Assignment #2

Answer the following questions:

2-1. For a temperature increase of ΔT, a certain amount of an ideal gas requires 30 J when heated at constant volume and 50 J when heated at constant pressure. How much work is done by the gas in the second situation?

2-2. Does the temperature of an ideal gas increase, decrease, or stay the same during (a) an isothermal expansion, (b) an expansion at constant pressure, (c) an adiabatic expansion, and (d) an increase in pressure at constant volume?

2-3. (a) What is the volume occupied by 1.00 mol of an ideal gas at standard conditions, that is, at 1.00 atm (= 1.01 x 10^5 Pa) and 0°C (= 273 K)? (b) Show that the number of molecules per cubic centimeter (the Loschmidt number) at standard conditions is 2.69 X 10^{19}.

2-4. A quantity of ideal gas at 10.0°C and a pressure of 100 kPa occupies a volume of 2.50 m^3. (a) How many moles of the gas are present? (b) If the pressure is now raised to 300 kPa and the temperature is raised to 30.0°C, how much volume will the gas occupy? Assume no leaks.
Answer: a. 106; b. 0.892 m^3

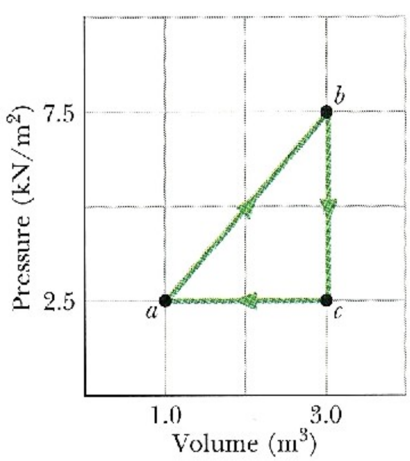
2-5. (a) What is the number of molecules per cubic meter in air at 20°C and at a pressure of 1.0 atm (= 1.01 X 10^5 Pa)? (b) What is the mass of this 1 m^3 of air? Assume that 75% of the molecules are nitrogen (N_2) and 25% oxygen (0_2),
Answer: 2.5x10^{25}; b. 1.2 kg

2-6. Pressure P, volume V, and temperature T for a certain material are related by

$$P = (AT - BT^2) / V$$

where A and B are constants. Find an expression for the work done by the material if the temperature changes from T_l to T_2 while the pressure remains constant.

2-7. A sample of an ideal gas is taken through the cyclic process abca shown in figure; at point a, T = 200 K.
(a) How many moles of gas are in the sample?
What are
(b) the temperature of the gas at point b,
(c) the temperature of the gas at point c, and
(d) the net heat added to the gas during the cycle?



2-8. An air bubble of 20 cm^3 volume is at the bottom of a lake 40 m deep where the temperature is 4.0°C. The bubble rises to the surface, which is at a temperature of 20°C. Take the temperature of the bubble to be the same as that of the surrounding water and find its volume just before it reaches the surface.
Answer: 100 cm^3

2-9. (a) Compute the root-mean-square speed of a nitrogen molecule at 20.0°C. At what temperatures will the root-mean-square speed be (b) half that value and (c) twice that value?

2-10. The mass of the H_2 molecule is 3.3 X 10^{-24} g. If 10^{23} H_2 molecules per second strike 2.0 cm^2 of wall at an angle of 55° with the normal when moving with a speed of 1.0 X 10^5 cm/s, what pressure do they exert on the wall?
Answer: 1.9 kPa

2-11. Water standing in the open at 32.0°C evaporates because of the escape of some of the surface molecules. The heat of vaporization (539 cal/g) is approximately equal to εn, where ε is the average energy of the escaping molecules and n is the number of molecules per gram. (a) Find ε. (b) What is the ratio of ε to the average kinetic energy of H_20 molecules, assuming the latter is related to temperature in the same way as it is for gases?
Answer: a. 6.75x10^{-20} J; b. 10.7

2-12. The mean free path of nitrogen molecules at 0.0°C and 1.0 atm is 0.80 X 10-5 cm. At this temperature and pressure there are 2.7 X 10^{19} molecules/cm^3. What is the molecular diameter?

2-13. At 2500 km above Earth's surface, the density of the atmosphere is about I molecule/cm^3. (a) What mean free path is predicted by the equation

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 \, N/V}$$

and (b) what is its significance under these conditions? Assume a molecular diameter of 2.0 X 10^{-8} cm.

2-14. (a) What is the molar volume (volume per mole) of an ideal gas at standard conditions (0.00°C, 1.00 atm)? (b) Calculate the ratio of the root-mean-square speed of helium atoms to that of neon atoms under these conditions. (c) What is the mean free path of helium atoms under these conditions? Assume the atomic diameter *d* to be 1.00 X 10^{-8} cm. (d) What is the mean free path of neon atoms under these conditions? Assume the same atomic diameter as for helium. (e) Comment on the results of (c) and (d) in view of the fact that the helium atoms are traveling faster than the neon atoms.
Answer: a. 22.5 L; b. 2.25; c. 8.4x10^{-5} cm; d. same as c

2-15. Suppose 12.0 g of oxygen (0_2) is heated at constant atmospheric pressure from 25.0°C to 125°C. (a) How many moles of oxygen are present? (b) How much heat is transferred to the oxygen? (The molecules rotate but do not oscillate.) (c) What fraction of the heat is used to raise the internal energy of the oxygen?
Hint: v_{rms} for oxygen is 483 m/s and molar mass 32 g/mol
Answer: a. 0.375 mol; b. 1090 J; c. 0.714

2-16. Show that a system that expands into a vacuum performs no work.

2-17. Consider an ideal gas enclosed in a cylinder equipped with a movable piston.

(a) Suggest a method to stop heat flow in or out of the system. What is such a system called?

(b) If the internal pressure P is equal to the external pressure pI, what would be the condition of the system?

(c) Assume that the pressure P' on the piston is greater than the internal pressure P and that the piston moves to the left without heat flowing in or out of the system. Explain what happens to the motion of the gas molecules inside the system, the energies of these molecules and their average energies. Which observable variables of the system can be used to detect the overall change in average energy of the molecules?

2-18. Does heat depend on path? Show that, when heat capacity of a body is known as a function of temperature in the form of an empirical equation, the quantity of heat is given by:

$$Q = \int_{T_1}^{T_2} (a + bT + cT^2 + ...)dT$$

2-19. Using the concepts of the elementary kinetic theory of gases, derive the equations for the root mean square velocity of the molecules of an ideal gas in terms of pressure and density.