ATMS/CHEM 458 Problem Set 1 **Due in class: Wed Oct 13 2010**

In this first problem set you will use a software of your choice (Excel, Matlab, etc…) to calculate pressure, temperature, densities, mixing ratios, and partial pressures as a function of altitude. I ask that you turn in two things: (1) a paper copy of the homework showing how you answered the various questions and (2) print out of the plots you generated. In addition, please e-mail me the actual Excel spreadsheet or Matlab code that you used.

1. Pressure versus Altitude:
Here you will calculate pressure as a function of altitude.

a. Calculate the scale height (in km) assuming a mean temperature of the atmosphere T_{mean} = 250 K. Make sure that you are using the correct units. All units should be in S.I. Constants: R=8.31J $mol^{-1}K^{-1}$; molecular mass of air M_{air}=29 10^{-3} kg mol^{-1}

b. Create an altitude vector in kilometers (from 0 to 100 km in 1 km increments). Calculate the pressure using the barometric law (e.g., $P = P_o*exp(-z/H)$) where P_o=1000 hPa is the average pressure at the surface and H is your scale height.

c. Generate two plots of pressure as a function of altitude: one using a linear scale and one using a log scale for the pressure. The latter plot should look similar to your textbook figure 2-2.

2. Mars versus Earth
The atmosphere on Mars is mainly CO_2 and its average temperature is 220K. The acceleration due to gravity on Mars is 3.7 m s^{-2} and the radius of Mars is 3400 km.

a. Calculate a scale height for Mars using a typical surface pressure of 6 mbar. Calculate pressure as a function of altitude on Mars using the same altitude vector as in question 1.b.

b. Plot atmospheric pressure versus altitude for both Mars and Earth on the same figure.

c. Which atmosphere exhibits the steeper drop in pressure versus altitude, and why?

d. Calculate the mass of the atmospheres on Mars and Earth. Which atmosphere is more massive, and why? How much more or less mass is contained below 15 km on Mars versus Earth? (For Earth, use a radius of 6400 km).

3. Hydroxyl Radical (OH)
OH is an important trace oxidant throughout the atmosphere

a. The 24-hour average number density of OH is remarkably constant versus altitude at $1x10^6$ molec/cm^3 (at least up to about 50 km). Using your pressure vector and other information from above, calculate the OH mixing ratio versus altitude in units of parts per trillion (ppt).

b. Plot the OH mixing ratio versus altitude and zoom in so that you are only viewing z = 0 to z = 50 km. Explain the functional behavior of the mixing ratio versus altitude and comment on this relative abundance, e.g. does it surprise you that it is responsible for the removal of CO and CH4 which have mixing ratios of 100 – 2000 parts per billion?

4. Vapor versus Liquid Water: atmospheric water exists in both gaseous and condensed forms with important consequences.

a. The saturation vapor pressure of water depends on temperature, which in turn depends on altitude. Generate a new altitude vector for the mid troposphere (from z=0 km to 5 km altitude in 0.25 km increments). Then, calculate temperature as a function of altitude using the dry adiabatic lapse rate (e.g. $T(z)=T(0)-\Gamma*z$, where z is the altitude in km). Assume $T(0) = 289$ K and $\Gamma=9.8$ K km^{-1}.

b. Let's now assume that the water vapor mixing ratio is constant with altitude (which is definitely not the case because clouds/precipitation scavenges it). Calculate the partial pressure of water P_{H2O} as a function of altitude if its mixing ratio is 1% (hint: in order to calculate total pressure, use the same approach as in question 1.b).

c. Now using the equation below, calculate the saturation vapor pressure of water, P_{sat}, as a function of altitude. The equation yields P_{sat} in units of hPa and requires T to be in Kelvin. Indicate the lowest altitude you expect liquid water cloud formation to be possible.

$$P_{sat}(T) = \exp(53.67957 - 6743.79/T - 4.845*\ln(T))$$

[Note that ln(T) is the natural logarithm of T]

d. Plot P_{sat} and P_{H2O} versus altitude. How would the actual partial pressure of water look like if you assume that you can't go above 100% relative humidity?