An initially empty bottle is filled with water from a line at 0.800 MPa and 350°C. Assume that there is no heat transfer and that the bottle is closed when the pressure reaches the line pressure. If the final mass is 0.750 kg, find the final temperature and the volume of the bottle.

**Solution**

**Assumptions:** Kinetic and potential energy are not important.

Conservation of mass:

\[
m_2 - m_1 \neq m_i - m_e \neq 0 \quad m_2 = m_i
\]

Conservation of Energy:

\[
m_2 u_2 - m_1 u_1 \neq 0 = \oint \dot{Q} - \oint W + m_i h_i - m_e h_e \neq 0
\]

Inlet State (i)

\[
\begin{align*}
P_i &= 800 \text{ kPa} \\
T_i &= 350^\circ \text{C}
\end{align*}
\]

From table B.1.3 \( h_i = 3162 \text{ kJ/kg} \)

Final State (2)

\[
\begin{align*}
P_2 &= 800 \text{ kPa} \\
u_2 &= 3162 \text{ kJ/kg}
\end{align*}
\]

Interpolation on table B.1.3 gives \( T_2 = 520^\circ \text{C} \) and \( v_2 = 0.4555 \text{ m}^3/\text{kg} \)

\[
V = m v
\]

\[
V = (0.750 \text{ kg}) \left( \frac{0.4555 \text{ m}^3}{\text{kg}} \right)
\]

\[
V = 0.342 \text{ m}^3
\]
6.120

A 200-L tank initially contains water at 100 kPa and a quality of 1%. Heat is transferred to the water, thereby raising its pressure and temperature. At a pressure of 2.00 MPa, a safety valve opens and saturated vapor at 2.00 MPa flows out. The process continues, maintaining a pressure of 2.00 MPa inside until the quality of the tank is 90%, then stops. Determine the total mass of water that flowed out and the total heat transfer.

**Solution**

**Assumptions:** Kinetic and potential energy are not important.

Conservation of mass:

\[
m_2 - m_1 = m_e - m_e
\]

Conservation of Energy:

\[
m_2 u_2 - m_1 u_1 = Q - W + m_e h_e
\]

**Initial State (1)**

\[P_1 = 100 \text{ kPa}\]
\[x_1 = 0.01\]

From Table B.1.2
\[v_1 = v_f + x v_fg = 0.001043 \frac{m^3}{kg} + (0.01)1.693 \frac{m^3}{kg} = 0.0180 \frac{m^3}{kg}\]
\[u_1 = u_f + x u fg = 417.3 \frac{kJ}{kg} + (0.01)2089 \frac{kJ}{kg} = 438.2 \frac{kJ}{kg}\]
\[m_1 = V/v_1 = 0.200 \text{ m}^3 / 0.0180 \frac{m^3}{kg} = 11.1 \text{ kg}\]

**Final State (2) \(P_2 = 2.00 \text{ MPa}\)**

\[x_2 = 0.90\]

From Table B.1.2
\[v_2 = v_f + x v_fg = 0.001177 \frac{m^3}{kg} + (0.90)0.09845 \frac{m^3}{kg} = 0.0898 \frac{m^3}{kg}\]
\[u_2 = u_f + x u fg = 906.4 \frac{kJ}{kg} + (0.90)1694 \frac{kJ}{kg} = 2431 \frac{kJ}{kg}\]
\[m_2 = V/v_2 = 0.200 \text{ m}^3 / 0.0898 \frac{m^3}{kg} = 2.23 \text{ kg}\]

**Exit State (e)**

\[P_e = 2.00 \text{ MPa}\]
\[x_e = 1.00\]
\[m_e = m_2 - m_1 = 11.1 \text{ kg} - 2.23 \text{ kg} = 8.88 \text{ kg}\]

From Table B.1.2
\[h_e = h_g = 2800 \frac{kJ}{kg}\]

\[Q = m_2 u_2 - m_1 u_1 + m_e h_e\]
\[Q = (2.23 \text{ kg})2431 \frac{kJ}{kg} - (11.1 \text{ kg})438.2 \frac{kJ}{kg} + (8.88 \text{ kg})2800 \frac{kJ}{kg}\]

\[Q = 25.4 \text{ MJ}\]
A 750-L tank initially contains water at 250°C, which is 50% liquid and 50% vapor by volume. A valve at the top of the tank is opened, and vapor is slowly withdrawn. Heat transfer takes place such that the temperature remains constant. Find the amount of heat transfer required to reach a state where half of the initial mass is withdrawn.

Solution

Assumptions: Kinetic and potential energy are not important.

Conservation of mass:

\[ m_2 - m_1 = \mu_1 \rho_0 - m_e \]

Conservation of Energy:

\[ m_2 u_2 - m_1 u_1 = Q - W_0 + m_e h_1 - m_e he \]

Initial State (1)

Need to find the quality from the given info. Find the mass of vapor and the mass of liquid in the tank.

\[ m_v = V/v_v = V/v_g|_{T=250^\circ C} = 0.375 \text{ m}^3/0.05013 \text{ m}^3/\text{kg} = 299.8 \text{ kg} \]
\[ m_l = V/v_l = V/v_f|_{T=250^\circ C} = 0.375 \text{ m}^3/0.001251 \text{ m}^3/\text{kg} = 7.48 \text{ kg} \]
\[ x_1 = m_v/(m_l + m_v) = 7.48 \text{ kg}/307.2 \text{ kg} = 0.0243 \]

\[ T_1 = 250^\circ C \]
\[ u_1 = u_f + xu_f g = 1080.4 \frac{kJ}{kg} + (0.0243)1522 \frac{kJ}{kg} = 1117 \frac{kJ}{kg} \]

Final State (2)

\[ T_2 = 250^\circ C \]
\[ v_2 = V/m_2 = V/(0.5m_1) = 0.750 \text{ m}^3/153.6 \text{ kg} = 0.00488 \text{ m}^3/\text{kg} \]
\[ x_2 = (v_2 - v_f)/(v_f g) = (0.00488 \text{ m}^3/\text{kg} - 0.001251 \text{ m}^3/\text{kg})/0.04887 \text{ m}^3/\text{kg} = 0.0743 \]
\[ u_2 = u_f + xu_f g = 1080.4 \frac{kJ}{kg} + (0.0743)1522 \frac{kJ}{kg} = 1193 \frac{kJ}{kg} \]

Exit State (e)

\[ T_e = 250^\circ C \]

Saturated Vapor \( x = 1 \)
\[ h_e = h_g = 2803 \frac{kJ}{kg} \]

\[ Q = m_2 u_2 - m_1 u_1 + m_e he \]
\[ Q = (153.6 \text{ kg})1193 \frac{kJ}{kg} - (307.2 \text{ kg})1117 \frac{kJ}{kg} + (153.6 \text{ kg})2803 \frac{kJ}{kg} \]
\[ Q = 271 \text{ MJ} \]

Note that 155 kg of vapor leaves the system during the process even though there was only 7.5 kg of vapor in the tank to start. During the heating process liquid water is continuously turned into vapor.