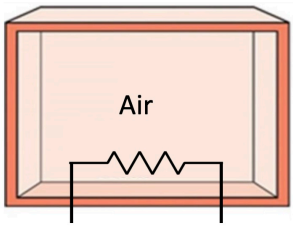
Example

Electricity is used to heat air in a rigid, insulated container from an initial pressure and temperature of 100 kPa and 300 K, respectively, to a final temperature of 400 K.

a) How much electrical work is done?
b) Is this a reversible process?



$P_1 = 100\ kPa$

$T_1 = 300\ K$ Ideal gas

$T_2 = 400\ K$

Avg temp = 350 K

Table A-2:

$\bar{c}_v$ @ 350 K = 0.721 $[kJ/kg \cdot K]$

$V_2 = V_1$ ("rigid")

a. $\Delta u = u_2 - u_1 = \cancel{Q_{1-2}}^{0\ (adiabatic)} - W_{1-2}$

$m\bar{c}_v (T_2 - T_1) = -(-W_{in})$

$W_{in} = 2[kg] + 0.721\ [kJ/kg \cdot K]\ (400\ [K] - 300\ [K])$

$= \boxed{144.2\ [kJ]}$

b. $S_2 - S_1 = \sum \frac{\cancel{Q_k}^{0\ (adiabatic)}}{T_k} + S_{gen}$

$S_{gen} = m(s_2 - s_1)$

$= m\left(\bar{c}_v \ln \frac{T_2}{T_1} + R \ln \cancel{\frac{V_2}{V_1}}^{V_2 = V_1}\right)$

$= 2[kg]\left(0.721\ [kJ/kg \cdot K] \ln\left(\frac{400\ [K]}{300\ [K]}\right)\right)$

$= \boxed{0.415\ [kJ/K]}$

$S_{gen} > 0$ ∴ Irreversible

Thermal energy Δu from the box will not spontaneously arrange itself to generate electrical current (work) for us via the resistor, even though first law says $\Delta u = w$. Instinctively we know this, but 2nd law gives us rules/guidelines.