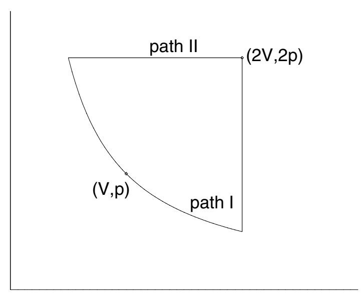
14. (a) The pV diagram depicting the two "paths" is shown:



(b) "Path I" consists of an isothermal (constant T) process in which the volume doubles, followed by a constant-volume process. We consider the Q for each of these steps. We note that the connection between molar heat capacity and the degrees of freedom of a monatomic gas is given by setting $f = 3$ in Eq. 20-51. Thus, $C_V = \frac{3}{2}R$, $C_p = \frac{5}{2}R$, and $\gamma = \frac{5}{3}$.

- Isothermal: Since this is an ideal gas, Eq. 20-45 holds, which implies $\Delta E_{\text{int}} = 0$ for this process. Eq. 20-14 also applies, so that by the first law of thermodynamics, $Q = 0 + W = nRT \ln V_f/V_i = pV \ln 2$. The ideal gas law is used in the last step.
- Constant-volume: The gas law in ratio form (see Sample Problem 20-1) implies that the pressure decreased by a factor of 2 during the isothermal portion, so that it needs to increase by a factor of 4 in this portion of "path I." That same ratio form now applied to this constant-volume process, yielding $4 = T_f/T_i$ which is used in the following:

$$\begin{aligned} Q &= nC_V\Delta T = n\left(\frac{3}{2}R\right)(T_f - T_i) \\ &= \frac{3}{2}nRT_i\left(\frac{T_f}{T_i} - 1\right) \\ &= \frac{3}{2}pV\,(4-1) \;=\; \frac{9}{2}pV\ . \end{aligned}$$

"Path II" consists of an isothermal (constant T) process in which the volume halves, followed by a isobaric (constant p) process. We again consider the Q for each of these steps.

- Isothermal: Here the gas law applied to the isothermal portion leads to a volume half as big as the original. Since $\ln\left(\frac{1}{2}\right) = -\ln 2$, the reasoning used above leads to $Q = -pV \ln 2$.
- Isobaric: To obtain a final volume twice as big as the original, then this portion of the "path" needs to increase the volume by a factor of 4. Now, the gas law applied to this isobaric portion leads to a temperature ratio $T_f/T_i = 4$. Thus,

$$\begin{aligned} Q &= nC_p\Delta T = n\left(\frac{5}{2}R\right)(T_f - T_i) \\ &= \frac{5}{2}nRT_i\left(\frac{T_f}{T_i} - 1\right) \\ &= \frac{5}{2}pV\,(4-1) = \frac{15}{2}pV\ . \end{aligned}$$

(c) Much of the reasoning has been given in part (b). Here and in the next part, we will be brief.

- Path I – Isothermal expansion: Eq. 20-14 gives $W = nRT \ln V_f/V_i = pV \ln 2$.
- Path I – constant-volume part: $W = 0$.
- Path II – Isothermal compression: Eq. 20-14 gives $W = nRT \ln V_f/V_i = pV \ln 1/2 = -pV \ln 2$.