Chemistry 342

Problem Set 1

1. Five grams of ethane are confined in a bulb of one liter capacity. The bulb is so weak that it will burst if the pressure exceeds 10 atm. At what temperature will the pressure of the gas reach the bursting value? Answer in °Celsius.

2. The coefficient of thermal expansion α is defined by $\alpha = (1/V)(\partial V/\partial T)_p$. Using the equation of state, compute the value of α for an ideal gas. The coefficient of compressibility β is defined by $\beta = -(1/V)(\partial V/\partial p)_T$. Compute the value of β for an ideal gas. For an ideal gas, express the derivative $(\partial p/\partial T)_V$ in terms of α and β.

3. A mixture of nitrogen and water vapor is admitted to a flask which contains a solid drying agent. Immediately after admission, the pressure in the flask is 760 mm. After standing some hours, the pressure reaches a steady value of 745 mm. (a) Calculate the composition, in mole percent, of the original mixture. (b) If the experiment is done at 20°C and the drying agent increase in weight by 0.150 g what is the volume of the flask? (The volume occupied by the drying agent may be ignored.)

4. A mixture of oxygen and hydrogen is analyzed by passing it over hot copper oxide and through a drying tube. Hydrogen reduces the CuO to metallic Cu. Oxygen then reoxidizes the copper back to CuO. 100 cm^3 of the mixture measured at 25°C and 750 mm yields 84.5 cm^3 of dry oxygen measured at 25°C and 750 mm after passage over CuO and the drying agent. What is the original composition of the mixture? {Hint: First write balanced chemical equations for the reactions.}

5. A balloon having a capacity of 10,000 m^3 is filled with helium at 20°C and 1 atm pressure. If the balloon is loaded with 80% of the load that it can lift at ground level, at what height will the balloon come to rest? Assume that the volume of the balloon is constant, the atmosphere isothermal, 20°C; the molecular weight of air is 28.8 and the ground level pressure is 1 atm. The mass of the balloon is 1.3×10^6 g.

6. For a gas mixture in a gravity field, it can be shown that each of the gases obeys the distribution law independent of the others. For each gas, $p_i = p_{i0}\exp[-M_i gz/RT]$ where p_i is the partial pressure of the *i*th gas in the mixture at the height z, p_{i0} is the partial pressure of the gas at ground level, and M_i is the molecular weight of the gas. The approximate composition of the atmosphere at sea level is given in the table below:

Gas	Mole percent	p_i (atm) at 50 km	Mole percent at 50 km	p_i (atm) at 100 km	Mole percent at 100 km
Nitrogen	78.09				
Oxygen	20.93				
Argon	0.93				
Carbon Dioxide	0.03				
Neon	0.0018				
Helium	0.0005				
Krypton	0.0001				
Hydrogen	5×10^{-5}				
Xenon	8×10^{-6}				
Ozone	5×10^{-5}				
Total					

Ignoring the last four components, compute the partial pressures of the others, the total pressure, and the composition of the atmosphere in mole percent, at altitudes of 50 and 100 km (assuming t = 25°C). Check out the oxygen!

7. (a) Show that if we calculate the total number of molecules of a gas in the atmosphere using the barometric formula, we would get the same result if we assumed that the gas had the ground level pressure up to a height, $z = RT/Mg$, and had zero pressure above that level.

(b) Show that the total mass of the earth's atmosphere is given by Ap_0/g, where p_0 is the total ground-level pressure and A is the area of the earth's surface. Note that this result does not depend on the composition of the atmosphere. (Do this problem first by calculating the mass of each constituent, mole fraction = x_i, molecular weight = M_i, and summing. Then by examining the result, do it the easy way.)

(c) If the mean radius of the earth is 6.37×10^8 cm, $g = 980$ cm/sec^2, and $p_0 = 1$ atm, calculate the mass of the atmospheres in grams. (Watch out for units!!)

8. When Julius Caesar expired, (soon after saying "Et tu Brutus?") his last exhalation had a volume of about 500 cm^3. This expelled air was 1 mole % argon. Assume that the temperature was 300 K and the ground level pressure was 1 atm. Assume that the temperature and pressure are uniform over the earth's surface and still have the same values. If Caesar's argon molecules have all remained in the atmosphere and have been completely mixed throughout the atmosphere, how many inhalations, 500 cm^3 each, must we make on average to inhale one of Caesar's argon atoms? (Watch out for units!!)