a.) Air in ~80% N₂ and ~20% O₂ (both diatomic)

So, \( \xi_{\text{th}} = nC_v T_i = \frac{nS}{2} \)

and \( PV = nRT \)

So: \( \xi_{\text{th}} = \frac{S}{2} (PV) = 2.026 \times 10^6 J \)

b.)

Conservation of mechanical energy:

\[ \Delta E = 0 \]

\[ \xi_i = k_i + u_i = 0 \]

\[ k_1 = U_2 = mgh = 9.8J \]

\[ k_1 = \frac{4.64 \times 10^{-6}}{\xi_{\text{th}}} \]

c.) For \( \Delta E_{\text{th}} = nC_v \Delta T = \frac{S}{2} Nk_B \Delta T = -9.8J \).

Now \( PV = Nk_B T_i \Rightarrow Nk_B = \frac{PV}{T_i} \)

So

\[ \frac{S}{2} \frac{PV \Delta T}{T_i} \Rightarrow \Delta T = \frac{2T_i \Delta E_{\text{th}}}{SV} = -1.42 \times 10^{-3}K \]

d.) This process does not violate the First Law of Thermodynamics. The Second Law of Thermodynamics does not say it will never happen—but it does say that the process is exceedingly unlikely to happen.