CHAPTER 17:

The mass of atoms is almost entirely due to the number of protons (Z) and neutrons (N) in the nucleus. The total number of nucleons is A = N + Z and physicists write atomic information in the form ^{A}Chemical symbol. For example, ^{12}C or ^{208}Pb. The chemical symbol tells you Z. It is 6 for carbon and 82 for lead.

To a good approximation, the mass of an atom is just A times the mass of a proton. (Since protons and neutrons have about the same mass). The proton mass is about 1.67 $\times 10^{-27}$ kg.

A ***kilomole*** is A kg of any substance. For example a kilomole of ^{208}Pb is 208 kg.

A kilomole of any substance clearly has the same number of atoms: $N_A = 6 \times 10^{26}$. This is called Avogadro's number.

THE IDEAL GAS LAW:

$$pV = NkT.$$

This law is valid if the potential energy of the constituents of the gas relative to one another can be neglected, so that the internal energy of the gas is all kinetic. k is a fundamental constant of nature with the value

$$k = 1.38 \times 10^{-23}\ \mathrm{J/K}.$$

Chemists like to define $R = kN_A$ and $n = N/N_A$ to get

$$pV = nRT.$$

Here $R = 8314$ J/(K-kilomole).

If you apply classical physics to an ideal gas you can show $pV = (2/3)NK_{\rm avg}$ so by comparison to the empirical law, you see that

$$K_{\rm avg} = (3/2)kT.$$

The absolute temperature in K tells us the average kinetic energy of a constituent of the system.

If we define $v_{\rm rms} = \sqrt{(v^2)_{\rm avg}}$, it is easy to see that

$$v_{\rm rms} = \sqrt{\frac{3kT}{m_a}}.$$

Phase Changes:

When a system melts, all the input heat goes into increasing the potential energy from that characteristic of a solid, to that characteristic of a liquid, while the temperature and internal kinetic energy remain fixed. The heat per unit mass to melt is called L_f. The similar heat to convert from liquid to vapor is called L_v.

That is $Q_m = mL_f$, and $Q_v = mL_v$.

Linear Expansion:

When a solid is heated, a good fraction of the input energy goes into increasing the internal potential energy, and the rest goes into increasing the internal kinetic energy.

We can write $\Delta L = \alpha L_0 \Delta T$ and $\Delta V = \beta V_0 \Delta T$.

It is also easy to see that $\Delta\rho = -\rho_0 \beta \Delta T$.

MAXWELL-BOLTZMANN DISTRIBUTION:

What is the probability that an atom or molecule of mass m in an ideal gas has a speed between v and $v + dv$?

$$f(v) = \sqrt{\left(\frac{m}{2\pi kT}\right)^3} 4\pi v^2 e^{-\frac{mv^2}{2kT}}$$

What is the most probable speed?

$$v_p = \sqrt{\frac{2kT}{m}}$$

What is the average speed?

$$\langle v \rangle = \int_0^\infty v\, f(v)\, dv = \sqrt{\frac{8kT}{\pi m}} = \frac{2}{\sqrt{\pi}} v_p$$

What is the "root mean square speed," $\sqrt{[v^2]_{\text{avg}}}$, the square root of the average of the speed squared?

$$\sqrt{\langle v^2 \rangle} = \left(\int_0^\infty v^2\, f(v)\, dv\right)^{1/2} = \sqrt{\frac{3kT}{m}}$$