Note: Both English and Chinese are acceptable for answering these questions.

1. (20 points) (a) Please briefly explain the difference between first-order and second-order phase transitions. [10 points] (b) Please give an example of second-order phase transition. [10 points]

2. (20 points) Joule-Thomson effect suggests that when a stream of non-ideal gas is passed through a thermally insulated tube, in which a throttle valve is inserted, the temperature of the gas changes and the state of the gas is changed from P_1, T_1 to P_2, T_2. (a) Please briefly draw a schematic plot to explain Joule-Thomson effect. [4 points] (b) Please show that this process is isenthalpic. [8 points] (c) Show that the Joule-Thomson coefficient, which is defined as $\mu_{J-T} \equiv (\partial T / \partial P)_H$, can be expressed as $\mu_{J-T} = -V(1-\alpha T)/c_p$, where α is the thermal expansion coefficient. [8 points]

3. (20 points) Consider a real gas n-butane that can be described by the virial equation $\frac{PV}{RT} = 1 + \frac{A}{V} + \frac{B}{V^2}$ with $A = -265\,\text{cm}^3 \cdot \text{mole}^{-1}$ and $B = 30250\,\text{cm}^6 \cdot \text{mole}^{-2}$. Calculate the change in the Gibbs free energy when the volume of 1 mole of n-butane is decreased from 400 to 200 cm^3 at 460 K.

4. (20 points) At 700 K, the activity of Ga in a liquid Ga-Cd solution of composition $X_{\text{Ga}} = 0.5$ has the value 0.79. Assuming that the liquid solutions of Ga and Cd exhibit regular solution behavior, estimate the energy of the Ga-Cd bond in the solution. Note that the molar enthalpies of evaporation of liquid Ga and liquid Cd at their melting temperatures are 270,000 J and 100,000 J, respectively. Also note that the coordination numbers of liquid Ga and liquid Cd at their melting temperatures are 8 and 11, respectively. For the 50:50 solution, assume the coordination number to be 9.5 (the average of 8 and 11).

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5. (20 points) The Helmholtz free energy A is related to the partition function Z of the system through $A = -Nk_BT \ln Z$, where N is the number of particles or oscillators in the system. (a) Please obtain the simplified expressions of both A and S of an Einstein solid. [10 points] (b) Show that the entropy approaches zero as the temperature approaches zero in such system. [10 points]

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