1. You are given 4 blocks of Al_2O_3, each having a mass of 1 kg. The 4 pieces each have different initial temperatures: 700, 800, 1000 and 1600 K. (30 %)

(a) Explain the distinction between nonequilibrium and quasistatic processes. (5%)

(b) If the 4 pieces are placed in thermal contact, what will be their final temperature? Please list the equation(s) you are trying to solve the problem in detail. DO NOT waste your time to find the numerical value. (5%)

(c) Is this process reversible or irreversible? Assume the final temperature of part (b) is 1036 K. Determine the total entropy change in Prat (b). (10%)

(d) Having at your disposal a reversible heat engine and a reversible refrigerator. Please make a schematic diagram of a reversible heat engine to drive a reversible refrigerator. Determine the lowest temperature that could be achieved by one of the blocks. Please list the equation(s) you are trying to solve the problem in detail. DO NOT waste your time to find the numerical value. (10%)

* Assume the blocks remain at a pressure of 10^5 Pa during the process. C_p for Al_2O_3 over this temperature range is given below:

$$C_p = 109.3 + (1.84 \times 10^{-2})\,T - (3.04 \times 10^{-6}) / T^2$$

The unit is J/mole K.

** Molecular weight of Al_2O_3 is 101.96 g/mole.

2. For many elements, determining the boiling point may present overwhelming experimental challenges (e.g., high temperature or toxicity). (20%)

(a) Use the Clausius-Clapeyron equation to estimate the boiling point of Cd (a toxic element) from the following vapor pressure data in equilibrium with liquid Cd. (10%)

T (K)	500	600	700
P (Pa)	0.47	25.3	432

(b) What value do you get for the heat of vaporization? Estimate the difference in $\triangle H$ at 500 K and the boiling point. Assume the liquid heat capacity of Cd is 30 J/mole K, and the heat capacity of monoatomic gas is approximated as 2.5R, 20.8 J/mole K. (5%)

(c) Could a reasonable estimate of the boiling point be obtained from the knowledge of the vapor pressure over a solid phase? Please makes a simple schematic diagram of H vs T to illustrate the vaporization correction between the solid and liquid. (5%)

*The actual boiling point of Cd is 1038 K, and one atmospheric pressure equals 10^5 Pa.

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3. (10%) Consider the following reaction

$$SO_{2(g)} + 1/2O_{2(g)} = SO_{3(g)}$$

The standard free energy change for this reaction is

$$\Delta G^{o} = -94600 + 89.37T \qquad [J]$$

Initially there are 1 mole of SO_2 at 1 atm and 0.5 mole of O_2 at 1 atm, what is the final partial pressure for each component when the system reaches equilibrium at 1 atm and 1000 K?

4. (14%) The molar excess Gibbs free energy of formation of solid solutions in the system Au-Ni can be represented by

$$G^{xs}=X_{Ni}X_{Au}\,(24140X_{Au} + 38280X_{Ni} - 14230X_{Au}X_{Ni})\,[1-(T/2660)] \quad J$$

Calculate the activities of Au and Ni in the alloy of $X_{Au}=0.5$ at 1100 K.

(3%) Does this solution at $X_{Au}=0.5$ and 1100 K exhibit positive deviation or negative deviation?

(3%) Do Au and Ni atoms at $X_{Au}=0.5$ and 1100 K like or dis-like each other?

5. A solution exhibits the sub-regular solution behavior with

$$\Delta H_{mix} = 5000x_1x_2 \qquad J/mol$$

(a) (10%) Derive the equation for the boundary for the spinodal region. Express your equation in term of x_2 and T.

(b) (10%) Find the critical temperature and critical composition for the miscibility gap of this solution.

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