Chemistry 230
Problem Set # 2 -- 9/3/99

Recommended Problems: Levine 1.1-1.11, 1.29-1.37, 1.51-1.60. [These are mainly exercises that review your math and general chemistry background.]

1. 20.0 mg of a certain gaseous hydrocarbon exerts a pressure of 24.7 torr in a 500-mL vessel at 25˚C. Determine the molar mass and molecular weight of the substance and identify it.
2. Calcium carbide reacts with water to produce acetylene and calcium hydroxide. If the acetylene is collected over water at a total pressure of 0.9950 atm and a temperature of 40.0˚C, what is the mass of acetylene per liter of "wet" acetylene collected in this way, assuming ideal gas behavior. (The vapor pressure of water at this temperature is 0.0728 atm.)
3. 1.600 mol of ammonia is placed in a 1.600×10^3-cm^3 vessel at 25˚C, and the vessel is then heated to 500.0 K, where the ammonia is partially decomposed to N_2 and H_2. If the total pressure is 4.85 MPa, how many moles of each component are present?
4. Two bulbs of equal volume are connected by a tube of negligible volume. One bulb is placed in a constant-temperature bath at 411 K and the other in a bath at 299 K. The system is then evacuated and 1.000 mol of an ideal gas is injected. What amount (in mol) of the gas will be contained in each bulb?

   Suppose the experiment is repeated with 1.000 g of an ideal gas. What mass of gas will be contained in each bulb?
5. A hypothetical gas obeys the equation of state, $PV = nRT(1 + aP)$, where a is a constant. For this gas: (a) show that $\alpha = 1/T$ and $\kappa = [P(1 + aP)]^{-1}$; (b) verify that $(\partial P/\partial T)_V = \alpha/\kappa$.
6. Use the following densities of water as a function of T and P to estimate α, κ, and $(\partial P/\partial T)_{V_m}$ for water at 25˚C and 1 atm: 0.997044 g/cm^3 at 25.00˚C and 1.00 atm; 0.996783 g/cm^3 at 26.00˚C and 1.00 atm; 0.997092 g/cm^3 at 25.00˚C and 2.00 atm.
7. For H_2O at 17˚C and 1 atm, $\alpha = 1.7 \times 10^{-4}$ K^{-1} and $\kappa = 4.7 \times 10^{-5}$ atm^{-1}. A closed, rigid container is completely filled with liquid water at 14˚C and 1 atm and then heated to 20˚C. Estimate the pressure in the container. (Neglect the P and T dependence of α and κ.)
8. The measured density of a certain nonmetallic oxide at 0.0˚C as a function of pressure is:

P (atm):	0.25000	0.50000	1.00000
ρ (g/L):	0.71878	1.44614	2.92655

   Plot ρ/P vs P and extrapolate to $P = 0$ to find an accurate molecular weight. Identify the gas.
9. (This problem is intended to give insight into the measurement of temperature with a constant-volume ideal gas thermometer.)

   To a good approximation CO_2 gas obeys the van der Waals equation of state (Eq. 1.39), with $a = 359 \times 10^4$ cm^6 atm mol^{-2} and $b = 42.7$ cm^3/mol. Suppose CO_2 is employed as the working gas in a constant-V ideal gas thermometer, which is used to measure the boiling point of water at $P = 1$ atm.

   (a) Using the van der Waals equation, calculate the CO_2 pressure at the reference point (the triple point of water) and the boiling point (100.0˚C), for each of the following concentrations in the device: $(n/V) = 0.1000$, 0.03000, and 0.01000 mol/L.

   (b) Use the results obtained in (a) and the working relation for the constant-V ideal gas thermometer to calculate the apparent (*i.e.*, ideal gas) temperature T_{app} of the boiling water, for each of the three CO_2 concentrations.

   (c) Plot T_{app} vs P_{ref} and extrapolate to $P_{ref} = 0$ to obtain the true temperature. Does the result agree with the value $T = 100$˚C assumed in (a)?

   (d) Without repeating the entire set of calculations, show on the same plot the approximate behavior you would expect for He as a working gas. (For He, $a = 3.41 \times 10^4$ cm^6 atm mol^{-2} and $b = 23.7$ cm^3/mol.)