(b) During the compression : $pV^n = \text{constant}$

Determine the total amount of work during the compression

$$W = \int_{V_1}^{V_2} p\,dV \leftarrow pV^n = \text{const} = p_1 V_1^{\,n} = p_2 V_2^{\,n}, \quad p = \text{const}/V^n = \frac{p_1 V_1^{\,n}}{V^n}$$

$$= \int_{V_1}^{V_2} \frac{\text{const}}{V^n}\,dV$$

$$= \text{const} \cdot \frac{1}{1-n} \cdot V^{1-n} \Big]_{V_1}^{V_2} \qquad 1 < n < k$$

$$= \frac{\text{const}}{1-n} \cdot \left(V_2^{\,1-n} - V_1^{\,1-n}\right)$$

$$= \frac{p_2 V_2^{\,n} \cdot V_2^{\,1-n} - p_1 V_1^{\,n} \cdot V_1^{\,1-n}}{1-n} = \frac{p_2 V_2 - p_1 V_1}{1-n} = \frac{(2471.9)(0.1) - (100)(1)}{1-1.393} = -374.53\ \text{kJ}$$

Ans.

$n = ?$

$$p_1 V_1^{\,n} = p_2 V_2^{\,n}$$

$$(100)(1)^n = (2471.9) \cdot (0.1)^n$$

$$100/2471.9 = 0.1^n$$

$$n \log(0.1) = \log(100/2471.9) \longrightarrow n = 1.393$$

(c) Determine the heat transfer from the surrounding into the piston-cylinder process

State 1	→	State 2
Liq. water air		Liq. water + water vapor air

$$\Delta E = Q - W = \Delta U + \cancel{\Delta KE} + \cancel{\Delta PE}$$

$$Q - (-W_{in} + W_b) = \Delta U$$

$$Q = \Delta U + W_b - W_{in} \qquad H = U + PV$$

$$\Delta H = \Delta U + \Delta(PV)$$

$$Q = \Delta H - W_{in} \longleftarrow dH = dU + \cancel{dP \cdot V} + P \cdot dV$$

$= \delta W_b$

$$Q = \Delta H - W_{in}$$

$$= (\Delta H)_{air} + (\Delta H)_{wv} + (\Delta H)_{wl} - W_{in}$$

$$= \{m C_p (T_2 - T_1)\}_{air} + \{m_2 h_2 - m_1 h_1\}_{wv} + \{m_2 h_2 - m_1 h_1\}_{wl} - W_{in}$$

- $(\Delta H)_{air} = m_{air} C_p \cdot (T_2 - T_1) \longleftarrow C_p - C_v = R$

$C_p = C_v + R$

$$= (1.13\ \text{kg})(1.015\ \text{kJ/kg·K}) \cdot (180 - 25)\ \text{K}$$

$$= 177.78\ \text{kJ}$$

m_1, liq. water = 1 kg

if all liq. water turned into sat. vapor $v_2 = 0.1\ m^3/kg$

Table A-4 $T = 180°C \longrightarrow v_f = 0.001127 \sim v_g = 0.19384$

$$m_{2,wv} = V_2 / v_g = \frac{0.1\ m^3}{0.19384\ m^3/kg} = 0.51589\ kg$$

$$m_{2,wl} = 1 - 0.51589 = 0.484\ kg$$

$\cdot\ (\Delta H)_{wv} = m_{2,wv} \cdot h_{2,wv} - m_{1,wv} \cdot h_{1,wv}$

no water vapor at stage 1

$$= (0.5159\ kg) \cdot (1802.16) = 929.73\ kJ$$

$T = 180°C$, Table A-4 $\longrightarrow$ $h_f = 763.05$, $h_{fg} = 2014.2$, $h_g = 2777.2$

$$x_2 = \frac{0.5159}{1} \longrightarrow h_{2,wv} = 1802.16$$

$(\Delta H)_{wl} = m_{2,wl} \cdot h_{2,wl} - m_{1,wl} \cdot h_{1,wl}$

* $m_{2,wl} = 0.484\ kg$ $\quad h_{2,wl} = h_f = 763.05$

$m_{1,wl} = 1\ kg$ $\quad h_{1,wl} = 104.83 \longleftarrow$ Table A-4, $T_1 = 25°C$

$$= (0.484) \cdot (763.05) - (1)(104.83) = 264.48$$

$$\therefore Q = (177.78) + (929.73) + (264.48) - 374.53$$

$$= 997.46\ kJ$$

Ans.