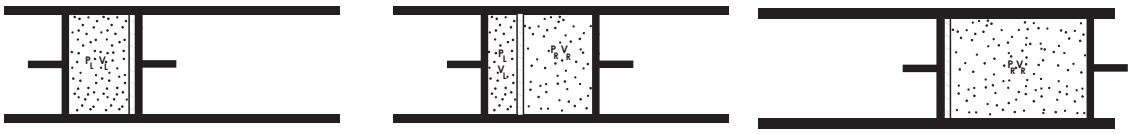
2. The figure below shows a throttling process in which two pistons "push" and "pull" gas through a porous divider (shown as a lightly hatched line) that is fixed inside a thermally insulated cylinder. No heat flows into or out of the cylinder. Initially, all the gas is on the left hand side of the divider and the right hand piston is up against the divider (top left plot). The top right figure shows an intermediate state and the bottom figure shows the final state. The pistons are moved in such a way that the pressure on the left hand side is always P_L and the pressure on the right side is P_R, with $P_R < P_L$. The final volume is larger than the initial volume.



(a) What thermodynamic potential has the same value at the end of the process as it did at the start? Prove it!

(b) If the gas is ideal, what is its change in the internal energy between initial and final states?

(c) Suppose now that the gas has a van der Waals equation of state

$$\left(P + \frac{N^2 a}{V^2}\right)(V - Nb) = NkT \tag{2}$$

where a and b are small numbers. The Helmholtz free energy is

$$F = -NkT\Big\{\ln[n_Q(V - Nb)/N] + 1\Big\} - N^2 a/V \tag{3}$$

where $n_Q = (mkT/2\pi\hbar^2)^{3/2}$. What is the internal energy U?

(d) What is the condition on the van der Waals coefficients a and b such that the gas cools on expansion into a very large volume in a throttling process? Qualitatively interpret the result. [Hint: $0 < Nb/V << 1$]