

**CH353 – Physical Chemistry I**  
Spring 2013, Unique 52575

**Homework, Week 12**

1. Interstellar space has an average temperature of 10 K and average density of hydrogen gas of about  $1 \text{ molecule m}^{-3}$ . Determine the mean free path of hydrogen gas in interstellar space. You may assume that  $\text{H}_2(\text{g})$  is a sphere of diameter  $1.15 \text{ \AA}$  ( $1 \text{ \AA} = 10^{-10} \text{ m}$  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	$3.2 \times 10^{-3}$	260
60.0	$2.8 \times 10^{-4}$	260
80.0	$1.3 \times 10^{-5}$	180

Assuming that the atmosphere is composed of 80%  $\text{N}_2(\text{g})$  and 20%  $\text{O}_2(\text{g})$ , 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  $3.8 \text{ \AA}$  for  $\text{N}_2(\text{g})$  and  $3.6 \text{ \AA}$  for  $\text{O}_2(\text{g})$ .

3. A sample of argon gas is held in a 1 L vessel and maintained at  $25^\circ\text{C}$ . 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  $1.9 \text{ \AA}$ .
4. The interior of the Sun is thought to consist of 36% H and 64% He by mass, at a density of  $158 \text{ g cm}^{-3}$ . Both atoms are completely ionized. The approximate dimensions of the nuclei can be calculated from the formula  $r_{\text{nucleus}} = 1.4 \times 10^{-15} A^{1/3} \text{ m}$ , where  $A$  is the mass number. (The size of the free electron is  $10^{-18} \text{ m}$ , and is negligible compared to the size of the nuclei.) The pressure in the stellar interior is thought to be  $2.5 \times 10^{11} \text{ atm}$ .
  - a) Determine the excluded volume of  $1.0 \text{ cm}^3$  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  $k$ ?