6.4

(a) first law

$Q = \Delta U + W \Rightarrow W_{\text{by nitrogen}} = Q - m\Delta u$

$\Rightarrow W_{\text{on nitrogen}} = m\Delta u - Q$ — (a)

$$Q_{\text{to nitrogen}} = \frac{m(s_2 - s_1)}{T}$$

from Nitrogen table:

$s_1 = 6.8418$ kJ/kg K

$s_2 = 5.1630$ kJ/kg K

$Q_{\text{to Nitrogen}} = \cancel{26608\,4128}.2(5.163 - 6.8418)$ kJ — (b)

$\Delta u = u_2 - u_1 = (h_2 - P_2 v_2) - (h_1 - P_1 v_1)$

from Nitrogen table

$u_2 - u_1 = $

$\hookrightarrow = (279.01 - 20000 \times 0.004704)$

$- (311.163 - 101.325 \times 0.878604)$ — (c)

from (a), (b) & (c)

$$W_{\text{on Nitrogen}} = -\left(\frac{m(s_2 - s_1)}{T}\right) + \left(m(u_2 - u_1)\right)$$

$Q$, $\Delta U$

$= +932.864$ kJ

(b) $Q_{\text{to Nitrogen}} = mT(s_2 - s_1) = 2 \times 300(5.163 - 6.8418)$

$= (-)1007.28$ kJ

heat rejected to surroundings

(c) $\Delta S_{\text{total}} = \Delta S_{\text{steam}} + \Delta S_{HR}$

$$= m(s_2 - s_1) + \frac{Q_{HR}}{T_{HR}} \qquad T_{HR} = 300\text{K} = \text{gas temp.} = T_{gas}$$

$= m(s_2 - s_1) + (-Q_{\text{to Nitrogen}})$

$$= m(s_2 - s_1) + \left(-\frac{m(s_2 - s_1)T_{gas}}{T_{HR}}\right)$$

Hence process is overall reversible

$\Delta S_{\text{total}} = 0$

If we consider Nitrogen gas as system, then work is being done (compression) in quasi-static mode, hence process is internally reversible. Further temp of gas = temp of environment. So very very small amount of ~~g~~ heat will go to surrounding ~~throughout the process~~. Hence process is also externally reversible.