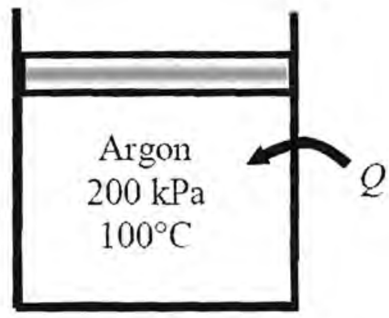
1. A piston-cylinder device containing argon gas as the system undergoes an isothermal process from 200 kPa and 100°C, to 50 kPa. During the process, 1500 kJ of heat is transferred to the system. Determine a) the amount of boundary work produced, and b) the mass of the argon.

   Assume an ideal gas, and that changes in kinetic and gravitational potential energies are negligible.

   Argon $\quad R = 0.2081$ kJ/kg·K, ← Table A-1
   $\qquad\quad M = 39.948$ kg/kmol



CCT 5-69 $\quad$ 12 points $\left\}\begin{array}{l}\text{a) 4 pts}\\ \text{b) 8 pts}\end{array}\right.$

(a) This is a closed system. from 1st law

$$Q_{net,in} - W_{net,out} = m(u_2 - u_1)$$

$$= m\,c_v\,\cancel{(T_2 - T_1)} \rightarrow 0 \quad \text{because } T_2 = T_1 \text{ (isothermal)}$$

$$= 0$$

☆ isothermal ⇒ no change in internal energy ☆

$$\therefore W_{net\,out} = Q_{net,in} \boxed{= 1500\text{ kJ}}$$

(b) Boundary work for a closed system, isothermal, ideal gas

$$W_b = P_1 V_1 \left[\ln\left(\frac{V_2}{V_1}\right)\right]$$

$T_1 = T_2 = T$

use ideal gas relation: $P_1 V_1 = mRT = P_2 V_2$

$$\therefore \frac{V_2}{V_1} = \frac{P_1}{P_2}$$

$$W_b = mRT \ln\left(\frac{P_1}{P_2}\right) \quad \therefore \text{solve for } m$$

$$m = \frac{W_b}{RT \ln(P_1/P_2)} = \frac{1500\text{ kJ}}{\left(0.2081 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right)(273+100)\text{K}\,\ln(200/50)}$$

$$\boxed{m = 13.9\text{ kg}}$$

2. Steam enters an adiabatic turbine at 10 MPa and 500°C and leaves at 10 kPa with a quality of 90 percent. Neglecting changes in kinetic and potential energies, calculate the mass flow rate required for a power output of 5 MW.

CCT 6-45 10 points

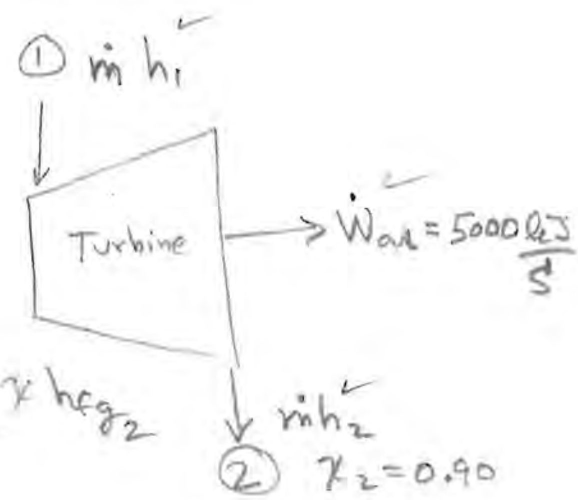
Properties of H_2O at 10 MPa and 500°C ①

$v = 0.032811\ \text{m}^3/\text{kg}$
$u = 3047.0\ \text{kJ/kg}$
$h = 3375.1\ \text{kJ/kg}$

Properties of H_2O at 10 kPa saturated ②

$v_f = 0.001010\ \text{m}^3/\text{kg}$
$v_g = 14.670\ \text{m}^3/\text{kg}$
$u_f = 191.79\ \text{kJ/kg}$
$u_{fg} = 2245.4\ \text{kJ/kg}$
$u_g = 2437.2\ \text{kJ/kg}$
$h_f = 191.81\ \text{kJ/kg}$
$h_{fg} = 2392.1\ \text{kJ/kg}$
$h_g = 2583.9\ \text{kJ/kg}$

$h_2 = h_{f_2} + x\, h_{fg_2}$



calculate $\dot{m}$

use 1st law for steady state, steady flow $(\dot{Q}_{in} = \dot{W}_{in} = \dot{Q}_{out} = \Delta KE = \Delta PE = 0)$

$$\dot{m}\, h_1 = \dot{W}_{out} + \dot{m} h_2$$

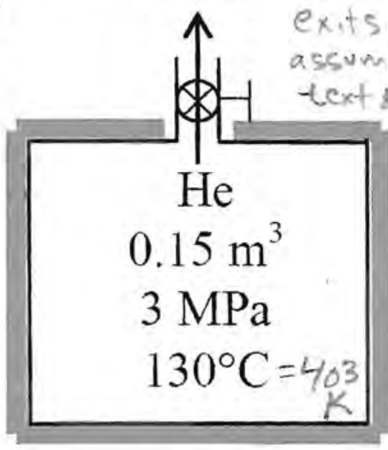
$$\dot{m} = \frac{\dot{W}_{out}}{(h_1 - h_2)} = \frac{5000\ \text{kJ/s}}{\left[\underbrace{3375.1}_{h_1} - \left(\underbrace{191.81}_{h_{f_2}} + \underbrace{0.90}_{x_2}\underbrace{[2392.1]}_{h_{fg_2}}\right)\right]}$$

$$= \frac{5000\ \text{kJ/s}}{(3375.1 - 2344.7)\ \text{kJ/kg}} = \frac{5000}{1030.4}$$

$$\boxed{\dot{m} = 4.85\ \text{kg/s}}$$

3. An insulated (adiabatic) 0.15 m^3 tank contains helium at 3 MPa and 130°C. A valve is now opened, allowing some helium to escape. The valve is closed when ½ (50%) of the initial mass has escaped. Calculate the final temperature in the tank.
   Also given: assume ideal gas
   Assume uniform state and uniform flow conditions. Neglect changes in kinetic and potential energies. Assume constant properties at 300K apply for helium: ← for He that exits (same assumption in text homework)
   - $R = 2.0769$ kJ/kg·K,
   - $M = 4.003$ kg/kmol
   - $c_v = 3.1156$ kJ/kg·K
   - $c_p = 5.1926$ kJ/kg·K
   - $k = 1.667$

CCT 6-131
12 points



1st law USUF, $0 = \Delta KE = \Delta PE = Q_{in} = Q_{out} = W_{in} = W_{out}$
ie. no work, no heat transfer

$$\underbrace{\cancel{m_{in} h_{in}}}_{\text{input}} - \underbrace{m_{out} h_{out}}_{\text{output}} = \underbrace{m_2 u_2}_{\text{final}} - \underbrace{m_1 u_1}_{\text{initial}}$$

0 $m_{in} = 0$

continuity, mass balance $m_1 - m_2 = m_{out}$

given: $m_2 = \frac{1}{2} m_1 \quad \therefore \; m_{out} = m_1 - \frac{1}{2} m_1 = \frac{1}{2} m_1$

$$\Rightarrow \quad -\frac{1}{2} m_1 h_{out} = \frac{1}{2} m_1 u_2 - m_1 u_1$$

divide by m_1 $\Rightarrow \; 0 = \frac{1}{2} h_{out} + \frac{1}{2} u_2 - u_1$

For h_{out}, use c_p at 300K $\Rightarrow h_{out} = C_p \left(\frac{T_1 + T_2}{2}\right)$

$u_1 = C_v T_1 \qquad u_2 = C_v T_2$

$$\Rightarrow 0 = \frac{1}{2} C_p \left(\frac{T_1 + T_2}{2}\right) + \frac{1}{2} C_v T_2 - C_v T_1 \quad \text{solve for } T_2$$

divide by C_v and $k \equiv c_p / c_v$. also multiply both sides by 2

$$0 = \frac{1}{2} k \left(\frac{T_1 + T_2}{2}\right) + \frac{1}{2} T_2 - T_1 \Rightarrow 0 = \frac{k T_1}{2} + \frac{k T_2}{2} + T_2 - 2T_1$$

$$0 = \left(1 + \frac{k}{2}\right) T_2 + \left(\frac{k}{2} - 2\right) T_1 \Rightarrow T_2 = \frac{\left(2 - \frac{k}{2}\right) T_1}{\left(1 + \frac{k}{2}\right)} = \frac{1.1665\,(403\text{ K})}{1.8335}$$

$$\boxed{T_2 = 256\text{ K}}$$

4. Bananas ($c_P = 3.35\ \mathrm{kJ/kg \cdot K}$) are to be cooled from 24°C to 13°C at a rate of 215 kg/h by a refrigeration system. The power input to the refrigerator is 1.4 kW. Determine a) the rate of cooling in kJ/min, and b) the COP of the refrigerator.

a) calc $\dot{Q}_L$

b) calc $COP_R = \frac{\dot{Q}_L}{\dot{W}_{net}} = \frac{Q_L}{1.4\ kJ/s}$

CCT 7-47 6 points

(a) $\dot{Q}_L = \dot{m} c_P (T_1 - T_2)$ is heat removed from the bananas (a solid substance)

$= \left(\frac{215\ kg}{h}\right)\left(3.35 \frac{kJ}{kg\,°C}\right)(24-13)°C \left(\frac{h}{60\ min}\right)$

$\Delta T(°C) = \Delta T(K)$

$$\boxed{\dot{Q}_L = 132\ kJ/min}$$

(b) $COP = \frac{\dot{Q}_L}{\dot{W}_{net}} = \frac{132\ kJ/min}{1.4\ kJ/s}\left(\frac{min}{60\ s}\right)$

$$\boxed{COP = 1.57}$$