1) $h_f @ 10kPa = 191.81 kJ\,kg^{-1}$

$s_f @ 10kPa = 0.6492 kJ\,kg^{-1}K^{-1}$

$v_f @ 10kPa = 0.001010\, m^3\,kg^{-1}$

a) $$\frac{0.6492-0.5666}{0.8234-0.5666} = \frac{h_2-180.77}{263.74-180.77}$$

$$h_2 = 207.45739 kJ\,kg^{-1}$$

$$\Delta h = W_{in} = 207.45739 - 191.81$$
$$= 15.64739097 kJ\,kg^{-1}$$
$$\approx 15.65 kJ\,kg^{-1}$$

b) $$w = v(P_2 - P_1)$$
$$= 0.001010(15\times10^6 - 10\times10^3)$$
$$= 15139.9 J\,kg^{-1}$$
$$\approx 15.14 kJ\,kg^{-1}$$

Error: $$\frac{15.65-15.14}{15.65} = 3.258785942\%$$
$$\approx 3.3\%$$

1c) $$\frac{0.6492-0.5666}{0.8234-0.5666} = \frac{v_2 - 0.001013}{0.0010105 - 0.0010013}$$

$$v_2 = 0.00100425919 \, m^3 kg^{-1}$$

$$\bar{v} = \frac{0.00100425919 + 0.001010}{2}$$

$$= 0.00100712959 \, m^3 kg^{-1}$$

$$w = \bar{v}(P_2 - P_1)$$

$$= 0.00100712959(15 \times 10^6 - 10 \times 10^3)$$

$$= 15096.87263 \, J \, kg^{-1}$$

$$\approx 15.10 \, kJ \, kg^{-1}$$

Error: $\frac{15.65 - 15.10}{15.65} = 3.534360196\%$

$$\approx 3.5\%$$

2) $k = \frac{1.039}{0.743}$

$= \frac{1039}{743}$

a) $\dot{W}_{isen} = \frac{\dot{m}\frac{1039}{743}(0.2968)(273+27)}{1-\frac{1039}{743}}\left[\left(\frac{480}{80}\right)^{\frac{\frac{1039}{743}-1}{\frac{1039}{743}}}-1\right]$

$-10 = -208.167247\dot{m}$

$\dot{m} = 0.04803820967$

$\approx 0.048 \text{ kgs}^{-1}$

b) $\dot{W}_{poly} = -\dot{m}\frac{1.3(0.2968)(273+27)}{1.3-1}\left[\left(\frac{480}{80}\right)^{\frac{1.3-1}{1.3}}-1\right]$

$-10 = -197.5790616\dot{m}$

$\dot{m} = 0.05061265055 \text{ kgs}^{-1}$

$\approx 0.051 \text{ kgs}^{-1}$

c) $\dot{W}_{iso} = -\dot{m}(0.2968)(273+27)\ln\left(\frac{480}{80}\right)$

$-10 = -159.5382631\dot{m}$

$\dot{m} = 0.06268088798 \text{ kgs}^{-1}$

$\approx 0.063 \text{ kgs}^{-1}$

2d) $$\dot{w}_{comp} = -\frac{\dot{m}(1.3)(0.2968)(273+27)(2)}{1.3-1} \times \left[\left(\frac{\sqrt{480 \times 80}}{80}\right)^{\frac{1.3-1}{1.3}} - 1\right]$$

$$-10 = -177.227605\,\dot{m}$$

$$\dot{m} = 0.0564246184\,kgs^{-1}$$

$$\simeq 0.056\,kgs^{-1}$$

a) $T_{avg} = 400K$

$k = 1.397$

Check T_{avg}:

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$= (27+273)\left(\frac{480}{80}\right)^{\frac{1.397-1}{1.397}}$$

$$= 499.2K$$

$T_{avg} = 400K$ (verified)

3) $h_1 = 3399.5 \text{ kJ kg}^{-1}$

$s_1 = 6.7266 \text{ kJ kg}^{-1}\text{K}^{-1}$

a) $T_2 = T_{sat}$ @ 30kPa

$= 69.09°C$

$\approx 69.1°C$

b) $x = \dfrac{6.7266 - 0.9441}{6.8234}$

$= 0.8474514172$

$h_{2s} = 289.27 + 0.8474514172(2335.3)$

$= 2268.323295 \text{ kJ kg}^{-1}$

$\eta_T = \dfrac{h_1 - h_{2a}}{h_1 - h_{2s}}$

$0.9 = \dfrac{w_s}{3399.5 - 2268.323295}$

$w_s = 1018.059035 \text{ kJ kg}^{-1}\text{s}^{-1}$

$W_{out} = 1018.059035 \times 3$

$= 3054.177105 \text{ kW}$

$\approx 3054 \text{ kW}$

4) $h_1 = 300.19 \text{ kJ kg}^{-1}$

$h_{2a} = 555.74 \text{ kJ kg}^{-1}$

b) For an isentropic process,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$T_2 = 300\left(\frac{600}{95}\right)^{\frac{1.395-1}{1.395}}$$

$$= 505.5517775$$
$$\approx 506\text{K}$$

a) $$\frac{505.5517775 - 500}{510 - 500} = \frac{h_{2s} - 503.02}{513.32 - 503.02}$$

$$h_{2s} = 508.7383308 \text{ kJ kg}^{-1}$$

$$\eta_T = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$
$$= \frac{508.7383308 - 300.19}{555.74 - 300.19}$$
$$= 0.8160444937$$
$$\approx 0.816$$

4b) At $T_{avg} = 425\,K$, $k = 1.393$

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$T_{2s} = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$= (273+27)\left(\frac{600}{95}\right)^{\frac{0.393}{1.393}}$$

$$= 504.6\,K$$

$\therefore$ $T_{avg} = 400\,K$, $k = 1.395$

$$T_{2s} = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$= (273+27)\left(\frac{600}{95}\right)^{\frac{0.395}{1.395}}$$

$$= 505.6\,K$$

5) $h_1 = 843.98\,kJkg^{-1}$

$$h_1 - h_{2a} = \frac{V_{2a}^2}{2}$$

$$h_{2a} = 843.98 - \frac{240^2}{2} \times 10^{-3}$$

$$= 815.18\,kJkg^{-1}$$

$$\frac{815.18 - 800.03}{821.95 - 800.3} = \frac{T_2 - 780}{800 - 780}$$

$$T_2 = 793.7459584\,K$$

$$\approx 793.7\,K$$

$$\eta_N = \frac{h_1 - h_{2a}}{h_1 - h_{2s}} = \frac{\cancel{cp}(T_1 - T_{2a})}{\cancel{cp}(T_1 - T_{2s})}$$

$$T_{2s} = \frac{T_1 - T_{2a}}{\eta_N}$$

$$= 820 - \frac{820 - 793.7}{0.9}$$

$$= 790.8288427\,K$$

5) $P_2 = P_1 \left(\frac{T_2}{T_1} \right)^{\frac{k}{k-1}}$

$$= 400 \left(\frac{790.8288427}{820} \right)^{\frac{1.354}{0.354}}$$

$$= 348.2489306 \, kPa$$

$$\approx 348.2 \, kPa$$