17.66. Model: Assume that the gas is an ideal gas and that the work, heat, and thermal energy are connected by the first law of thermodynamics.

Visualize: Please refer to Figure P17.66.

Solve: **(a)** For point 1, $V_1 = 1000\ \text{cm}^3 = 1.0 \times 10^{-3}\ \text{m}^3$, $T_1 = 133°\text{C} = 406\ \text{K}$, and the number of moles is

$$n = \frac{M}{M_{\text{mol}}} = \left(\frac{120 \times 10^{-3}\ \text{g}}{4\ \text{g/mol}}\right) = 0.030\ \text{mol}$$

Thus, the pressure p_1 is

$$p_1 = \frac{nRT_1}{V_1} = 1.012 \times 10^5\ \text{Pa} = 1.0\ \text{atm}$$

The process $1 \rightarrow 2$ is isochoric ($V_2 = V_1$) and $p_2 = 5p_1 = 5.0$ atm. Thus,

$$T_2 = T_1(p_2/p_1) = (406\ \text{K})(5) = 2030\ \text{K} = 1757°\text{C}$$

The process $2 \rightarrow 3$ is isothermal ($T_2 = T_3$), so

$$V_3 = V_2(p_2/p_3) = V_2(p_2/p_1) = 5V_2 = 5000\ \text{cm}^3$$

	p (atm)	T (°C)	V (cm^3)
Point 1	1.0	133	1000
Point 2	5.0	1757	1000
Point 3	1.0	1757	5000

(b) The work $W_{1\rightarrow 2} = 0$ J because it is an isochoric process. The work in process $2 \rightarrow 3$ can be found using Equation 17.16 as follows:

$$W_{2\rightarrow 3} = -nRT_2 \ln(V_3/V_2) = -(0.030\ \text{mol})(8.31\ \text{J/mol K})(2030\ \text{K})\ln(5) = -815\ \text{J}$$

The work in the isobaric process $3 \rightarrow 1$ is

$$W_{3\rightarrow 1} = -p(V_f - V_i) = -(1.012 \times 10^5\ \text{Pa})(1.0 \times 10^{-3}\ \text{m}^3 - 5.0 \times 10^{-3}\ \text{m}^3) = 405\ \text{J}$$

(c) The heat transferred in process $1 \rightarrow 2$ is

$$Q_{1\rightarrow 2} = nC_V \Delta T = (0.030\ \text{mol})(12.5\ \text{J/mol K})(2030\ \text{K} - 406\ \text{K}) = 609\ \text{J}$$

The heat transferred in the isothermal process $2 \rightarrow 3$ is $Q_{2\rightarrow 3} = -W_{2\rightarrow 3} = 815\ \text{J}$. The heat transferred in the isobaric process $3 \rightarrow 1$ is

$$Q_{3\rightarrow 1} = nC_P \Delta T = (0.030\ \text{mol})(20.8\ \text{J/mol K})(406\ \text{K} - 2030\ \text{K}) = -1013\ \text{J}$$