CH353 – Physical Chemistry I
Spring 2015, Unique 51170

Homework, Week 12

1. Interstellar space has an average temperature of 10 K and average density of hydrogen gas of about 1 molecule m^{-3}. Determine the mean free path of hydrogen gas in interstellar space. You may assume that $H_2(g)$ is a sphere of diameter 1.15 Å (1 Å = 10^{-10} m and is a convenient unit of length in chemistry).

2. The following table describes the pressure and temperature of Earth's upper atmosphere as a function of altitude:

altitude (km)	*P* (bar)	*T* (K)
20.0	0.056	220
40.0	3.2×10^{-3}	260
60.0	2.8×10^{-4}	260
80.0	1.3×10^{-5}	180

Assuming that the atmosphere is composed of 80% $N_2(g)$ and 20% $O_2(g)$, determine the frequency of collisions between nitrogen and oxygen gas at each of these altitudes. You may assume the molecules are spheres with a diameter of 3.8 Å for $N_2(g)$ and 3.6 Å for $O_2(g)$.

3. A sample of argon gas is held in a 1 L vessel and maintained at 25˚C. At what pressure does the mean free path of the gas become comparable to the size of the container? You may assume the diameter of the argon atom is 1.9 Å.

4. The interior of the Sun is thought to consist of 36% H and 64% He by mass, at a density of 158 g cm^{-3}. Both atoms are completely ionized. The approximate dimensions of the nuclei can be calculated from the formula $r_{nucleus} = 1.4 \times 10^{-15} A^{1/3}$ m, were A is the mass number. (The size of the free electron is 10^{-18} m, and is negligible compared to the size of the nuclei.) The pressure in the stellar interior is thought to be 2.5×10^{11} atm.

a) Determine the excluded volume of 1.0 cm^3 of the stellar interior based on this model. The excluded volume is the volume of a sphere of radius equal to the sum of the radii of the collision pair.

b) Determine the temperature in the stellar interior based on this model. Would the van der Waals equation be more appropriate for this system?

5. The rate law for a certain reaction is reported to be:

$$\frac{d[C]}{dt} = k[A][B][C]$$

What are the units of k?