Phase 1 using PvT first:



Corrected phase 1 in PvT first:



→ use A-13 @ 1MPa, 150°C →

$v_1 = 0.032512 \frac{m^3}{kg}$

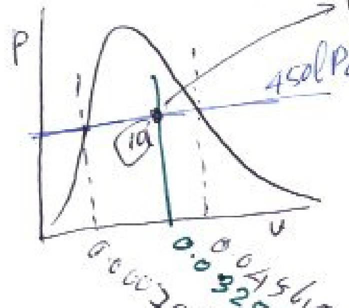
$m_1 = m = \frac{V_1}{v_1} = \left(\frac{0.032512 \frac{m^3}{kg}}{0.5 m^3}\right)^{-1} = 15.379 kg$

$u_1 = 355.71 kJ/kg$

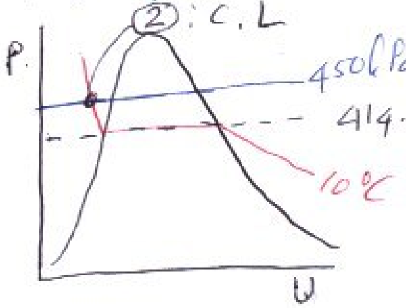
State 1a: $P_{1a} = 450kPa$ $v_{1a} = v_1 = 0.032512$

→ 1a is SAT →(A-12) $T = 12.460 > 10°C$

yes, it comes off the stops



State 2: C.L



No compressed liquid table → use saturated @ 10°C $u_2 \approx u_f = 65.10 \frac{kJ}{kg}$

$v_2 \approx v_f = 0.0007930 \frac{m^3}{kg}$

$V_2 = m v_2$ $_{1a}W_2 = P_2(V_2 - V_{1a}) = P_2 m (v_2 - v_{1a})$

$_{1a}W_2 = 450kPa \cdot 15.379 kg \, (0.0007930 - 0.032512) \frac{m^3}{kg}$

$= -219.511 kJ$

$_1Q_2 = U_2 - U_1 + {}_1W_2 = m(u_2 - u_1) + {}_{1a}W_2 = $ ~~0.0656025~~ 15.3791 kg $(65.10 - 355.71)\frac{kJ}{kg}$ − ~~0.92123~~ 219.511 kJ

= ~~−19.825 kJ~~ (negative since heat goes out of the substance.

= −4689 kJ

Combined Pv diagram