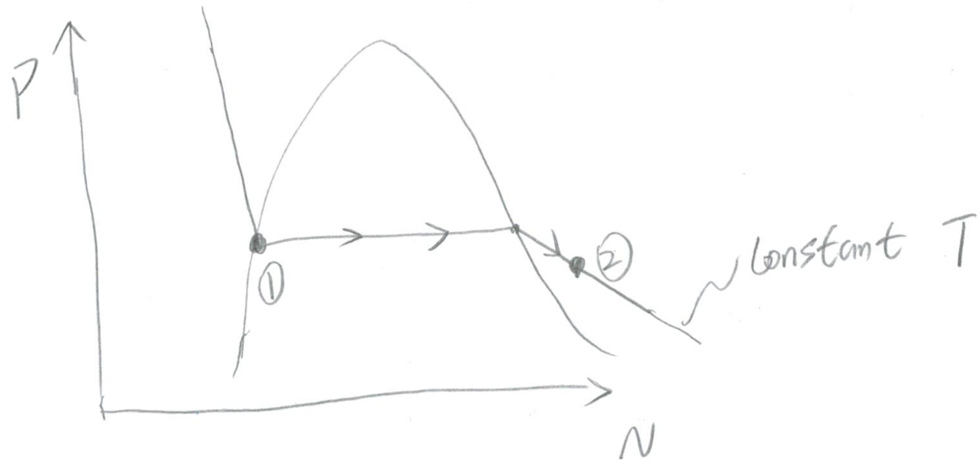
1.

(a)



$P_{②} < P_{①}$

(b.1) $C_v = 0.657 \ kJ/kg \cdot k$

$\Delta u = C_v(T_2 - T_1) = 0.657 \times (127 - 27) = 65.7 \ kJ/kg$

(b.2) $C_p = 0.846 \ kJ/kg \cdot k$, $R = 0.1889 \ kJ/kg \cdot k$

$\Delta u = \Delta h - p\Delta v$

ideal gas: $P_1 v_1 = RT_1$, $P_2 v_2 = RT_2$, $P_1 = P_2$

$\Rightarrow P_2 v_2 - P_1 v_1 = RT_2 - RT_1$, $\Delta h = C_p(T_2 - T_1)$

$\Rightarrow \Delta u = C_p(T_2 - T_1) - R(T_2 - T_1) = 65.7 \ kJ/kg$

or, simply $\Delta u = C_v(T_2 - T_1) = 65.7 \ kJ/kg$ for ideal gas.

only for ideal gas, we have $\Delta u = C_v \Delta T$

(c)

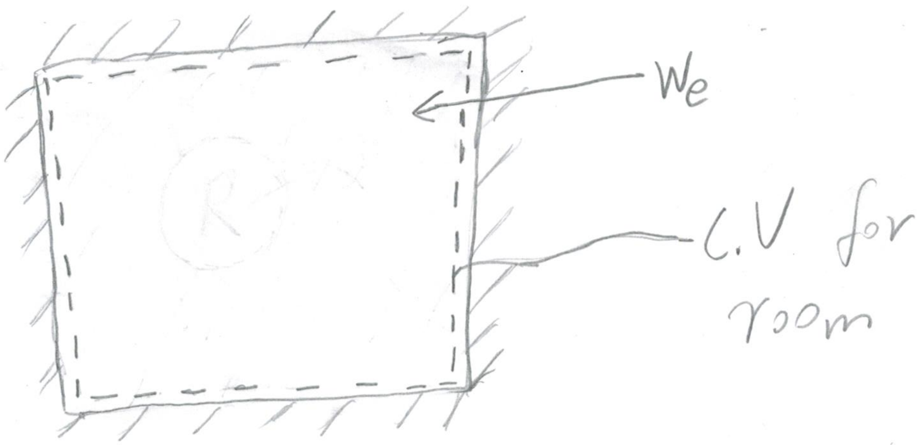
(c.1) $u_2 - u_1 = c(T_2 - T_1) = 1 \times (200 - 500) = -300 \ kJ/kg$

(c.2)

$h_2 - h_1 = \Delta u + v \Delta P = c(T_2 - T_1) + \frac{1}{\rho}(P_2 - P_1) = -300 \frac{kJ}{kg} + \frac{1}{3000}(2 \times 10^3 - 100 \times 10^3) \ kJ/kg$

$\Rightarrow h_2 - h_1 = -332.67 \ kJ/kg$

(d)

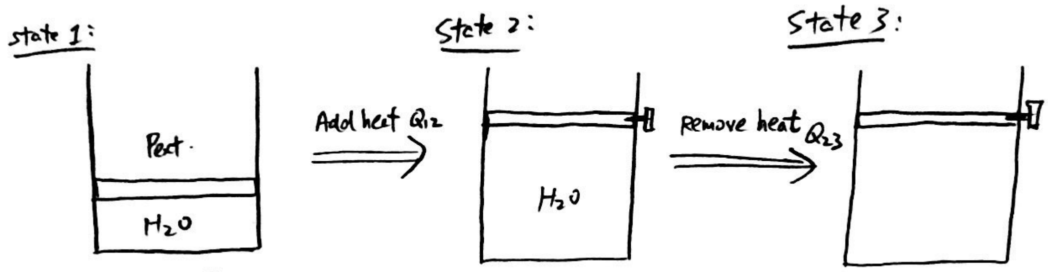


Q from refrigerator to room due to electrical work. We.

$\Rightarrow \Delta U_{CV} = W_e \Rightarrow U_2 - U_1 = W_e > 0 \Rightarrow T \uparrow$

$\Rightarrow$

Q2). water, $m = 5\,kg$. , $P_{ext} = 2.5\,MPa$.



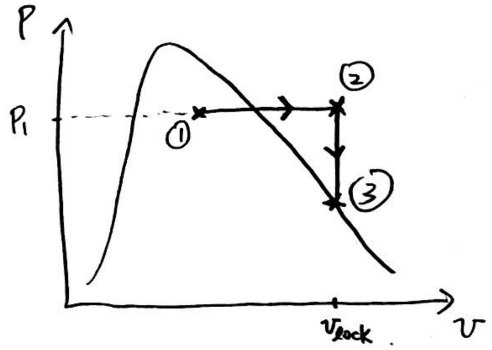
$P_1 = 2.5\,MPa$

$x_1 = 0.6$.

$V_{lock} = 0.7\,m^3$

Sat. vapor.

a)



b). • Initially, constant pressure heat addition. When $V = V_{lock}$, constant volume heat removal.

$$v_3 = v_2 = v_{lock} = \frac{V_{lock}}{m} = \frac{0.7\,m^3}{5\,kg} = 0.14\,m^3/kg.$$

• Find sat. T and P that $v_g = v_{lock} = 0.14\,\frac{m^3}{kg}$

$$\Rightarrow \boxed{P_3 = 1400\,kPa, \quad T_3 = 195.04\,^\circ C.}$$

c) 1st Law: (Closed system, neglect ΔKE, ΔPE)

Process 1-2: $Q_{12} = \Delta U + W_{12}$

$\Delta U = m(u_2 - u_1)$

• $u_1 = u_f(1-x_1) + u_g x_1$ @ $P = 2.5\,MPa$

$= (958.87\,\frac{kJ}{kg})(1-0.6) + (2602.1\,\frac{kJ}{kg})(0.6)$

$u_1 = 1944.808\,kJ/kg$

• Find u_2 from superheated table where $P = 2.5\,MPa$, $v = 0.14\,\frac{m^3}{kg}$

$\Rightarrow u_2 = 3112.8\,kJ/kg.$

ΔU
$= (5\,kg)(3112.8 - 1944.808)$
$\approx 5840\,kJ$

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c) (Cont'd) $W_{12} = P_1(v_2 - v_1)m$ (Constant-Pressure process)

- $v_1 = v_f(1-x_1) + v_g x_1 = (0.001197 \frac{m^3}{kg})(1-0.6) + (0.079952 \frac{m^3}{kg})(0.6) = 0.04845 \frac{m^3}{kg}$.

$W_{12} = (2500\,kPa)(0.14 - 0.04845 \frac{m^3}{kg})(5kg) \approx 1144\,kJ$

$\Rightarrow Q_{12} = 5840 + 1144 = \underline{\underline{6984\,kJ}}$

d). There are two ways to calculate Q_{13}.

Method 1: Energy balance from state 1-3

$Q_{13} = W_{13} + (U_3 - U_1)$

$U_3 - U_1 = m(u_3 - u_1)$

$= (5kg)(2591.8 - 1944.808 \frac{kJ}{kg})$

$= 3235\,kJ$.

$W_{13} = W_{12} + \underbrace{W_{23}}_{=0\ (\because \text{ constant volume})}$.

$= 1144\,kJ$

$\Rightarrow Q_{13} = 3235 + 1144 = \underline{\underline{4379\,kJ}}$

Method 2: Energy balance from state 2-3, sum Q_{12} and Q_{23}

$Q_{23} = W_{23} + (U_3 - U_2)$

$U_3 - U_2 = m(u_3 - u_2)$

$= (5kg)(2591.8 - 3112.8 \frac{kJ}{kg})$

$= -2605\,kJ$.

$W_{23} = 0$ (constant volume).

$\Rightarrow Q_{23} = -2605\,kJ$

(Negative sign, heat removal ✓)

Finally:

$Q_{13} = Q_{12} + Q_{23}$

$= 6984 + (-2605)$

$Q_{13} = \underline{\underline{4379\,kJ}}$

match ✓✓

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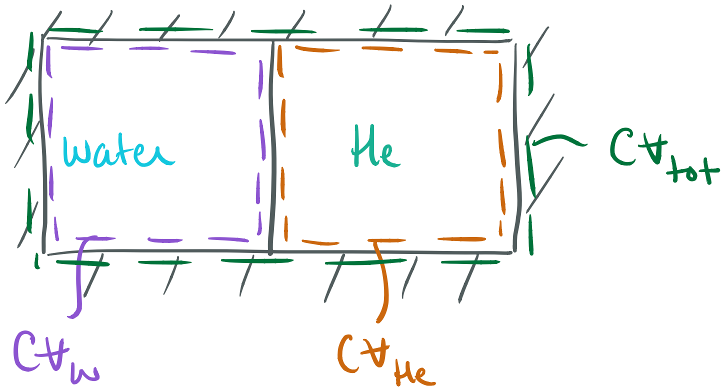
Problem 3



a) Ideal gas law (He only): $P\forall = mRT \rightarrow m = \dfrac{P\forall}{RT}$

$$R = \frac{R_u}{M} \left[\frac{kJ}{kg\text{-}K}\right]$$

$$m = \frac{(7 \times 10^3 \text{ kPa})(2 \text{ m}^3)}{\left(2.0769 \frac{kJ}{kg\,K}\right)(670+273)K}$$

absolute temperature!

from table

units check: $\dfrac{\cancel{kPa \cdot m^3}^{\,\cancel{kJ}}}{\frac{\cancel{kJ}}{kg\,\cancel{K}} \cdot \cancel{K}} = kg$ ✓

$$m = 7.1483 \text{ kg} \rightarrow \boxed{m_{He} = 7.15 \text{ kg}}$$

b) division is rigid $\rightarrow \forall_2 = \forall_1$ for each compartment

$P_1\forall_1 = mRT_1$ & $P_2\forall_2 = mRT_2$

$\dfrac{P_1\forall_1}{T_1} = mR$ ① $\qquad \dfrac{P_2\forall_2}{T_2} = mR$ ②

① ∧ ②

$$\frac{P_1\cancel{\forall_1}}{T_1} = \frac{P_2\cancel{\forall_2}}{T_2} \rightarrow T_2 = \frac{P_2 T_1}{P_1}$$

$$T_2 = \frac{(5\,\cancel{MPa})(670+273)K}{7\,\cancel{MPa}}$$

$$T_2 = 673.6 \text{ K}$$

$$\boxed{T_2 = 400\,^\circ C}$$

c) $\Delta U_{sys} = \Delta U_w + \Delta U_{He} = 0 \longrightarrow \Delta U_w = -\Delta U_{He}$

rigid / insulated container

$\Delta U_{He} = -Q_{He \to w} - \cancel{W}_{He}$ with $W_{He} = 0$; $\xrightarrow[\text{const. sp. heat}]{\text{IG}}$ $\Delta U_{He} = C_v dT = Q_{He}$

↳ neg sign b/c know heat flowing out (steam 2-ph → SH)

$$Q_{He \to w} = -mC_v(T_2 - T_1) = -(7.15\,\cancel{kg})\left(3.1156\,\frac{kJ}{\cancel{kg\text{-}K}}\right)(400 - 670)\,\cancel{K}$$

ok to use °C b/c taking a difference!

$$\boxed{Q_{He \to w} = 6 \times 10^3\ kJ}$$

d) It turns out this problem was over specified and there were therefore two approaches to solving this part with the given information. We will give full credit for either approach.

i) $m_w = \dfrac{V}{v_{1w}}$, where $v_{1w} = v_f(950\,kPa) + x v_{fg}(950\,kPa) = 0.1513\ m^3/kg$

$$m_w = \frac{2\,\cancel{m^3}}{0.1513\,\cancel{m^3}/kg} \longrightarrow \boxed{m_w = 13.2\ kg}$$

ii) $\Delta U_w = -\Delta U_{He}$

$$m_w \Delta u_w = -m_{He} c_v (T_{2He} - T_{1He}) = Q_{He \to w}$$

$$m(u_{2w} - u_{1w}) = Q_{He \to w}$$

$$m = \frac{Q}{u_{2w} - u_{1w}}$$

$u_{1w} = u_f + x u_{fg} = 2105.6\ kJ/kg$

$v_{2w} = v_f + x v_{fg} = 0.1513\ m^3/kg$ ↓ constant

→ $v_{2w} = v_{1w} = v_w$ & @ 400°C (b/c $T_{2w} = T_{2He}$)

→ SH table, look for $T = 400°C$ & $v = 0.1513\ \frac{m^3}{kg}$

(Note: P_{2He} doesn't have to equal P_{2w} b/c the partition is rigid!)

$T = 400°C$ & $P = 2.00\ MPa$, $v = 0.15122\ m^3/kg \simeq v_w$

→ $u_{2w} = 2945.9\ kJ/kg$

$$m_w = \frac{6\times10^3\ \text{kJ}}{(2945.9 - 2105.6)\ \text{kJ/kg}} \rightarrow \boxed{m_w = 7.14\ \text{kg}}$$

Note that the two approaches give different answers, indicating there was something unphysical in the problem. This could be remedied many ways, e.g. by not specifying the volume of the water side of the box.