PHY 3513 Fall 1998 – Homework 1

Due at the start of class on Wednesday, September 2.

Answer all questions. You must explain your reasoning and show all working to obtain the maximum possible marks. Please write neatly and remember to include your name on the front page of your answers.

1. As mentioned in class, the molar heat capacity $c_{\rm mol}$ of most substances approaches a universal constant value at high temperatures. At low temperatures, however, $c_{\rm mol}$ varies greatly from material to material, and is also temperature dependent. For many metals, the molar heat capacity is well-described by the low-temperature form

$$c_{\rm mol} = \gamma\, T + \alpha\, T^3, \tag{1}$$

where T is the *absolute* temperature; both γ and α depend on the metal in question.

Starting from the equation

$$đQ = n\, c_{\rm mol}\, dT,$$

where n is the number of moles, find the total heat Q when 0.4 mol of a metal described by Eq. (1) is cooled from 40 K to 10 K. Take $\gamma = 1.0\,\mathrm{mJ\,mol^{-1}K^{-2}}$ and $\alpha = 0.2\,\mathrm{mJ\,mol^{-1}K^{-4}}$.

2. Suppose that 10 g of ice initially at −20 °C is brought into thermal contact with 1 g of superheated steam initially at 116 °C. Assuming that the combined ice-steam system is closed (i.e., no material or heat crosses its boundaries and no work is done by/on the system), what is the final equilibrium state? Express your final answer in roughly the same format as the following sample answers (all of which are physically nonsensical): "16 g of ice at −30 °C," "4 g of ice at −5 °C and 7 g of steam at 103 °C," and "8 g of water and 5 g of steam, both at 100 °C."

Data: $c_{\rm ice} = 2220\,\mathrm{J\,kg^{-1}K^{-1}}$, $c_{\rm water} = 4190\,\mathrm{J\,kg^{-1}K^{-1}}$, $c_{\rm steam} = 1520\,\mathrm{J\,kg^{-1}K^{-1}}$,
$L_{\rm F} = 333\,\mathrm{J\,kg^{-1}}$, $L_{\rm V} = 2256\,\mathrm{J\,kg^{-1}}$.

3. A certain sample of gas closed in a cylinder obeys the so-called van der Waals equation relating its pressure P, volume V and temperature T:

$$\left(P + \frac{a}{V^2}\right)(V - b) = c\,T. \tag{2}$$

Here a, b, and c are positive constants.

Calculate the total work done by the gas on expanding from volume V_1 to $V_2 > V_1$ when the expansion is performed in each of four different ways specified by the various constraints specified in (a)–(d) below.

(a) Isothermal: $T = T_0$, a constant.

(b) Isobaric: $P = P_0$, a constant.

(c) Isochoric: $V = V_1 = V_2$.

(d) Arbitrary: $T = d(V - b)$.