First Law

1) $800 \text{ Cal} \times \frac{4.184 \text{ kJ}}{1 \text{ Cal}} \Rightarrow \boxed{3{,}347.2 \text{ kJ or } 3{,}347{,}200 \text{ J}}$

2) $\Delta E_{th} = Q + W$

(a) $\Delta E_{th} = \frac{3}{2} N k_B \Delta T$, $\Delta T = 250 \text{K}$

$\Rightarrow \Delta E_{th} = \frac{3}{2}(6.022\times10^{23})(1.38\times10^{-23})(250)$

$\boxed{\Delta E_{th} = 3116.4 \text{ J}}$

(b) $Q = -W + \Delta E_{th} = -2000 \text{ J} + 3116.4 = 1116.4 \text{ J}$

$\Rightarrow$ 1116.4 Joules entered the system as heat during this thermodynamic process.

3) $\Delta E_{th} = \frac{3}{2} N k_B \Delta T$ (for a monatomic gas.)

$\Rightarrow \Delta T = \frac{\frac{2}{3}\Delta E_{th}}{N k_B}$

$\Delta E_{th} = Q + W = -8 \text{ kJ} + 20 \text{ kJ}$
$= 12 \text{ kJ}$

$N = 3 \text{ mol} \times \frac{6.022\times10^{23} \text{ particles}}{1 \text{ mol}} = 1.8\times10^{24}$

$= \frac{\frac{2}{3}(12\times10^{3} \text{ J})}{(1.8\times10^{24})(1.38\times10^{-23})}$

$\Rightarrow \boxed{\Delta T = 322 \text{ K}}$