Thermal Physics: Problem Set #1

Thermal Energy and the First Law

$$\Delta U = Q + W \;;\; U_{\text{thermal}} = N \cdot f \cdot \tfrac{1}{2} kT \;;\; PV = NkT \;;\; C_X \equiv \left(\frac{Q}{\Delta T}\right)_X \;;\; L \equiv \frac{Q}{m}$$

Due: Friday Jan. 16 by 6 pm

Reading Assignment: for Mon, 1.1-1.4 (20 pgs) (first law and ideal gas processes)
for Wed, 1.5-1.6 (17 pgs) (work, heat capacity, and latent heat)
for Fri, 2.1 (4 pgs) (two-state system and multiplicity)

Overview: Much of this first chapter should be something of a review. The reading is rather gentle, but some of the issues can be subtle, so be sure you understand what is being said. The first law is simply a statement of energy conservation, but we make a critical distinction about energy transfer via heat (Q) and via work (W). [By the way, there is an old argument about the signs in the 1st law. Schroeder takes the modern (symmetric) approach wherein both Q and W refer to energy transfers *to* the system]. A simple kinetic theory analysis provides a link between the total energy U and temperature of a classical ideal gas. Similarly, the classical mechanics definition of work as $\vec{F} \cdot d\vec{r}$ allows us to compute the work associated with compressing or expanding a gas. We usually associate heat flow with a change in temperature and thus we define the heat capacity, for conditions of constant X, as $C_X = Q/\Delta T$. Our results for the ideal gas allow us to compute C_P and C_V for this system. When a system undergoes a phase transformation (*e.g.*, liquid→solid or gas→liquid) we have a heat flow without a temperature change. In this case we define a latent heat (at constant pressure) as the ratio of the heat flow to the mass of material that changes phase.

Problem Assignment: (9 problems total)

- **1.12** (Intermolecular distance in an ideal gas ... also estimate distance between molecules in liquid water which has density 1.0 g/cm^3 ... give results in Å)
- ***1.16** (Barometric equation and the exponential atmosphere ... also determine the pressure at Hiram, OH: elevation = 382 m) **[Richard]**
- **1.17a,b** (Real gas virial expansion)
- **1.22a-d** (Effusion of a gas through a small hole)
- **1.28** (Time to boil water in a microwave ... assume a cup = 250 ml)
- **1.31** (Gas expansion with P/V=constant)
- ***1.36** (Adiabatic compression of air) **[Andrew]**
- **1.41** (Measuring heat capacity using a Styrofoam cup calorimeter ... reverse words "lost" and "gained" in parts a and b)
- ***1.47** (Cooling hot tea with ice) **[Christian]**

*denotes a problem to be presented in class