PHY 3513 Fall 1998 – Homework 9

Due at the start of class on Friday, October 30. No credit will be given for late homework this week.

This is supposed to be an indication of the sort of questions that will appear on Exam 1. You will be asked to solve four problems similar to these during the two-hour exam.

Answer all questions. To obtain full credit, please explain your reasoning and show all working. Please write neatly and remember to include your name on the front page of your answers.

1. Answer each of the following short questions.

   (a) Classify each of the following thermodynamic quantities as either extensive or intensive: volume, pressure, molar heat capacity at constant volume, mole number, isothermal compressibility, molar internal energy.

   (b) Which of the following fundamental equations violate(s) the Nernst postulate?

   $$U = \frac{\theta}{v_0}\frac{VS}{N}\exp(-S/NR), \qquad S = \left(\frac{R^2}{v_0\theta}NVU\right)^{1/3}, \qquad S = \frac{v_0}{R\theta^2}\frac{U^2}{V}.$$

   (c) Given the fundamental equation

   $$u = R\theta\left[(s/R)^{3/2} - (v/v_0)^{5/2}\right],$$

   write down three equations of state in the energy representation.

2. N moles of a van der Waals fluid, which obeys the equations

   $$\left(P + \frac{a}{v^2}\right)(v-b) = RT, \qquad u = cRT - \frac{a}{v},$$

   undergo an isothermal expansion from volume V_1 to V_2.

   (a) Calculate the work done by the gas during this process.

   (b) Calculate the change in internal energy during this process.

   (c) Deduce the change in entropy during this process.

   Your answer should be expressed solely in terms of symbols introduced above and pure numbers (i.e., don't define any new symbols).

3. Find the coefficient of thermal expansion α and the isothermal compressibility κ_T for the following systems:

   (a) An ideal gas, which obeys $Pv = RT$.

   (b) A non-ideal gas which obeys the Dieterici equation, $P(v-b) = RT\exp[-a/(vRT)]$.

   Express all answers as functions of T and v. Hint: Differentiate. Just do it!

4. A closed system is composed of two simple one-component subsystems, labeled A and B. Initially the subsystems are themselves closed, being separated by an adiabatic, rigid, impermeable barrier. Then the barrier is replaced by one that is diathermal, rigid, and permeable to particles.

   (a) List the full set of extensive parameters required to specify completely the state of subsystem A and of subsystem B. (Do not include the entropy, which we will take to be fully determined by the other thermodynamic variables.)

   (b) Indicate which of the parameters X from (a) may possibly change from their initial values X_i during the approach to thermodynamic equilibrium.

   (c) State clearly the full set of equations which determine the equilibrium values X_f of the variables you identified in (b).

   (d) Find the equilibrium values of the variables you identified in (b) for the example of two subsystems which obey the fundamental equations

$$S^{(\alpha)} = C^{(\alpha)} + N^{(\alpha)} R \ln \left[\left(U^{(\alpha)} \right)^{c} V^{(\alpha)} \left(N^{(\alpha)} \right)^{-(c+1)} \right], \quad \alpha = A, B.$$

   Here, C^{A}, C^{B}, and c are known constants.