**Thermodynamics**

**30 pts. 1)** Assuming that the working gas is an ideal gas with temperature-independent heat capacities, find the efficiency $\eta$ of the following cycle. Express the final answer for $\eta$ in terms of $\gamma$ (the heat capacity ratio) and $V_2/V_3$ only.

![Diagram of a thermodynamic cycle](image)

**30 pts. 2)** A mass $m$ of water at temperature $T_1$ is isobarically and adiabatically mixed with an equal mass of water at temperature $T_2$. Assume a constant specific heat $C_p$. Calculate the final temperature of the total system and the entropy change of the total system.

**40 pts. 3)** A certain solid can exist in two phases at low temperatures. At normal pressure (1 atm), the chemical potentials $\mu_i$ ($i = 1, 2$) of the two phases have the form

$$\mu_i = a_i - b_i T^2 - c_i T^4,$$

where the coefficients $a_1 = 3.5 \text{ J/g}$, $a_2 = 0.5 \text{ J/g}$, $b_1 = 4 \text{ J/gK}^2$, $b_2 = 2 \text{ J/gK}^2$, $c_1 = 2 \text{ J/gK}^4$, and $c_2 = 1 \text{ J/gK}^4$.

(a) Find the temperature $T_c$ of the phase transition. Indicate which phase is stable below $T_c$ and which phase is stable above $T_c$. Why?

(b) Calculate the latent heat of this transition? Based on your result, is this transition first or second order? Why?

(c) Calculate the specific heat jump $\Delta C_p$ at $T_c$. 
