1. (a) Consider a non-ideal gas that can be described by the equation of state $PV = RT(1+BP)$, where B is a constant independent of temperature T and pressure P. Show that the work done by this non-ideal gas during isothermal expansion from pressure P_1 to P_2 is the same as that achieved by an ideal gas. (10%)

(b) Show that for a van der Waals gas that can be described by $\left(P+{a}/{V^2}\right)(V-b)=RT$, the change in entropy can be expressed as $\Delta S=\int\frac{c_V}{T}dT+R\ln(V-b)$. (10%)

2. (a) Please briefly describe the second law of thermodynamics. (5%)

(b) Starting from Boltzmann's equation $S=k\ln\Omega$, show that when two closed systems A and B are in thermal contact, the condition for A to be in thermal equilibrium with B will lead to $T_A=T_B$. (5%)

(c) Generally speaking, the molar heat capacity of a metallic solid can be expressed as $c_V=K\left({T}/{\Theta}\right)^3+\gamma T$ at low temperatures. What are the physical origins of these two temperature-dependent terms? What is Θ? (5%)

(d) While dealing with different thermodynamic processes, under what circumstances (conditions) will you use Helmholtz free energy and Gibbs free energy? (5%)

3. A piece of copper goes through a reversible isothermal compression process from P = 1 atm to 1000 atm at $T = 273\text{K}$. Assume that the isobaric thermal expansivity α, the isothermal compressibility β, and the mass density ρ are $5\times10^{-5}\,\text{K}^{-1}$, $8\times10^{-12}\,\text{N}^{-1}\text{m}^2$, and $8.9\times10^3\,\text{kg m}^{-3}$, respectively. Please calculate: (a) How much work (per kg) is done on the copper? (10%) (b) How much heat is absorbed or released? (10%)

4. Consider a system with N particles, and the system obeys Maxwell-Boltzmann distribution. Show that: (a) The expectation value of number of particles that occupy i^{th} energy level (with energy ε_i) is $n_i=-Nk_BT\left({\partial\ln Z}/{\partial\varepsilon_i}\right)_T$, where $Z=\sum_i e^{-\varepsilon_i/k_BT}$ is the single particle partition function. (10%) (b) The internal energy U (expectation value of

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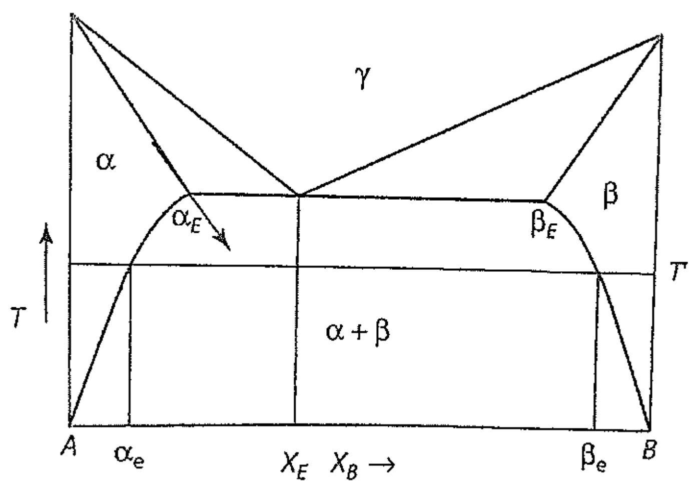
the total energy) of the system can be expressed as $U=-(\partial \ln Z/\partial \beta)_V$, where $\beta = 1/k_B T$. (5%) (c) The Helmholtz free energy A of the system can be expressed as $A=-\beta^{-1}\ln Z$. (5%)

5. The phase diagram of an alloy that possesses a eutectoid transformation is shown below. (a) Sketch the Gibbs free energy curves for this alloy at $T=T'$. (10%) (b) Show that the α/γ solvus must enter the α/β two-phase field as indicated by the arrow. (10%)



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