19.46. Path ac has constant pressure, so $W_{ac} = p\Delta V = nR\Delta T$, and

$W_{ac} = nR(T_c - T_a) = (3\,\text{mol})(8.3145\,\text{J/mol} \cdot \text{K})(492\,\text{K} - 300\,\text{K}) = 4.789 \times 10^3\,\text{J}$.

Path cb is adiabatic $(Q = 0)$, so $W_{cb} = Q - \Delta U = 2\,\Delta U = -nC_V\Delta T$, and using $C_V = C_p - R$,

$W_{cb} = -n(C_p - R)(T_b - T_c) = -(3\,\text{mol})(29.1\,\text{J/mol} \cdot \text{K} - 8.3145\,\text{J/mol} \cdot \text{K})(600\,\text{K} - 492\,\text{K}) = -6.735 \times 10^3\,\text{J}$.

Path ba has constant volume, so $W_{ba} = 0$. So the total work done is

$W = W_{ac} + W_{cb} + W_{ba} = 4.789 \times 10^3\,\text{J} - 6.735 \times 10^3\,\text{J} + 0 = 2\ 1.95 \times 10^3\,\text{J}$.

19.54. $pV = nRT.$ For an isothermal process $W = nRT\ln(V_2/V_1)$. For a constant pressure

process, $W = p\Delta V.$ $1\,\text{L} = 10^{-3}\,\text{m}^3$.

(a) The pV–diagram is sketched in Figure 19.54.
(b) At constant temperature, the product pV is constant, so

$V_2 = V_1(p_1/p_2) = (1.5\,\text{L})\left(\dfrac{1.00 \times 10^5\,\text{Pa}}{2.50 \times 10^4\,\text{Pa}}\right) = 6.00\,\text{L}$. The final pressure is given as being the

same as $p_3 = p_2 = 2.5 \times 10^4\,\text{Pa}$. The final volume is the same as the initial volume, so
$T_3 = T_1(p_3/p_1) = 75.0\,\text{K}$.
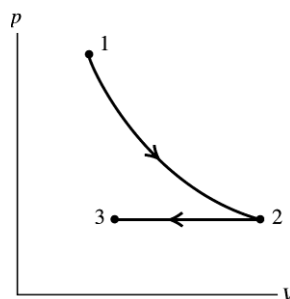(c) Treating the gas as ideal, the work done in the first process is

$W = nRT\ln(V_2/V_1) = p_1V_1\ln(p_1/p_2).$ $W = (1.00 \times 10^5\,\text{Pa})(1.5 \times 10^{-3}\,\text{m}^3)\ln\left(\dfrac{1.00 \times 10^5\,\text{Pa}}{2.50 \times 10^4\,\text{Pa}}\right) = 208\,\text{J}$.

For the second process, $W = p_2(V_3 - V_2) = p_2(V_1 - V_2) = p_2V_1(1 - (p_1/p_2))$.

$W = (2.50 \times 10^4\,\text{Pa})(1.5 \times 10^{-3}\,\text{m}^3)\left(1 - \dfrac{1.00 \times 10^5\,\text{Pa}}{2.50 \times 10^4\,\text{Pa}}\right) = -113\,\text{J}$.

The total work done is $208\,\text{J} - 113\,\text{J} = 95\,\text{J}$.
(d) Heat at constant volume. No work would be done by the gas or on the gas during
this process.

Figure 19.54

19.58. The process is adiabatic. Apply $p_1V_1^{\gamma} = p_2V_2^{\gamma}$ and $pV = nRT.$ $Q = 0$ so

$\Delta U = -W = -\dfrac{1}{\gamma - 1}(p_1V_1 - p_2V_2)$. For helium, $\gamma = 1.67$. $p_1 = 1.00\,\text{atm} = 1.013 \times 10^5\,\text{Pa}$.

$V_1 = 2.00 \times 10^3\,\text{m}^3$. $p_2 = 0.900\,\text{atm} = 9.117 \times 10^4\,\text{Pa}$. $T_1 = 288.15\,\text{K}$.

(a) $V_2^{\gamma} = V_1^{\gamma}\left(\dfrac{p_1}{p_2}\right)$. $V_2 = V_1\left(\dfrac{p_1}{p_2}\right)^{1/\gamma} = (2.00 \times 10^3\,\text{m}^3)\left(\dfrac{1.00\,\text{atm}}{0.900\,\text{atm}}\right)^{1/1.67} = 2.13 \times 10^3\,\text{m}^3$.

(b) $pV = nRT$ gives $\dfrac{T_1}{p_1 V_1} = \dfrac{T_2}{p_2 V_2}$.

$T_2 = T_1 \left(\dfrac{p_2}{p_1} \right)\left(\dfrac{V_2}{V_1} \right) = (288.15\ \text{K})\left(\dfrac{0.900\ \text{atm}}{1.00\ \text{atm}} \right)\left(\dfrac{2.13 \times 10^3\ \text{m}^3}{2.00 \times 10^3\ \text{m}^3} \right) = 276.2\ \text{K} = 3.0°\text{C}.$

(c) $\Delta U = -\dfrac{1}{0.67}([1.013 \times 10^5\ \text{Pa})(2.00 \times 10^3\ \text{m}^3)] - [9.117 \times 10^4\ \text{Pa})(2.13 \times 10^3\ \text{m}^3)] = -1.25 \times 10^7\ \text{J}.$

19.64. $pV = nRT$. For the isobaric process, $W = p\Delta V = nR\Delta T$. For the isothermal process,

$W = nRT \ln\left(\dfrac{V_\text{f}}{V_\text{i}} \right)$. $R = 8.315\ \text{J/mol} \cdot \text{K}$

(a) The pV diagram for these processes is sketched in Figure 19.64.

(b) Find T_2. For process $1 \to 2$, n, R and p are constant so $\dfrac{T}{V} = \dfrac{p}{nR} = \text{constant}.$

$\dfrac{T_1}{V_1} = \dfrac{T_2}{V_2}$ and $T_2 = T_1 \left(\dfrac{V_2}{V_1} \right) = (355\ \text{K})(2) = 710\ \text{K}.$

(c) The maximum pressure is for state 3. For process $2 \to 3$, n, R and T are

constant. $p_2 V_2 = p_3 V_3$ and $p_3 = p_2 \left(\dfrac{V_2}{V_3} \right) = (2.40 \times 10^5\ \text{Pa})(2) = 4.80 \times 10^5\ \text{Pa}.$
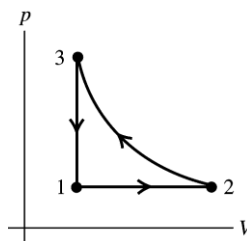
(d) process $1 \to 2$: $W = p\Delta V = nR\Delta T = (0.250\ \text{mol})(8.315\ \text{J/mol} \cdot \text{K})(710\ \text{K} - 355\ \text{K}) = 738\ \text{K}.$

process $2 \to 3$: $W = nRT \ln\left(\dfrac{V_3}{V_2} \right) = (0.250\ \text{mol})(8.315\ \text{J/mol} \cdot \text{K})(710\ \text{K}) \ln\left(\dfrac{1}{2} \right) = -1023\ \text{J}.$

process $3 \to 1$: $\Delta V = 0$ and $W = 0$.
The total work done is $738\ \text{J} + (-1023\ \text{J}) = -285\ \text{J}.$ This is the work done by the gas.
The work done on the gas is 285 J.

Figure 19.64