Physical Chemistry of Materials 2

Due date: November 7, 2012

Homework #4

1. How many collisions per second occur on a container wall with an area of 1 cm^2 for a collection of Ar particles at 1 atm and 298 K?

2. A 1 L container filled with Ar at 298 K and an initial pressure of 1.00×10^{-2} atm is allowed to effuse through an aperture having an area of 0.01 μm^2. What is the pressure inside the container after 1 hour effusion?

3. The speed of sound is given by $v_{sound} = \sqrt{\gamma kT/m} = \sqrt{\gamma RT/M}$, where $\gamma = C_p/C_V$.
   (a) What is the speed of sound in Ne, Kr, and Ar at 1000 K?
   (b) At what temperature will the speed of sound in Kr equal the speed of sound in Ar at 1000K?

4. The total collision frequency is defined as the total number of collisions that occurs for all gas particles. The total collision frequency for a collection of two types of gas molecules, Z_{12}, is given by

$$Z_{12} = \left(\frac{p_1 N_A}{RT}\right)\left(\frac{p_2 N_A}{RT}\right)\sigma\left(\frac{8kT}{\pi\mu}\right)^{1/2}.$$

   The unit of Z_{12} is the total number of collisions per unit volume.
   What is the total frequency (Z_{ArKr}) at 298 *K* for a collection of Ar and Kr confined to a 1 cm^3 with partial pressures of 360 Torr for Ar and 2400 Torr for Kr?

5. Starting with the Maxwell speed distribution, demonstrate that the probability distribution for translational energy for $\varepsilon_{Tr} \gg kT$ is given by

$$f(\varepsilon_t)d\varepsilon_t = 2\pi\left(\frac{1}{\pi kT}\right)^{3/2} e^{-\varepsilon_t/kT}\sqrt{\varepsilon_t}\,d\varepsilon_t$$

6. Hemoglobin is a protein responsible for oxygen transport. The diffusion coefficient of human hemoglobin in water at 298 K ($\eta = 0.891\ cP$) is $6.9 \times 10^{-11}\ m^2 s^{-1}$. Assuming this protein can be approximated as spherical, what is the radius of hemoglobin?

7. A solution consisting of 1 g of sucrose in 10 mL of water is poured into a 1 L graduated cylinder with a radius of 2.5 cm. Then the cylinder is filled with pure water.
   (a) The diffusion of sucrose can be considered diffusion in one dimension. Derive an expression for the average distance of diffusion $\langle x \rangle$.
   (b) Determine $\langle x \rangle$ and $\overline{x}$ (rms distance) for sucrose for time period of 1 s, 1 min, and 1 h.

7. For a one-dimensional random walk, determine the probability that the particle will have moved six steps in either the $+x$ or $-x$ direction after 10, 20, and 100 steps.

8. Atkins problems, 20.2, 20.7, 20.15, 20.25.