1. A well-insulated rigid tank contains 5 kg of a saturated liquid–vapor mixture of water at l00 kPa. Initially, three-quarters of the mass is in the liquid phase. An electric resistor placed in the tank is connected to a 110-V source, and a current of 8 A flows through the resistor when the switch is turned on. Determine how long (in minutes) it will take to vaporize all the liquid in the tank.

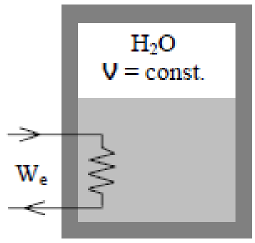
2. A piston cylinder contains 1 kg water at 20ºC with a constant load on the piston such that the pressure is 250 kPa. A nozzle in a line to the cylinder is opened to enable a flow to the outside atmosphere at 100 kPa. The process continues to half the mass has flowed out and there is no heat transfer. Assume constant water temperature and find the exit velocity (in m/s) and total work done (in kJ) in the process. Write down the answers in the google form as comma separated list.

3. Two blocks of metal, each having a mass of 10 kg and a specific heat of 0.4 kJ/kg K, are at a temperature of 40 °C. A reversible refrigerator receives heat from one block and rejects heat to the other. Calculate the minimum work required (in kJ) to cause a temperature difference of 100 °C between the two blocks.

4. Two vessels, A and B, each of volume 3 m^3 may be connected by a tube of negligible volume. Vessel a contains air at 0.7 MPa, 95 °C, while vessel B contains air at 0.35 MPa, 205 °C. Find the change of entropy (in kJ/K) when A is connected to B by working from the first principles and assuming the mixing to be complete and adiabatic.
   Take: C_v = 0.718 kJ/kg K, R = 0.287 kJ/kg K.

Assumptions **1** The tank is stationary and thus the kinetic and potential energy changes are zero. **2** The device is well-insulated and thus heat transfer is negligible. **3** The energy stored in the resistance wires, and the heat transferred to the tank itself is negligible.

Analysis We take the contents of the tank as the system. This is a closed system since no mass enters or leaves. Noting that the volume of the system is constant and thus there is no boundary work, the energy balance for this stationary closed system can be expressed as



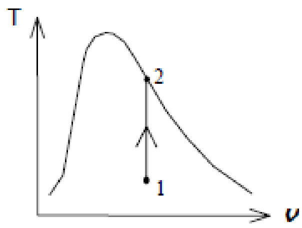
$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$W_{e,in} = \Delta U = m(u_2 - u_1) \quad (\text{since } Q = KE = PE = 0)$$

$$VI\Delta t = m(u_2 - u_1)$$

The properties of water are (Tables A-4 through A-6)

$$\left.\begin{array}{l} P_1 = 100\text{kPa} \\ x_1 = 0.25 \end{array}\right\} \begin{array}{l} v_f = 0.001043, \quad v_g = 1.6941 \text{ m}^3/\text{kg} \\ u_f = 417.40, \quad u_{fg} = 2088.2 \text{ kJ/kg} \end{array}$$



$$v_1 = v_f + x_1 v_{fg} = 0.001043 + [0.25 \times (1.6941 - 0.001043)] = 0.42431 \text{ m}^3/\text{kg}$$

$$u_1 = u_f + x_1 u_{fg} = 417.40 + (0.25 \times 2088.2) = 939.4 \text{ kJ/kg}$$

$$\left.\begin{array}{l} v_2 = v_1 = 0.42431 \text{ m}^3/\text{kg} \\ \text{sat.vapor} \end{array}\right\} u_2 = u_{g@0.42431\text{m}^3/\text{kg}} = 2556.2 \text{ kJ/kg}$$

Substituting,

$$(110 \text{ V})(8 \text{ A})\Delta t = (5 \text{ kg})(2556.2 - 939.4)\text{kJ/kg}\left(\frac{1000 \text{ VA}}{1 \text{ kJ/s}}\right)$$

$$\Delta t = 9186 \text{ s} \cong \mathbf{153.1 \text{ min}}$$

Solution:

C.V. The cylinder and the nozzle.

Continuity Eq.6.15: $m_2 - m_1 = - m_e$

Energy Eq.6.16: $m_2u_2 - m_1u_1 = - m_e(h_e + \frac{1}{2}\mathbf{V}_e^2) - {}_1W_2$

Process: $P = C \Rightarrow {}_1W_2 = \int P\, dV = P(V_2 - V_1)$

State 1: Table B.1.1, 20°C => $v_1 = 0.001002$, $u_1 = 83.94$ kJ/kg

State 2: Table B.1.1, 20°C => $v_2 = v_1$, $u_2 = u_1$;

$m_2 = m_1/2 = 0.5$ kg => $V_2 = V_1/2$

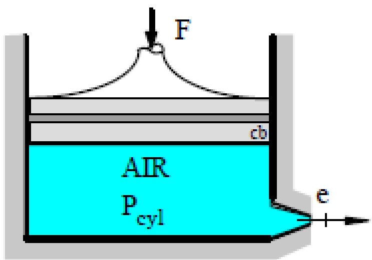
${}_1W_2 = P(V_2 - V_1) = 250\ (0.5 - 1)\ 0.001002 = \mathbf{-0.125\ kJ}$

Exit state: Table B.1.1, 20°C => $h_e = 83.94$ kJ/kg

Solve for the kinetic energy in the energy equation

$$\frac{1}{2}\mathbf{V}_e^2 = [m_1u_1 - m_2u_2 - m_eh_e - {}_1W_2]/m_e$$
$$= [1 \times 83.94 - 0.5 \times 83.94 - 0.5 \times 83.94 + 0.125] / 0.5$$
$$= 0.125/0.5 = 0.25 \text{ kJ/kg}$$
$$\mathbf{V} = \sqrt{2 \times 0.25 \times 1000} = \mathbf{22.36\ m/s}$$

All the work ended up as kinetic energy in the exit flow.



Solution: Mass = 10 kg

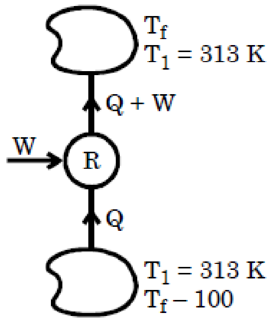
$C = 0.4$ kJ/kg – K

$T = 40° C = 313$ K

$$\therefore \quad (\Delta S)_{hot} = mc \ln\left(\frac{T_f}{313}\right)$$

$$(\Delta S)_{cold} = m\,c \ln\left(\frac{T_f - 100}{313}\right)$$

For minimum work requirement process must be reversible so $(\Delta S)_{univ} = 0$



$$\therefore \quad \ln\frac{T_f(T_f - 100)}{(313)^2} = 0 = \ln 1$$

$$\text{or} \quad T_f^2 - 100\,T_f - 313^2 = 0$$

$$\text{or} \quad T_f = \frac{100 \pm \sqrt{100^2 + 4 \times 313^2}}{2}$$

$$= 367 \text{ K or } (-267)$$

$$\therefore \quad Q + W = 10 \times 10.4 \times (367 - 313) = 215.87 \text{ kJ}$$

$$Q = 10 \times 0.4 \times (313 - 267) = 184 \text{ kJ}$$

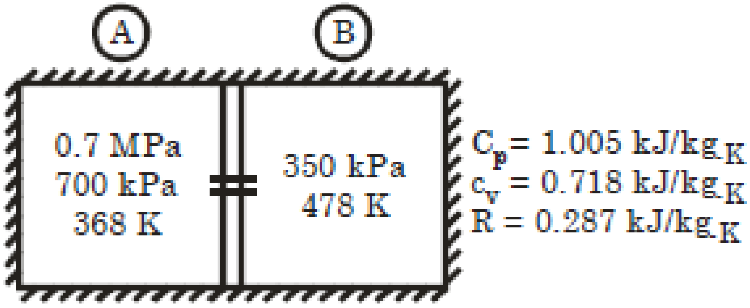
$$\therefore \quad W_{min} = 31.87 \text{ kJ}$$

Solution: Let the find temperature be (T_f)

$$\text{Mass of } (m_A) = \frac{p_A V_A}{RT_A}$$

$$= \frac{700 \times 3}{0.287 \times 368} \text{ kg}$$

$$= 19.88335 \text{ kg}$$



$$\text{Mass of gas } (m_B) = \frac{p_B V_B}{R\,T_B} = \frac{350 \times 3}{0.287 \times 478} = 7.653842 \text{ kg}$$

For adiabatic mixing of gas Internal Energy must be same

$$\therefore \quad u_A = m_A\, c_v\, T_A$$

$$= 19.88335 \times 0.718 \times 368 \text{ kJ} = 5253.66 \text{ kJ}$$

$$u_B = m_B\, c_v\, T_B$$

$$= 7.653842 \times 0.718 \times 478 \text{ kJ} = 2626.83 \text{ kJ}$$

$$U_{mixture} = (m_A c_v + m_B c_v)\, T_f$$

$$\text{Or} \quad T_f = 398.6 \text{ K}$$

If final pressure (p_f)

$$\therefore \quad p_f \times V_f = m_f\, RT_f$$

$$\therefore \quad p_f = \frac{27.5372 \times 0.287 \times 398.6}{6} \text{ kPa} = 525 \text{ kPa}$$

$$(\Delta S)_A = m_A\left[c_p \ln\frac{T_f}{T_A} - R\ln\left(\frac{p_f}{p_A}\right)\right] = 3.3277$$

$$(\Delta S)_B = m_B\left[c_p \ln\frac{T_f}{T_B} - R\ln\left(\frac{p_f}{p_B}\right)\right] = -2.28795 \text{ kJ/K}$$

$$\therefore \quad (\Delta S)_{univ} = (\Delta S)_A + (\Delta S)_B + 0 = 0.9498 \text{ kJ/K}$$