5. (45 Points) Consider the phase diagram above which describes reversible processes involving a monatomic ideal gas. The individual processes are 1 → 2 : isothermal \((T=\text{constant})\), 2 → 3 : isobaric \((P=\text{constant})\), 3 → 1 : isochoric \((V=\text{constant})\).

(a) Fill in the given table for the three individual steps and the entire process using \(P_1 = 1\ \text{atm}, P_2 = 5\ \text{atm}, V_1 = 1\ \text{m}^3, V_2 = 5\ \text{m}^3\).

(b) Explain how you might achieve step 2 → 3 : isobaric \((P=\text{constant})\).

(c) What is the net result of this cycle? (In other words, what could you do with the cycle).

<table>
<thead>
<tr>
<th>Process</th>
<th>(\Delta U)</th>
<th>(W)</th>
<th>(Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 → 2: isothermal</td>
<td>0</td>
<td>(-8.1 \times 10^5 J)</td>
<td>(+8.1 \times 10^5 J)</td>
</tr>
<tr>
<td>2 → 3: isobaric</td>
<td>(-6.0 \times 10^5 J)</td>
<td>(+4.0 \times 10^5 J)</td>
<td>(-1.0 \times 10^6 J)</td>
</tr>
<tr>
<td>3 → 1: isochoric</td>
<td>(+6.0 \times 10^5 J)</td>
<td>0</td>
<td>(+6.0 \times 10^5 J)</td>
</tr>
<tr>
<td>whole cycle</td>
<td>0</td>
<td>(-4.1 \times 10^5 J)</td>
<td>(+4.1 \times 10^5 J)</td>
</tr>
</tbody>
</table>

1→2 \(w = \frac{\Delta h}{T} \ln \frac{V_1}{V_f} = \left(\frac{\partial h}{\partial V}\right)_T V_0 \ln \frac{V_1}{V_f} = \left(10^5 \text{ Pa}\right) \left(\frac{5}{3}\right) \ln \frac{1}{5} = \approx -8.1 \times 10^5 J\)

\(\Delta u = 0\)

\(Q = -w\)

2→3

\(\Delta u = \frac{3}{2} \left[ P_f V_f - P_i V_i \right] - \frac{3}{2} \left[ P_f V_i - P_i V_f \right] = \frac{3}{2} \cdot 10^5 \text{ Pa} \cdot \left[ 1 \text{ m}^2 - 5 \text{ m}^3 \right] = -6.0 \times 10^5 J\)

\(w = -p \Delta V = -P \cdot (V_f - V_i) = -10^5 \text{ Pa} \left(1 \text{ m}^2 - 5 \text{ m}^3\right) = +4.1 \times 10^5 J\)

\(Q = \Delta u - w = -6.0 \times 10^5 J - (+4.1 \times 10^5 J) = -1.0 \times 10^6 J\)

3→1

\(w = 0\)

\(Q = +\Delta u\) find from table since \(\Delta u = 0\)

for whole cycle