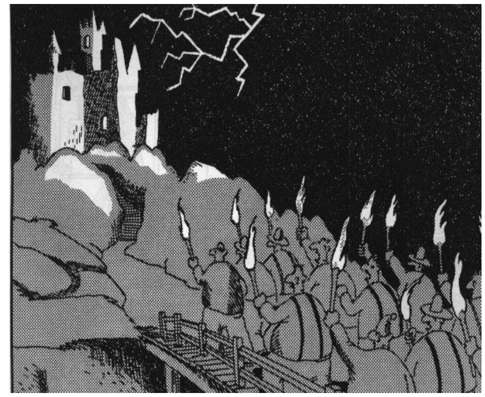
Physics 213 --- Pre-Lab # 3

Phase Transitions and Latent Heat



Name: ____

Section: ______________ TA: ____________________

Lab Date: ____________________________

In this lab, we will measure the vapor pressure and latent heat of water. To familiarize yourself with the relevant physics and equations, carry out the following calculations.

A. The latent heat for the water/steam transition is 2256 kJ/kg, i.e., to convert 1 kg of water into steam requires 2256 kJ. What is the latent heat per molecule of H_2O? Express your answer in Joules and in eV.

B. Water boils at 373 K in atmospheric pressure. That tells you that at 373 K the 'vapor pressure' of pure water, the pressure of water vapor which is in equilibrium with the liquid, is ______________ Pa.

C. At 273 K, ice and liquid water are in equilibrium. What relation then must be true of the vapor pressures of pure ice and pure liquid water at 273 K?

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D. Now let's make a crude picture of how the vapor pressure of water varies with T. Let's say that the vapor is a collection of molecules in states with energies greater than those of the liquid by an amount ΔE, since each molecule loses some energy when it sticks to its neighbors in the liquid. That means that the concentration, n, of molecules in the vapor will fall off as $\exp(-\Delta E/kT)$ compared to the nearly fixed concentration of molecules in the liquid (the fluid is essentially incompressible). Using $p=nkT$, the vapor pressure p would be proportional to $T \exp(-\Delta E/kT)$, i.e., it varies rapidly with T because of the Boltzmann factor. Keeping better track of the way the number of states available in the liquid and gas vary with T gives instead the **Clausius-Clapeyron relation: $p=p_0 \exp(-L/kT)$,** where L, the latent heat per molecule, is pretty close to the ΔE we just mentioned. The exponential dependence of the vapor pressure on 1/T is still really just the Boltzmann factor in action.

Sketch the expected curve for ln(p) versus 1/T (**not** versus T!):

How could you find L from the curve?

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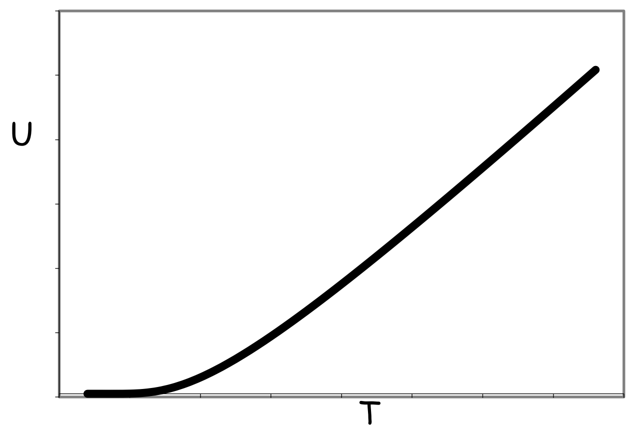
E. We know that at a pressure of 1 Atm, water boils at a temperature of 373 K (= 100°C). Assuming that the Clausius-Clapeyron relation holds, and using your answer from part A, calculate the temperature inside a pressure cooker operating at a pressure of 2 Atm.

F. We showed in class (Lect. 8) that the average energy of solid (approximated as a collection of N 3-D oscillators) is given by

$$U = 3N < E > \; = \frac{3N\varepsilon}{e^{\varepsilon/kT} - 1}$$

where ε is the energy spacing of the oscillators. Plotted versus T, this looks like:



Given that the heat capacity is defined as c = dU/dT, sketch the heat capacity of a typical solid: