BÖLÜM 3 –SAF MADDELERİN ÖZERLLİKLERİ

3-35. 1.595 m^3 hacimli bir piston-silindir düzeneğinde -26.4 $^{\circ}$C sıcaklıkta on kilogram R-134a bulunmaktadır. Kap sıcaklığı 100^{o} C olana kadar ısıtılmıştır. R-134a'nın son hacmini hesaplayınız.

3-50. 1.4 MPa basınçta ve 250^{o} C sıcaklıktaki kızgın su buharı sabit hacimde sıcaklığı 120^{o}C' ye düşene kadar soğutmaya bırakılmıştır. Son durumdaki (a) Basıncını (b) Kuruluk derecesini ve (c) Entalpisini hesaplayınız. Ayrıca işlemi T-v diyagramında gösteriniz. *Çözüm: (a) 198.7 kPa, (b) 0.1825, (c) 905.7 kJ/kg*

3-60. 0.5 m^3 ' lük sabit hacimli bir kapta, -20^{o} C sıcaklıkta 10 kg soğutucu akışkan R-134a bulunmaktadır. Buna göre (a) Basıncı, (b) Toplam iç enerjiyi ve (c) Sıvı faz tarafından kaplanan hacmi hesaplayınız. *Çözüm (a) 132.82 kPa, (b) 904.2 kj, (c) 0.00489 m^3*

3-127. Eğer yeterli veri sağlanmışsa, aşağıdaki suyun özellikleri tablosundaki boşlukların tamamlayın. Son sütundaki suyun fazını sıkıştırılmış sıvı, doymuş karışım, kızgın buhar ya da eksik bilgi ifadelerini kullanarak tanımlayın ve eğer mümkünse kuruluk derecesini veriniz.

P,kPa	T,^{o}C	v,m^3/kg	u, kj/kg	Faz tanımı
	250		2728.9	
300			1560.0	
101.42	100			
3000	180			

BÖLÜM 4- KAPALI SİSTEMLERİN ENERJİ ANALİZLERİ

4-9. Sürtünmesiz bir piston-silindir düzeneğinde başlangıçta doymuş sıvı halinde 50 L soğutucu akışkan R-134a bulunmaktadır. Piston serbest hareket edebilmektedir ve kütlesi soğutucu akışkan üzerinde 500 kPa basınç olmasını sağlayacak büyüklüktedir. Soğutucu akışkan daha sonra 70^{o}C sıcaklığa ısıtılmaktadır. Hal değişimi sırasında yapılan işi hesaplayınız. *Çözüm: 1600 kJ*

4-11. Kapalı bir kapta bulunan 200^{o}C sıcaklıkta 1 m^3 hacmindeki doymuş sıvı su kuruluk derecesi yüzde 80 olana kadar izotermal olarak genişletilmiştir. Genişleme sırasında üretilen toplam işi kJ cinsinden hesaplayınız.

4-12. 150 kPa basınç ve 12^{o}C sıcaklıkta 2.4 kg hava, sızdırmaz ve sürtünmesiz bir piston-silindir düzeneğinde bulunmaktadır. Daha sonra hava 600 kPa basınca sıkıştırılmaktadır. Bu işlem sırasında havadan çevreye ısı geçişi olmakta ve silindir içindeki sıcaklık sabit kalmaktadır. Hal değişimi sırasında yapılan işi hesaplayınız. *Çözüm: 272 kJ*

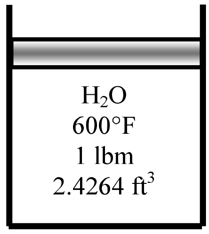
4-31. Bir piston silindir düzeneğindeki 200^{o}C ' deki doymuş su buharı izotermal olarak doymuş sıvı haline yoğuşturulmuştur. İşlem sırasında gerçekleşen ısı transferini ve yapılan işi kJ/kg cinsinden hesaplayınız. *Çözüm: 1940 kJ/kg , 196 kJ/kg*

4-32. 10 L hacmindeki kapalı bir kapta başlangıç 100^oC sıcaklığı ve yüzde 12.3 kuruluk derecesi olan su buhar karışımı bulunmaktadır. Karışım sıcaklığı 150 ^oC olana kadar ısıtılmıştır. Bu işlem için gereken ısı transferini hesaplayınız. *Çözüm: 46.9 kJ*

3-38E A piston-cylinder device that is filled with water is cooled. The final pressure and volume of the water are to be determined.

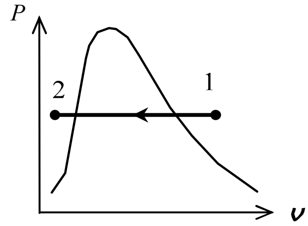
Analysis The initial specific volume is

$$v_1 = \frac{V_1}{m} = \frac{2.4264\ \text{ft}^3}{1\ \text{lbm}} = 2.4264\ \text{ft}^3/\text{lbm}$$



This is a constant-pressure process. The initial state is determined to be superheated vapor and thus the pressure is determined to be

$$\left.\begin{aligned} T_1 &= 600°\text{F} \\ v_1 &= 2.4264\ \text{ft}^3/\text{lbm} \end{aligned}\right\} P_1 = P_2 = \mathbf{250\ psia}\ \ (\text{Table A-6E})$$



The saturation temperature at 250 psia is 400.1°F. Since the final temperature is less than this temperature, the final state is compressed liquid. Using the incompressible liquid approximation,

$$v_2 = v_{f\ @\ 200°\text{F}} = 0.01663\ \text{ft}^3/\text{lbm}\ \ (\text{Table A-4E})$$

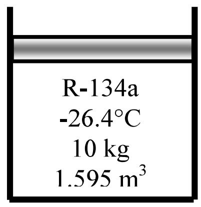
The final volume is then

$$V_2 = m v_2 = (1\ \text{lbm})(0.01663\ \text{ft}^3/\text{lbm}) = \mathbf{0.01663\ ft^3}$$

3-39 A piston-cylinder device that is filled with R-134a is heated. The final volume is to be determined.

Analysis This is a constant pressure process. The initial specific volume is

$$v_1 = \frac{V}{m} = \frac{1.595\ \text{m}^3}{10\ \text{kg}} = 0.1595\ \text{m}^3/\text{kg}$$

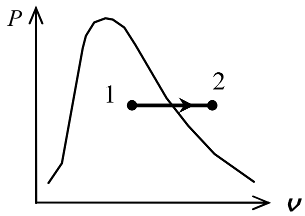


The initial state is determined to be a mixture, and thus the pressure is the saturation pressure at the given temperature

$$P_1 = P_{\text{sat}\ @\ -26.4°\text{C}} = 100\ \text{kPa}\ \ (\text{Table A-12})$$

The final state is superheated vapor and the specific volume is

$$\left.\begin{aligned} P_2 &= 100\ \text{kPa} \\ T_2 &= 100°\text{C} \end{aligned}\right\} v_2 = 0.30138\ \text{m}^3/\text{kg}\ \ (\text{Table A-13})$$



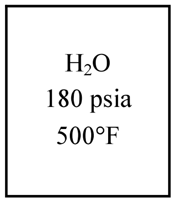
The final volume is then

$$V_2 = m v_2 = (10\ \text{kg})(0.30138\ \text{m}^3/\text{kg}) = \mathbf{3.0138\ m^3}$$

3-55E Superheated water vapor cools at constant volume until the temperature drops to 250°F. At the final state, the pressure, the quality, and the enthalpy are to be determined.

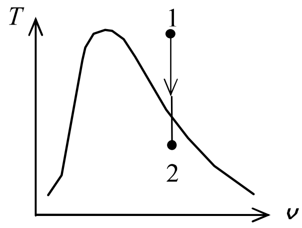
Analysis This is a constant volume process ($v = V/m$ = constant), and the initial specific volume is determined to be

$$\left.\begin{array}{l} P_1 = 180 \text{ psia} \\ T_1 = 500^\circ\text{F} \end{array}\right\} v_1 = 3.0433 \text{ ft}^3/\text{lbm} \qquad \text{(Table A-6E)}$$



At 250°F, $v_f = 0.01700$ ft³/lbm and $v_g = 13.816$ ft³/lbm. Thus at the final state, the tank will contain saturated liquid-vapor mixture since $v_f < v < v_g$, and the final pressure must be the saturation pressure at the final temperature,

$$P = P_{\text{sat@250}^\circ\text{F}} = \mathbf{29.84\ psia}$$



(*b*) The quality at the final state is determined from

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{3.0433 - 0.01700}{13.816 - 0.01700} = \mathbf{0.219}$$

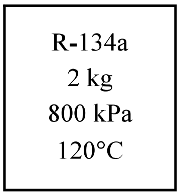
(*c*) The enthalpy at the final state is determined from

$$h = h_f + xh_{fg} = 218.63 + 0.219 \times 945.41 = \mathbf{426.0\ Btu/lbm}$$

3-65 A rigid vessel is filled with refrigerant-134a. The total volume and the total internal energy are to be determined.

Properties The properties of R-134a at the given state are (Table A-13).

$$\left.\begin{array}{l} P = 800 \text{ kPa} \\ T = 120^\circ\text{C} \end{array}\right\} \begin{array}{l} u = 327.87 \text{ kJ/kg} \\ v = 0.037625 \text{ m}^3\text{/kg} \end{array}$$



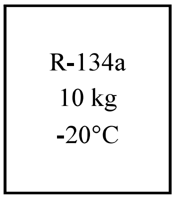
Analysis The total volume and internal energy are determined from

$$V = mv = (2 \text{ kg})(0.037625 \text{ m}^3\text{/kg}) = \mathbf{0.0753 \ m^3}$$

$$U = mu = (2 \text{ kg})(327.87 \text{ kJ/kg}) = \mathbf{655.7 \ kJ}$$

3-66 A rigid vessel contains R-134a at specified temperature. The pressure, total internal energy, and the volume of the liquid phase are to be determined.

Analysis (*a*) The specific volume of the refrigerant is



$$v = \frac{V}{m} = \frac{0.5 \text{ m}^3}{10 \text{ kg}} = 0.05 \text{ m}^3\text{/kg}$$

At -20°C, v_f = 0.0007362 m^3/kg and v_g = 0.14729 m^3/kg (Table A-11). Thus the tank contains saturated liquid-vapor mixture since $v_f < v < v_g$, and the pressure must be the saturation pressure at the specified temperature,

$$P = P_{\text{sat@}-20^\circ\text{C}} = \mathbf{132.82 \ kPa}$$

(*b*) The quality of the refrigerant-134a and its total internal energy are determined from

$$x = \frac{v - v_f}{v_{fg}} = \frac{0.05 - 0.0007362}{0.14729 - 0.0007362} = 0.3361$$

$$u = u_f + xu_{fg} = 25.39 + 0.3361 \times 193.45 = 90.42 \text{ kJ/kg}$$

$$U = mu = (10 \text{ kg})(90.42 \text{ kJ/kg}) = \mathbf{904.2 \ kJ}$$

(*c*) The mass of the liquid phase and its volume are determined from

$$m_f = (1 - x)m_t = (1 - 0.3361) \times 10 = 6.639 \text{ kg}$$

$$V_f = m_f v_f = (6.639 \text{ kg})(0.0007362 \text{ m}^3\text{/kg}) = \mathbf{0.00489 \ m^3}$$

3-134 The first eight virial coefficients of a Benedict-Webb-Rubin gas are to be obtained.

Analysis The Benedict-Webb-Rubin equation of state is given by

$$P = \frac{R_u T}{\bar{v}} + \left(B_0 R_u T - A_0 - \frac{C_0}{T^2} \right) \frac{1}{\bar{v}^2} + \frac{b R_u T - a}{\bar{v}^3} + \frac{a\alpha}{\bar{v}^6} + \frac{c}{\bar{v}^3 T^2} \left(1 + \frac{\gamma}{\bar{v}^2} \right) \exp(-\gamma / \bar{v}^2)$$

Expanding the last term in a series gives

$$\exp(-\gamma / \bar{v}^2) = 1 - \frac{\gamma}{\bar{v}^2} + \frac{1}{2!} \frac{\gamma^2}{\bar{v}^4} - \frac{1}{3!} \frac{\gamma^3}{\bar{v}^6} + ...$$

Substituting this into the Benedict-Webb-Rubin equation of state and rearranging the first terms gives

$$P = \frac{R_u T}{\bar{v}} + \frac{R_u T B_0 - A_0 - C_0 / T^2}{\bar{v}^2} + \frac{b R_u T - a}{\bar{v}^3} + \frac{c(1+\gamma)}{\bar{v}^5 T^2} + \frac{a\alpha}{\bar{v}^6} - \frac{c\gamma(1+\gamma)}{\bar{v}^7 T^2} + \frac{1}{2!} \frac{c\gamma^2 (1+\gamma)}{\bar{v}^9 T^2}$$

The virial equation of state is

$$P = \frac{R_u T}{\bar{v}} + \frac{a(T)}{\bar{v}^2} + \frac{b(T)}{\bar{v}^3} + \frac{c(T)}{\bar{v}^4} + \frac{d(T)}{\bar{v}^5} + \frac{e(T)}{\bar{v}^6} + \frac{f(T)}{\bar{v}^7} + \frac{g(T)}{\bar{v}^8} + \frac{h(T)}{\bar{v}^9} ...$$

Comparing the Benedict-Webb-Rubin equation of state to the virial equation of state, the virial coefficients are

$$a(T) = R_u T B_0 - A_0 - C_0 / T^2$$
$$b(T) = b R_u T - a$$
$$c(T) = 0$$
$$d(T) = c(1+\gamma) / T^2$$
$$e(T) = a\alpha$$
$$f(T) = c\gamma(1+\gamma) / T^2$$
$$g(T) = 0$$
$$h(T) = \frac{1}{2!} \frac{c\gamma^2 (1+\gamma)}{T^2}$$

3-135 The table is completed as follows:

P, kPa	T, °C	v, m³/kg	u, kJ/kg	Condition description and quality, if applicable
300	250	**0.7921**	2728.9	**Superheated vapor**
300	**133.52**	**0.3058**	1560.0	**x = 0.504, Two-phase mixture**
101.42	100	**-**	**-**	**Insufficient information**
3000	180	**0.001127***	**761.92***	**Compressed liquid**

* Approximated as saturated liquid at the given temperature of 180°C

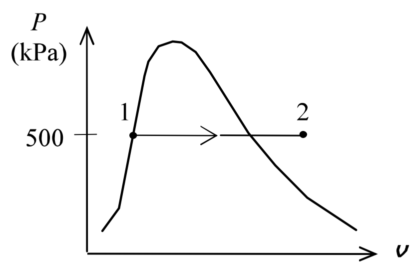
4-11 Refrigerant-134a in a cylinder is heated at constant pressure until its temperature rises to a specified value. The boundary work done during this process is to be determined.

Assumptions The process is quasi-equilibrium.

Properties Noting that the pressure remains constant during this process, the specific volumes at the initial and the final states are (Table A-11 through A-13)

$$\left.\begin{array}{l} P_1 = 500 \text{ kPa} \\ \text{Sat. liquid} \end{array}\right\} v_1 = v_{f\,@500\text{ kPa}} = 0.0008059 \text{ m}^3/\text{kg}$$

$$\left.\begin{array}{l} P_2 = 500 \text{ kPa} \\ T_2 = 70°\text{C} \end{array}\right\} v_2 = 0.052427 \text{ m}^3/\text{kg}$$



Analysis The boundary work is determined from its definition to be

$$m = \frac{V_1}{v_1} = \frac{0.05 \text{ m}^3}{0.0008059 \text{ m}^3/\text{kg}} = 62.04 \text{ kg}$$

and

$$W_{b,\text{out}} = \int_1^2 P\,dV = P(V_2 - V_1) = mP(v_2 - v_1)$$

$$= (62.04 \text{ kg})(500 \text{ kPa})(0.052427 - 0.0008059)\text{m}^3/\text{kg}\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)$$

$$= \mathbf{1600\ kJ}$$

Discussion The positive sign indicates that work is done by the system (work output).

4-13 Water is expanded isothermally in a closed system. The work produced is to be determined.

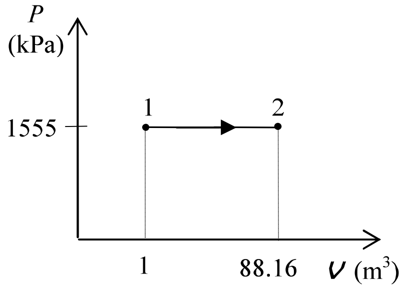
Assumptions The process is quasi-equilibrium.

Analysis From water table

$$P_1 = P_2 = P_{\text{sat @ 200°C}} = 1554.9\ \text{kPa}$$

$$v_1 = v_{\text{f @ 200°C}} = 0.001157\ \text{m}^3/\text{kg}$$

$$\begin{aligned} v_2 &= v_f + x v_{fg} \\ &= 0.001157 + 0.80(0.12721 - 0.001157) \\ &= 0.10200\ \text{m}^3/\text{kg} \end{aligned}$$



The definition of specific volume gives

$$V_2 = V_1 \frac{v_2}{v_1} = (1\ \text{m}^3)\frac{0.10200\ \text{m}^3/\text{kg}}{0.001157\ \text{m}^3/\text{kg}} = 88.16\ \text{m}^3$$

The work done during the process is determined from

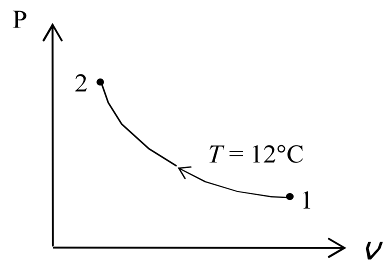
$$W_{b,\text{out}} = \int_1^2 P\,dV = P(V_2 - V_1) = (1554.9\ \text{kPa})(88.16-1)\text{m}^3\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right) = \mathbf{1.355\times 10^5\ kJ}$$

4-14 Air in a cylinder is compressed at constant temperature until its pressure rises to a specified value. The boundary work done during this process is to be determined.

Assumptions **1** The process is quasi-equilibrium. **2** Air is an ideal gas.

Properties The gas constant of air is R = 0.287 kJ/kg.K (Table A-1).

Analysis The boundary work is determined from its definition to be



$$\begin{aligned} W_{b,\text{out}} &= \int_1^2 P\,dV = P_1V_1\ln\frac{V_2}{V_1} = mRT\ln\frac{P_1}{P_2} \\ &= (2.4\ \text{kg})(0.287\ \text{kJ/kg}\cdot\text{K})(285\ \text{K})\ln\frac{150\ \text{kPa}}{600\ \text{kPa}} \\ &= \mathbf{-272\ kJ} \end{aligned}$$

Discussion The negative sign indicates that work is done on the system (work input).

4-15 Several sets of pressure and volume data are taken as a gas expands. The boundary work done during this process is to be determined using the experimental data.

Assumptions The process is quasi-equilibrium.

Analysis Plotting the given data on a P-V diagram on a graph paper and evaluating the area under the process curve, the work done is determined to be **0.25 kJ**.

4-13 Water is expanded isothermally in a closed system. The work produced is to be determined.

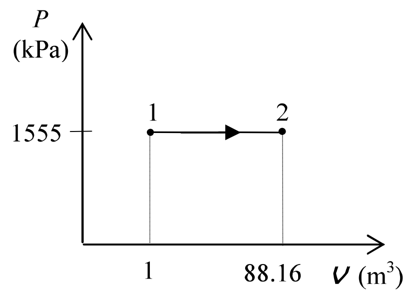
Assumptions The process is quasi-equilibrium.

Analysis From water table

$$P_1 = P_2 = P_{\text{sat @ 200°C}} = 1554.9\ \text{kPa}$$

$$v_1 = v_{\text{f @ 200°C}} = 0.001157\ \text{m}^3/\text{kg}$$

$$\begin{aligned} v_2 &= v_f + x v_{fg} \\ &= 0.001157 + 0.80(0.12721 - 0.001157) \\ &= 0.10200\ \text{m}^3/\text{kg} \end{aligned}$$



The definition of specific volume gives

$$V_2 = V_1 \frac{v_2}{v_1} = (1\ \text{m}^3)\frac{0.10200\ \text{m}^3/\text{kg}}{0.001157\ \text{m}^3/\text{kg}} = 88.16\ \text{m}^3$$

The work done during the process is determined from

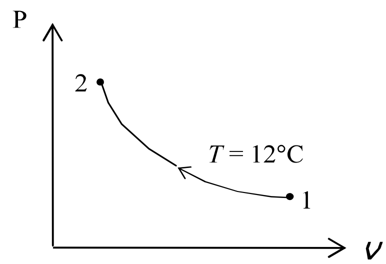
$$W_{b,\text{out}} = \int_1^2 P\,dV = P(V_2 - V_1) = (1554.9\ \text{kPa})(88.16-1)\text{m}^3\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right) = \mathbf{1.355 \times 10^5\ kJ}$$

4-14 Air in a cylinder is compressed at constant temperature until its pressure rises to a specified value. The boundary work done during this process is to be determined.

Assumptions **1** The process is quasi-equilibrium. **2** Air is an ideal gas.

Properties The gas constant of air is R = 0.287 kJ/kg.K (Table A-1).

Analysis The boundary work is determined from its definition to be



$$\begin{aligned} W_{b,\text{out}} &= \int_1^2 P\,dV = P_1V_1 \ln\frac{V_2}{V_1} = mRT\ln\frac{P_1}{P_2} \\ &= (2.4\ \text{kg})(0.287\ \text{kJ/kg}\cdot\text{K})(285\ \text{K})\ln\frac{150\ \text{kPa}}{600\ \text{kPa}} \\ &= \mathbf{-272\ \ kJ} \end{aligned}$$

Discussion The negative sign indicates that work is done on the system (work input).

4-15 Several sets of pressure and volume data are taken as a gas expands. The boundary work done during this process is to be determined using the experimental data.

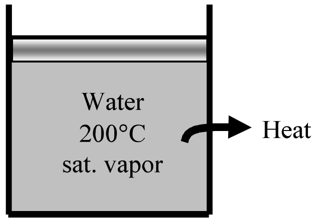
Assumptions The process is quasi-equilibrium.

Analysis Plotting the given data on a P-V diagram on a graph paper and evaluating the area under the process curve, the work done is determined to be **0.25 kJ**.

4-34 Saturated water vapor is isothermally condensed to a saturated liquid in a piston-cylinder device. The heat transfer and the work done are to be determined.

Assumptions **1** The cylinder is stationary and thus the kinetic and potential energy changes are zero. **2** There are no work interactions involved other than the boundary work. **3** The thermal energy stored in the cylinder itself is negligible. **4** The compression or expansion process is quasi-equilibrium.

Analysis We take the contents of the cylinder as the system. This is a closed system since no mass enters or leaves. The energy balance for this stationary closed system can be expressed as

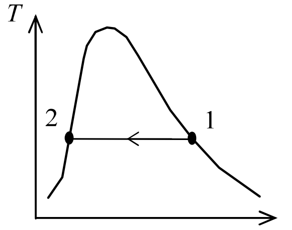


$$\underbrace{E_{\rm in} - E_{\rm out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\rm system}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$W_{b,\rm in} - Q_{\rm out} = \Delta U = m(u_2 - u_1) \quad \text{(since KE = PE = 0)}$$

$$Q_{\rm out} = W_{b,\rm in} - m(u_2 - u_1)$$

The properties at the initial and final states are (Table A-4)



$$\left.\begin{array}{l} T_1 = 200°\text{C} \\ x_1 = 1 \end{array}\right\} \begin{array}{l} v_1 = v_g = 0.12721 \text{ m}^3/\text{kg} \\ u_1 = u_g = 2594.2 \text{ kJ/kg} \end{array}$$

$$P_1 = P_2 = 1554.9 \text{ kPa}$$

$$\left.\begin{array}{l} T_2 = 200°\text{C} \\ x_2 = 0 \end{array}\right\} \begin{array}{l} v_2 = v_f = 0.001157 \text{ m}^3/\text{kg} \\ u_2 = u_f = 850.46 \text{ kJ/kg} \end{array}$$

The work done during this process is

$$w_{b,\rm out} = \int_1^2 P\,dV = P(v_2 - v_1) = (1554.9 \text{ kPa})(0.001157 - 0.12721) \text{ m}^3/\text{kg}\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right) = -196.0 \text{ kJ/kg}$$

That is,

$$w_{b,\rm in} = \mathbf{196.0\ kJ/kg}$$

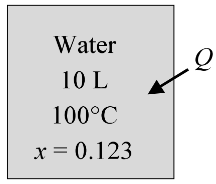
Substituting the energy balance equation, we get

$$q_{\rm out} = w_{b,\rm in} - (u_2 - u_1) = w_{b,\rm in} + u_{fg} = 196.0 + 1743.7 = \mathbf{1940\ kJ/kg}$$

4-35 Water contained in a rigid vessel is heated. The heat transfer is to be determined.

Assumptions **1** The system is stationary and thus the kinetic and potential energy changes are zero. **2** There are no work interactions involved **3** The thermal energy stored in the vessel itself is negligible.

Analysis We take water as the system. This is a closed system since no mass enters or leaves. The energy balance for this stationary closed system can be expressed as



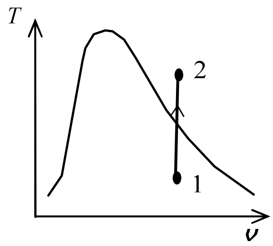
$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

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

The properties at the initial and final states are (Table A-4)

$$\left.\begin{array}{l} T_1 = 100°\text{C} \\ x_1 = 0.123 \end{array}\right\} \begin{array}{l} v_1 = v_f + xv_{fg} = 0.001043 + (0.123)(1.6720 - 0.001043) = 0.2066 \text{ m}^3/\text{kg} \\ u_1 = u_f + xu_{fg} = 419.06 + (0.123)(2087.0) = 675.76 \text{ kJ/kg} \end{array}$$

$$\left.\begin{array}{l} T_2 = 150°\text{C} \\ v_2 = v_1 = 0.2066 \text{ m}^3/\text{kg} \end{array}\right\} \begin{array}{l} x_2 = \dfrac{v_2 - v_f}{v_{fg}} = \dfrac{0.2066\text{-}0.001091}{0.39248\text{-}0.001091} = 0.5250 \\ u_2 = u_f + x_2 u_{fg} \\ \quad = 631.66 + (0.5250)(1927.4) = 1643.5 \text{ kJ/kg} \end{array}$$



The mass in the system is

$$m = \frac{V_1}{v_1} = \frac{0.100 \text{ m}^3}{0.2066 \text{ m}^3/\text{kg}} = 0.04841 \text{ kg}$$

Substituting,

$$Q_{in} = m(u_2 - u_1) = (0.04841 \text{ kg})(1643.5 - 675.76) \text{ kJ/kg} = \mathbf{46.9\ kJ}$$