53. (II) Show that the rms speed of molecules in a gas is given by $v_{\text{rms}} = \sqrt{3P/\rho}$, where P is the pressure in the gas, and ρ is the gas density.

54. (II) Show that for a mixture of two gases at the same temperature, the ratio of their rms speeds is equal to the inverse ratio of the square roots of their molecular masses.

55. (II) What is the rms speed of nitrogen molecules contained in an 8.5-m^3 volume at 2.1 atm if the total amount of nitrogen is 1300 mol?

56. (II) Calculate (*a*) the rms speed of an oxygen molecule at 0°C and (*b*) determine how many times per second it would move back and forth across a 7.0-m-long room on the average, assuming it made very few collisions with other molecules.

57. (II) What is the average distance between nitrogen molecules at STP?

58. (II) (*a*) Estimate the rms speed of an amino acid whose molecular mass is 89 u in a living cell at 37°C. (*b*) What would be the rms speed of a protein of molecular mass 50,000 u at 37°C?

59. (II) Show that the pressure P of a gas can be written $P = \frac{1}{3}\rho v^2$, where ρ is the density of the gas and v is the rms speed of the molecules.

60. (III) The two isotopes of uranium, ^{235}U and ^{238}U (the superscripts refer to their atomic mass), can be separated by a gas-diffusion process by combining them with fluorine to make the gaseous compound UF_6. Calculate the ratio of the rms speeds of these molecules for the two isotopes, at constant T.

* 13–12 Real Gases; Phase Changes

*61. (I) (*a*) At atmospheric pressure, in what phases can CO_2 exist? (*b*) For what range of pressures and temperatures can CO_2 be a liquid? Refer to Fig. 13–21.

*62. (I) Water is in which phase when the pressure is 0.01 atm and the temperature is (*a*) 90°C, (*b*) −20°C?

* 13–13 Vapor Pressure; Humidity

*63. (I) What is the dew point (approximately) if the humidity is 50% on a day when the temperature is 25°C?

*64. (I) What is the air pressure at a place where water boils at 90°C?

*65. (I) If the air pressure at a particular place in the mountains is 0.72 atm, estimate the temperature at which water boils.

*66. (I) What is the temperature on a day when the partial pressure of water is 530 Pa and the relative humidity is 40%?

*67. (I) What is the partial pressure of water on a day when the temperature is 25°C and the relative humidity is 35%?

*68. (I) What is the approximate pressure inside a pressure cooker if the water is boiling at a temperature of 120°C? Assume no air escaped during the heating process, which started at 20°C.

*69. (II) If the humidity in a room of volume 680 m^3 at 25°C is 80%, what mass of water can still evaporate from an open pan?

*70. (III) Air that is at its dew point of 5°C is drawn into a building where it is heated to 25°C. What will be the relative humidity at this temperature? Assume constant pressure of 1.0 atm. Take into account the expansion of the air.

* 13–14 Diffusion

*71. (II) Estimate the time needed for a glycine molecule (see Table 13–4) to diffuse a distance of 15 μm in water at 20°C if its concentration varies over that distance from 1.00 mol/m^3 to 0.40 mol/m^3. Compare this "speed" to its rms (thermal) speed. The molecular mass of glycine is about 75 u.

*72. (II) Oxygen diffuses from the surface of insects to the interior through tiny tubes called tracheae. An average trachea is about 2 mm long and has cross-sectional area of 2×10^{-9} m^2. Assuming the concentration of oxygen inside is half what it is outside in the atmosphere, (*a*) show that the concentration of oxygen in the air (assume 21% is oxygen) at 20°C is about 8.7 mol/m^3, then (*b*) calculate the diffusion rate J, and (*c*) estimate the average time for a molecule to diffuse in. Assume the diffusion constant is 1×10^{-5} m^2/s.

General Problems

73. A precise steel tape measure has been calibrated at 20°C. At 34°C, (*a*) will it read high or low, and (*b*) what will be the percentage error?

74. A Pyrex measuring cup was calibrated at normal room temperature. How much error will be made in a recipe calling for 300 mL of cool water, if the water and the cup are hot, at 80°C, instead of at 20°C? Neglect the glass expansion.

75. The gauge pressure in a helium gas cylinder is initially 28 atm. After many balloons have been blown up, the gauge pressure has decreased to 5 atm. What fraction of the original gas remains in the cylinder?

76. Estimate the number of air molecules in a room of length 6.5 m, width 3.1 m, and height 2.5 m. Assume the temperature is 22°C. How many moles does that correspond to?

77. In outer space the density of matter is about one atom per cm^3, mainly hydrogen atoms, and the temperature is about 2.7 K. Calculate the rms speed of these hydrogen atoms, and the pressure (in atmospheres).

78. The lowest pressure attainable using the best available vacuum techniques is about 10^{-12} N/m^2. At such a pressure, how many molecules are there per cm^3 at 0°C?

79. If a scuba diver fills his lungs to full capacity of 5.5 L when 10 m below the surface, to what volume would his lungs expand if he quickly rose to the surface? Is this advisable?

80. A space vehicle returning from the Moon enters Earth's atmosphere at a speed of about 40,000 km/h. Molecules (assume nitrogen) striking the nose of the vehicle with this speed correspond to what temperature? (Because of this high temperature, the nose of a space vehicle must be made of special materials; indeed, part of it does vaporize, and this is seen as a bright blaze upon reentry.)

81. The temperature of an ideal gas is increased from 110°C to 360°C while the volume and the number of moles stay constant. By what factor does the pressure change? By what factor does v_{rms} change?