

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 $1 \text{ molecule m}^{-3}$. 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 \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	3.2×10^{-3}	260
60.0	2.8×10^{-4}	260
80.0	1.3×10^{-5}	180

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

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 \AA .
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 $r_{\text{nucleus}} = 1.4 \times 10^{-15} A^{1/3} \text{ m}$, where A is the mass number. (The size of the free electron is 10^{-18} 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 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 ?