Note: You are free to use Chinese to answer the questions.

1. (15 points) Please briefly explain "Gibbs paradox."

2. (25 points) Carbon has the following allotropes: graphite, diamond, and a metallic for called solid III. Graphite is the stable form of 298 K and 1 atm pressure, and increasing the pressure on graphite causes the transformation of graphite into diamond and then the transformation of diamond to solid III. It is therefore a common practice to enforce huge pressure onto graphite and turn graphite into diamond artificially. Please calculate the pressure required to cause the phase transformation of one mole of graphite into diamond at 298 K, with the following given information.

$$\Delta H_{\text{graphite} \to \text{diamond, 298 K}} = 1900 \text{ J}.$$

$$\Delta S_{\text{graphite} \to \text{diamond, 298 K}} = -3.37 \text{ J/K}.$$

The molar weight of carbon = 12 g/mole.

The density of graphite at 298 K = 2.22 g/cm^3.

The density of diamond at 298 K = 3.515 g/cm^3.

3. (25 points) One mole of copper at a temperature of 0°C is placed in thermal contact with a second mole of copper which is at 100°C. Please calculate the final temperature of the two-mole copper system, which is contained in an adiabatic enclosure, when thermal equilibrium is attained. Please also calculate the thermal energy that is transferred and the entropy being produced by this process. The constant pressure molar heat capacity of solid copper is temperature dependent and is expressed as: $c_P = 22.64 + 6.28\times10^{-3}T$ J/mole$\cdot$K.

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4. (15 points) For second-order phase transitions, $\Delta S = 0$ and $\Delta V = 0$ at the phase transition point. If that's the case, then the Clapeyron equation $(dP/dT)_{eq} = \Delta S/\Delta V$ will become problematic. Show that the modified Clapeyron equation for a second-order phase transition from phase 1 to phase 2 should be expressed as

$$\left(\frac{dP}{dT}\right)_{eq} = \frac{1}{TV}\left(\frac{c_{p2} - c_{p1}}{\alpha_2 - \alpha_1}\right)$$

or

$$\left(\frac{dP}{dT}\right)_{eq} = \frac{\alpha_2 - \alpha_1}{\beta_2 - \beta_1},$$

where α and β stand for isobaric thermal expansion coefficient and isothermal compressibility, respectively.

5. (20 points) The Cu impurity in liquid Pb can be removed by adding PbS into the Cu-Pb alloy and allowing the exchange reaction $2\,Cu_{(s)} + PbS_{(s)} = Cu_2S_{(s)} + Pb_{(l)}$ to come to equilibrium. The solid sulfides are mutually immiscible, while Pb is insoluble in solid Cu, and the Cu liquidus, below 850°C, is expressed as

$$\log X_{Cu} = -\frac{3500}{T} + 2.261,$$

where X_{Cu} is the solubility of Cu in liquid Pb (also note that T is in Kelvin). If Cu obeys Henry's law in liquid Pb, please calculate the extent to which Cu can be removed from liquid Pb by this process at 800°C. For this reaction at 800°C, $\Delta G^\circ = -30019$ J.

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