(14%) 1. (a) Use the first and second laws of thermodynamics to show that the Gibbs free energy G is a minimum (dG=0) for a system in equilibrium at constant temperature and pressure.
(b) Why can we usually use internal energy changes ΔE in place of enthalpy changes ΔH for condensed systems at atmospheric pressure?

(20%) 2. (a) Derive an expression for the increase in temperature for a process in which the volume of the system is changed at constant entropy.
(b) One mole of copper initially at 700 K and one atmosphere is contained in a thermally insulated jacket. The system is compressed reversibly to a pressure of 10,000 atm. Compute the change in temperature for this reversible adiabatic process.

(16%) 3. A non-ideal gas obeys the equation of state:

$$PV = RT + AP$$

where all symbols have their usual meaning, and A has units of volume and varies with temperature, i.e., $A = A(T)$.
(a) Derive an expression for the reversible work obtained from this gas when it is heated from T1 to T2. Express your answer in terms of R, T2, T1, P, A1, and A2, where A2 and A1 are the values of A at T2 and T1, respectively.
(b) Derive an expression for the reversible work obtained from the same gas during an isothermal expansion from V1 to V2, express your answer in terms of R, T, P1, and P2.

(15%) 4. Use the ideal gas equation to calculate the following gas densities in $g\ cm^{-3}$
(a) Air (79% nitrogen, 21% oxygen) at standard temperature and pressure.
(b) Air at $25\ ^{o}C$, 740 mm Hg.
(c) Air at $2000\ ^{o}F$, 100 psia.

(10%) 5. The vapor pressure over zinc is 10 mm Hg and 100 mm Hg at $593\ ^{o}C$ and $736\ ^{o}C$, respectively (m.p. = $419.5\ ^{o}C$). Determine the boiling point and heat of vaporization of zinc.

(15%) 6. Please draw a schematic diagram to show
(a) the liquidus curve,
(b) the solidus curve,
(c) the solvus curve, and
(d) the miscibility gap.

(10%) 7. Calculate the free energy change ΔG of the following reaction at 1000K.

$$Ca(a=0.9) = Ca(a=0.5)$$

where a is the activity of Ca.