

1. The distribution of particle speeds of a certain hypothetical gas is

$$N(v)dv = A v e^{-v/v_0} dv,$$

where A and v_0 are constants. (i) Determine A so that $f(v) \equiv N(v)/N$ is a true probability density function, i.e., $\int_0^\infty f(v)dv = 1$. (ii) Find \bar{v} and v_{rms} in terms of v_0 . (iii) Differentiate $f(v)$ with respect to v and set the result equal to zero to find the most probable speed v_m . (iv) The standard deviation of the speeds from the mean is defined as

$$\sigma = \left[\overline{(v - \bar{v})^2} \right]^{1/2},$$

where the bar denotes the mean value. Show that

$$\sigma = \left[\bar{v}^2 - (\bar{v})^2 \right]^{1/2}$$

in general. What is σ for this problem?

2. At standard temperature and pressure the mean speed of hydrogen molecules is $1.70 \times 10^3 \text{ m s}^{-1}$. What is the particle flux?

3. A vessel is divided into two parts of equal volume by means of a plane partition, in the middle of which is a very small hole. Initially, both parts of the vessel contain ideal gas at a temperature of 300 K and low pressure P . The temperature of one-half of the vessel is then raised to 600 K while the temperature of the other half remains at 300 K. Determine the pressure difference in terms of P between the two parts of the vessel when steady conditions are achieved.

4. Consider a gas of one kilomole of He atoms at $T = 300 \text{ K}$ and $P = 1 \text{ atm}$. The mean energy is $\bar{\epsilon} = \frac{3}{2}kT \approx 6 \times 10^{-21} \text{ J}$. Estimate the number of atoms of this gas whose energy ϵ lies in an interval of width 10^{-22} J around this mean value. [Hint: use the Maxwell distribution. It is a bit simpler to write it in terms of ϵ for this problem.]

5. The local poison control center wants to know more about carbonmonoxide and how it spreads through a room. You are asked (i) to calculate the mean free path of a carbon monoxide molecule and (ii) to estimate the mean time between collisions. The molar mass of carbon monoxide is 28 g/mol. Assume that the CO molecule is traveling in air at 300 K and 1 atm, and that the diameter of both CO molecules and air molecules are $3.75 \times 10^{-10} \text{ m}$.

6. The escape speed at the surface of a planet of radius R is $v_e = \sqrt{2\tilde{g}R}$, where \tilde{g} is the acceleration due to gravity at the surface of the planet. If the rms speed of a gas is greater than about 15% to 20% of the escape speed of a planet, virtually all the molecules of that gas will escape the atmosphere of the planet. (i) At what temperature is v_{rms} for O_2 equal to 15% of the escape speed of the Earth? (ii) At what temperature is v_{rms} for H_2 equal to 15% of the escape speed for Earth? (iii) Temperatures in the exosphere (upper atmosphere) reach 1000 K. How does this help account for the low abundance of hydrogen in Earth's atmosphere? (iv) Compute the temperatures for which the rms speeds of O_2 and H_2 are equal to 15% of the escape speed at the

surface of the moon, where \tilde{g} is about one-sixth of its value on Earth and the radius of the moon is $R = 1738$ km. How this account for the absence of an atmosphere on the moon? (v) The escape speed for gas molecules in the atmosphere of Jupiter is 60 km/s and the surface temperature of Jupiter is typically -150° . Calculate the rms speeds for H_2 , O_2 , and CO_2 at this temperature. Are H_2 , O_2 , and CO_2 likely to be found in the atmosphere of Jupiter? (vi) The escape speed for gas molecules in the atmosphere of Mars is 5.0 km/s and the surface temperature of Mars is typically 0° . Calculate the rms speeds for H_2 , O_2 , and CO_2 at this temperature. Are H_2 , O_2 , and CO_2 likely to be found in the atmosphere of Mars?