Chem/ATOC 5151

Homework #1

1. (a) If the Earth's atmosphere consisted of an incompressible fluid whose density was everywhere equal to that observed at sea level (about 1.25 kg m^{-3}), how deep would it have to be in order to account for the observed sea level pressure (1013 mbar)?

(b) If the density of air on Earth decreases exponentially with height from a value of 1.25 kg m^{-3} at sea level, calculate the scale height H that is consistent with the observed sea level pressure of 1013 mbar.

2. Titan's atmosphere has a surface pressure of about 1.5 times that of Earth, gravitational acceleration of 135 cm/sec^2 and a surface temperature of about 90K.

(a) Roughly how many molecules are there in a cm^3 of air at Titan's surface?
(b) What is the most probable velocity of hydrogen molecules at the surface of Titan?
(c) What is the scale height of Titan's atmosphere?
(d) Above what altitudes on Titan are ten percent and one percent of the atmospheric mass located?

3. Using the standard atmosphere given in your text on page 951, determine (a) the column mass and (b) the column number density for Earth's atmosphere at ground level, 20 km and 50 km.

4. (a) Over a region where the temperature changes linearly with height, and where gravity is constant, show that:

$$P/Po=(H/Ho)^{-(1/b)} \text{ and } N/No=(H/Ho)^{-[(1+b)/b]}$$

where b=dH/dz and Po, Ho, and No denote values of pressure, scale height, and number density, respectively, at the surface.

(b) On Venus assume that the temperature declines by 500 K uniformly over 60 km of altitude. Assuming that the atmosphere of Venus is made entirely of CO_2, P_0=92 bars, T_0=730 K and that g=8.8 m s^{-2} what is the scale height of the atmosphere at the surface?

(c) If the scale height is assumed to be independent of altitude, then what pressure would you expect to occur at 60 km?

(d) What is the pressure at 60 km if you take into account the changing temperature in the atmosphere of Venus?

5. Assume that the heat capacity for Venus is Cp=37.14 J/mole-K and that the acceleration due to gravity on Venus is $g= 8.8\ m/sec^2$.

(a) What is the dry adiabatic lapse rate for Venus?
(b) Assume an air parcel at 30 km is in an environment with $\Gamma e= -8$ K/km. Is the air stable or unstable?

6. Text, Chapter 2. Problems 1-8.

H. PROBLEMS

1. Measuring air pollution due to particles by mass can be quite misleading in terms of their ultimate impacts, for example on health. For example, the results of some laboratory studies show that ultrafine particles cause inflammatory responses while larger particles with the same chemical composition do not. Calculate how many particles with diameter 0.2 μm would need to be collected on a "hi-vol" sampler (which is essentially just a filter) to have the same mass as one particle of diameter 20 μm. Assume they have the same chemical composition and hence equal densities.

2. Derive the relationship between 1 ppt at 298 K and 1 atm pressure and the concentration of a species in $\mu g\ m^{-3}$ from first principles.

3. The most stringent 1-h AQS for CO shown in a review of such standards by Cochran *et al.* [*J. Air Waste Manage., 42,* 1567 (1992)] is 15,000 $\mu g\ m^{-3}$ (Canada) and the least stringent is 40,000 $\mu g\ m^{-3}$ (adopted by a number of countries, including the United States). What is this range of AQS in units of ppm?

4. Free radicals such as OH are present in such small concentrations that their concentrations are frequently given in units of molecules cm^{-3} rather than ppm, ppb, etc. A typical OH concentration in the lower troposphere is 5×10^5 radicals cm^{-3}. What is this concentration in terms of the mixing ratio unit ppt, assuming 298 K and 1 atm pressure?

5. You measure an air temperature of 260 K at a pressure of 600 mbar. What is the potential temperature, assuming a reference pressure of 1000 mbar?

6. An air parcel has a temperature of 7°F and a pressure of 450 Torr. What is its potential temperature (θ) if the reference pressure is 1 atm? Take c_p for air to be 29.1 J K^{-1} mol^{-1}.

7. Using the dry adiabatic lapse rate, by how much would you expect the temperature to change from the earth's surface to an altitude of 1000 feet, which, as seen in Fig. 2.19, sometimes corresponds to the bottom of the inversion layer in the Los Angeles area?

8. Estimate the mass of the atmosphere, given that the area of the surface of the earth is about 5.1×10^{14} m^2. Assume a uniform pressure of 1 atm at the earth's surface. Compare this to the mass of the earth itself, 6.0×10^{24} kg.

Pressures and Temperatures for Standard Atmosphere

Altitude (km)	P mbar	P Torr	T (K)
0	1.01325×10^3	760.0	288.15
5	540.5	405.4	255.68
10	265.0	198.8	223.25
15	121.1	90.8	216.65
20	52.29	39.2	216.65
25	25.49	19.1	221.55
30	11.97	8.978	226.51
35	5.746	4.310	236.51
40	2.871	2.153	250.35
50	0.79779	0.5983	270.65

[a] From "U.S. Standard Atmosphere, 1976," NOAA, 1976.

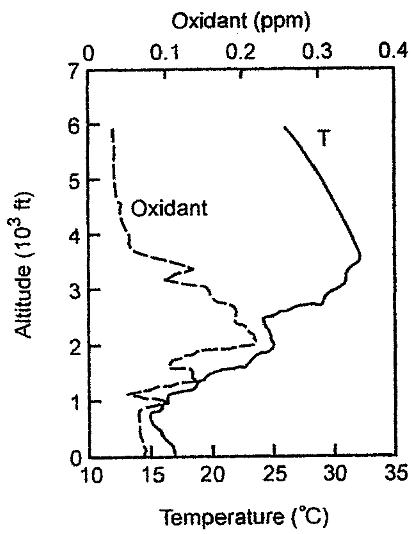

FIGURE 2.19 Temperature and oxidant profiles at 1:28 p.m. over Santa Monica, California, on June 20, 1970 (from Edinger, 1973).