Statistical and Thermal Physics: Homework 2

Due: 23 January 2016

1 Gould and Tobochnik, *Statistical and Thermal Physics*, 2.4, page 37.

2 Venus' atmosphere

The atmosphere of Venus consists of 96.5% carbon dioxide and 3.5% molecular nitrogen (N_2).

a) Determine the mass of one mole of Venus' "air."

b) The surface temperature of Venus is 740 K and the surface pressure 9.2×10^6 Pa. Determine the density of Venus' atmosphere.

3 Pressure and density for the atmosphere

The density of and pressure due to Earth's atmosphere vary with distance above sea level. The purpose of this exercise is to determine precisely how these depend on height above sea level. Throughout this exercise, you can assume that the air is an ideal gas and that there are no currents in the air. *This is a classic problem and is a starting point for understanding anything to do with a planetary atmosphere.*

a) Denote the height above sea level by z. Consider a thin rectangular slab of air whose top and bottom are parallel to Earth's surface. Denote the vertical thickness of the slab by dz. Use the fact that the slab is at rest to determine an expression for the pressure difference dP between the top and bottom of the slab. Use this to show that

$$\frac{dP}{dz} = -g\rho$$

where ρ is the density of the air in the slab. Hint, freebody this problem - $F_{airbelow} - mg - F_{airabove} = 0$. Remember the basic definition of a derivative, the definition for pressure, and that $\rho = \frac{m}{v}$. Also $m = \rho A dz$.

b) Assume that the air is an ideal gas, consisting of molecules of mass m. Show that

$$\frac{dP}{dz} = -\frac{gm}{kT}P$$

and solve this to get P as a function of z. Use the result to determine an expression for ρ as a function of z.

c) Air consists of a mixture of N_2 (78% by volume), O_2 (21% by volume) and argon (1% by volume). Determine the average mass of one molecule of air. This will be the value of m.

d) Determine the air pressure in Grand Junction and on top of the Grand Mesa (about 11000 ft above sea level, assuming that the air pressure at sea level is 1.01×10^5 Pa.

e) Determine the altitude at which the density of the atmosphere would be 0.10 of what it is at sea level.

4 van der Waals gas and temperature

A van der Waals gas with a fixed number of molecules is held at constant volume. The pressure of the gas is doubled. Which of the following is true, assuming that $a > 0$?

i) The temperature increases by exactly a factor of two.
ii) The temperature increases by more than a factor of two.
iii) The temperature increases by less than a factor of two.
iv) The temperature decreases.

Explain your answer.

5 van der Waals gas

In a real gas, molecules can exert attractive forces on each other as they approach each other. Consider two such gases, A and B. The number of molecules in A is the same as in B, the temperature pf A is the same as that of B and the volume of A is the same as that of B. Suppose that the molecules of gas A exert larger attractive forces on each other than the molecules of B.

a) Would you expect the pressure of A to be the same as that of B? If not how would it differ? Explain your answers.

b) What does the ideal gas law predict regarding the pressure of these gases? Could it be correct?

c) Could the van der Waals equation of state predict a difference in pressure? To simplify your answer suppose that the constant b is the same for both gases and focus on the constant a. Would a be the same for the gases? Explain your answers.