Properties Of Gases Problems

1. An ideal gas at 10 °C and a pressure of 100 kPa occupies a volume of 2.5 m^3.
   a. How many moles of gas are present?
   b. If the pressure is now raised to 300 kPa and the temperature raised to 30 °C, what volume will the gas now occupy?
   c. The best vacuum that can be attained in the laboratory corresponds to a pressure of about 10^{-18} atm, or 1.01×10^{-13} Pa. How many molecules are there per cubic centimetre in such a vacuum at 298 K?
2. The average velocity of the molecules in a gas must be zero if the gas as a whole is not in translational motion. Explain how it can be that the average speed is not zero.
3. The equation of state for a non-ideal gas is often written as a virial expansion, the first two terms of which are:

$$pV_m = RT\,(1 + B'p)$$

   The second virial coefficient, B', takes the form B' = a – b e c/T
   a. What is the physical origin of the second virial coefficient (i.e. why do real gases deviate from ideal behaviour)?
   b. The Boyle temperature is the temperature at which B' = 0. What is the physical significance of this temperature?
   c. For N_2, the coefficients in the above expression for B' take the values a = 185.4, b = 141.8, c = 88.7 K. Calculate the Boyle temperature for N_2.
4. A gas can transmit only those sound waves whose wavelength is long compared with the mean free path.
   a. What is the reason for this? Describe a situation where this limitation might be important.
   b. At what frequency would the wavelength of sound in air be equal to the mean free path in oxygen at 1.0 atm pressure and 0 °C. (Take the diameter of the oxygen molecule to be 3.0×10^{-10} m).
5. The sun may be treated as a huge ball of hot ideal gas. The corona (the sun's atmosphere) has a temperature and pressure of 2.0×10^6 K and 0.030 Pa, respectively. Calculate the rms speed of free electrons (m_e = 9.1 × 10-31 kg) in the corona.

6.
   a. Plot the Maxwell-Boltzmann distribution of molecular speeds for N_2 molecules at a temperature of 500 K.
   b. What is the most probable speed of the N_2 molecules?
   c. Write down an expression, in the form of an integral, that describes the probability of finding a particle with a speed lying between the two limits v_1 and v_2.
   d. The fraction of particles with velocities between zero and the rms speed is not equal to the fraction of particles with velocities between zero and the mean speed. Why are these fractions not equal?
7. An effusion cell has a circular orifice 1 mm in diameter. If the molar mass of the solid in the cell is 260 g mol^{-1} and its vapour pressure is 0.835 Pa at 400 K, by how much will the mass of the solid decrease over a period of two hours?
8. An electric light bulb contains argon at 50 Torr and has a tungsten filament of radius 0.10 mm and length 5.0 cm. When operating, the gas close to the filament surface has a temperature of around 1000 °C. How many collisions are made with the filament per second?

Answers To Numerical Problems

1. a) 106.2 mol

1. b) 0.89 m^3

1. c) 24.5 cm^{-3}

3. c) 330.8 K

4. b) 3.55 GHz

5. b) 5.4×10^6 ms^{-1}

6. 544.8 ms^{-1}

7. 16.7 mg

8. 2.45×10^{21} s^{-1}