9/21Lecture outline

• Why this class is *hot* (my personal perspective): thermodynamics and statistical physics are beautiful subjects. Amazingly predictive. Lots of output, from almost zero input!

• Mention laws 0,1,2 of theormodynamics. Full list of input! (3rd "law" too, but not of same stature as others.)

• Mention statistical approach. Now input is just energy conservation and properties of averaging over large collections of objects (molecules).

• Equilibrium. Not interested in non-equilibrium, time dependent processes –too hard! Wait long enough and an *isolated system* (enclosed by *adiabatic walls* achieves equilibrium. Equilibrium state is fully specified by pressure its P and volume V.

• Review pressure. Introduce notions of *intensive* and *extensive* quantities. E.g. intensive: pressure, temperature, density. Extensive: mass, volume, work. Can divide two extensive quantities to get intensive one, e.g. specific volume $v = V/n$. $n =$ mass in kilomoles.

• Review work. Work done **by** system $\not{d}W = pdV$. Work done **on** system has opposite sign.

• 0-th law. System A is in equilibrium. System B is in equilibrium. Put them in*thermal contact*. The combined system is in thermal equilibrium only some condition is satisfied, $F(P_A, V_A, P_B, V_B) = 0$, one condition on the 4 variables. Observed fact that if A and B happen to be in thermal equilibrium with each other, and A and C also happen to be in thermal equilibrium with each other, then B and C will be in thermal equilibrium with each other. Follows from this that the systems are in thermal equilibrium with each other if

$$\phi_A(P_A, V_A) = \phi_B(P_B, V_B) = \phi_C(P_C, V_C).$$

We call the quantity $\phi(P, T)$ the temperature of the system at equilibrium. Two different systems, initially in equilibrium, will remain in thermal equilibrium upon bringing them into thermal contact, only if the two systems have the same temperature. Otherwise, there is heat transfer from the hotter to the colder one, and eventually the re-achieve equilibrium for the combined system, at some common temperature (the colder one warms up, and the hotter one cools down, until they are the same temperature).

• Write the above condition as an *equation of state*: a system in equilibrium satisfies $f(p, V, T) = 0$ for some function. We wrote this above as $\phi(p, V) = T(p, V)$. More generally, the 3 quantities, p, V, and T, must satisfy one relation for the system to be in equilibrium. Picture equilibrium configurations as a 2 dimensional surface in 3 dimensions. If the system is off of this surface, it will change (according to some very complicated dynamics, that we won't try to understand in this class). Eventually, it will re-achieve equilibrium, and become a point on the $f(p, V, T) = 0$ surface.