Sample Homework Problem

(1.19) *Suppose you have a gas containing hydrogen molecules and oxygen molecules in thermal equilibrium. Which molecules are moving faster, on average? By what factor?*

Bad (albeit correct) answer:

$$\overline{v}^2 = 3\frac{k}{m}T$$

$$Hydrogen, 4.$$

Good Answer:

Thermal equilibrium means that a single temperature characterizes all the molecules. The temperature is related to the RMS speed $\overline{v}$ of the molecules via

$$\frac{3}{2}kT = \frac{1}{2}m\overline{v}^2.$$

Evidently,

$$\overline{v}^2 = 3\frac{k}{m}T, \quad \overline{v} = \sqrt{\frac{3kT}{m}}.$$

so that the molecule with the least mass will have the highest (RMS) speed. Because O_2 has 32 nucleons and H_2 has 2 nucleons, oxygen molecules have 16 times the mass of hydrogen molecules:

$$\frac{m_{hydrogen}}{m_{oxygen}} = 16.$$

Therefore, hydrogen molecules move faster by a factor of

$$\frac{\overline{v}_{hydrogen}}{\overline{v}_{oxygen}} = \sqrt{\frac{m_{oxygen}}{m_{hydrogen}}} = 4.$$