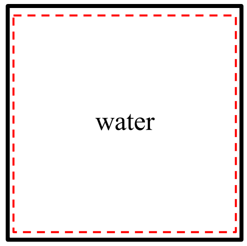
A closed, rigid tank is initially filled with 0.8 kg of water at 70 bar (abs) and a volume of 0.001 m^3 (state 1). Heat transfer occurs between the water and the surroundings until the pressure in the water is 35 bar (abs) (state 2).

a. Is the initial phase of the water a compressed liquid, saturated, or superheated vapor? Justify your answer.
b. Determine the specific internal energy at the initial state, in kJ/kg.
c. Calculate the specific volume at the final state, in m^3/kg.
d. Is the final phase of the water a compressed liquid, saturated, or superheated vapor? Justify your answer.
e. Determine the final specific internal energy of the water, in kJ/kg.
f. Determine the work done by the water during the process, in kJ.

SOLUTION:
The system is the water as shown in the following figure.



The specific volume at state 1 is,

$$v_1 = \frac{V}{m}, \quad (1)$$

where $V = 0.001\ \text{m}^3$ and $m = 0.8$ kg. Hence,

$$v_1 = 1.25*10^{-3}\ \text{m}^3/\text{kg}. \quad (2)$$

At a pressure of $p_1 = 70$ bar, the specific volume for a saturated liquid state is $1.3513*10^{-3}\ \text{m}^3/\text{kg}$ (from Table A-3 in Moran et al., 7th ed.). Since the specific volume at state 1 is smaller than this value, state 1 must be in a compressed liquid phase.

Since the water is in a compressed liquid state, we can use the saturated liquid value of the specific internal energy at the same temperature (recall that $u_{CL}(p,T) \approx u_l(T)$) to approximate the actual specific internal energy (found from Table A-3). Since the temperature isn't given we can estimate it from the specific volume. Recall that for a compressed liquid, $v_{CL}(p,T) \approx v_l(T)$. Thus, using Table A-2 in Moran et al., the temperature corresponding to $v_1 = v_{CL} = 1.25*10^{-3}\ \text{m}^3/\text{kg}$ is approximately $T = 250$ °C. The corresponding saturated liquid specific internal energy is,

$$u_1 = 1080.4\ \text{kJ/kg}. \quad (3)$$

The specific volume at state 2 will be identical to the specific volume at state 1 since the tank volume and water mass remain unchanged, i.e.,

$$v_2 = v_1 = 1.25*10^{-3}\ \text{m}^3/\text{kg}. \quad (4)$$

At $p_2 = 35$ bar (abs), the specific volumes for the saturated liquid and saturated vapor states (Table A-3) are, respectively,

$$v_{l2} = 1.2347*10^{-3}\ \text{m}^3/\text{kg}, \quad (5)$$

$$v_{v2} = 0.05707\ \text{m}^3/\text{kg}. \quad (6)$$

The specific volume for state 2 (Eq. (4)) falls between these two values. Hence, state 2 is in a saturated phase.

Since state 2 is in a saturated phase, the specific internal energy is found using the quality at state 2. The quality at state 2 can be found using the specific volume at state 2,

$$v_2 = x_2 v_{v2} + (1 - x_2) v_{l2} \Rightarrow x_2 = \frac{v_2 - v_{l2}}{v_{v2} - v_{l2}}, \quad (7)$$

$$x_2 = 2.74*10^{-4}. \quad (8)$$

The specific internal energy at the saturated liquid and saturated vapors states (Table A-3) is, respectively,

$$u_{l2} = 1045.4\ \text{kJ/kg}, \quad (9)$$

$$u_{v2} = 2603.7\ \text{kJ/kg}. \quad (10)$$

Hence, the specific internal energy at state 2 is,

$$u_2 = x_2 u_{v2} + (1 - x_2) u_{l2}, \quad (11)$$

$$u_2 = 1045.8\ \text{kJ/kg}. \quad (12)$$

Since the volume doesn't change during the process, there is no work done by the water,

$$W_{\substack{\text{on}\\ H_2O}} = 0. \quad (13)$$