1. Exercise E3.3 (p. 148). Also, as part (d), calculate $\Delta S$ for the process given in part (c).

2. Exercise E3.7 (p. 149).

3. A reversible Joule cycle consists of the following four steps: (i) isobaric expansion, (ii) adiabatic expansion, (iii) isobaric compression, (iv) adiabatic compression. Helium gas with the equation of state $pV_m = RT + BP$ (where $B > 0$) is carried through a Joule cycle.

   (a) Sketch the paths taken by the system in the following sets of coordinates: (i) $(p,V)$, (ii) $(U,V)$, and (iii) $(T,S)$. [For the sketches, only the general shapes and slopes of the lines are important, not the actual values of the variables at the end of each step.]

   (b) If $B = 0.015 \text{ L mol}^{-1}$, $T_h = 500 \text{ K}$, and $T_c = 298 \text{ K}$, calculate $w$, $q$, $\Delta U$, $\Delta H$, and $\Delta S$ for each step and for the total cycle.

   (c) What is the efficiency of this engine? Can it be expressed as a function of the two temperatures only?

4. (a) The model $C_{p,m} = \alpha + \beta T + \gamma T^2$ is applied to the data given in P4.3 (p. 199) in the range $14.98 \leq T \leq 50.20 \text{ K}$. The following parameters are found to be satisfactory for the range $14.98 \leq T \leq 50.20 \text{ K}$: $\alpha = -18.6002$, $\beta = 1.95645$, and $\gamma = -0.0155003$, in appropriate units. Find the parameter $a$ and the characteristic temperature $T^*$ that will ensure the smooth continuation of this curve to absolute zero with the Debye equation, according to which $C_{p,m} = aT^3$. Plot the graph of $aT^3$ in the range $0-T^*$ and $\alpha + \beta T + \gamma T^2$ from $14.98$-$50.20 \text{ K}$ to verify that the function is smooth and continuous.

   (b) Calculate $H_{50.20K} - H_{0K}$ by integrating the Debye equation up to $T^*$ and the expression given above for higher temperatures.

   (c) Also, using the same assumption, calculate $S_{50.20K} - S_{0K}$. 