CW2HWST-10)

Let's label these steps as (1), (2), and (3). The initial pressure is 5×10^5 Pa, and $\gamma = 5/3$. We'll need the temperature as well: $T_i = P_iV_i/nR = (5\times10^5)(2)/4(8.3) = 30{,}120$ K.

For (1), $\Delta U_{(1)} = 0$ (process is isothermal), so $Q_{(1)} = W_{(1)}$

We've worked out previously that, for an isothermal process,

$$W_{(1)} = nRT_o \ln\frac{V_f}{V_i} = 4(8.3)(30{,}120)\ln\frac{3}{2} = 405{,}459 \text{ J}$$

For (2), heat is clearly removed, and we don't need to know how much for finding the efficiency. The work is easy, but we will need to know the pressure:

$P_iV_i = P_fV_f \rightarrow P_f = P_i(V_i/V_f) = 500{,}000(2/3) = 333{,}333$ Pa

$W_{(2)} = P\,\Delta V = 333{,}333(2-3) = -\ 333{,}333$ J

For (3), there is no work done, but to find $Q_{(3)}$ we'll need the temperature at the end of (2):

$T = PV/nR = 333{,}333(2)/4(8.3) = 20{,}080$ K

Then, $Q = nc_{MV}\Delta T = (4)(^3/_2(8.3))(\ 30{,}120-20{,}080) = 499{,}992$ Jeq.

The efficiency is then

$$\text{eff} = \frac{W_{(1)} + W_{(2)}}{Q_H} = \frac{405{,}459 - 333{,}333}{405{,}459 + 499{,}992} = 0.080 = 8.0\ \%$$