Homework 3

This homework is a bit tougher than the previous two homework assignments so leave yourself sufficient time to finish it.

1. Read WH sections 3.2, 3.3 and 3.4

2. Rotational energy levels of a diatomic molecule
a. Calculate the first 4 energy levels of each of the 3 rotational modes of N_2.
b. Use the Boltzmann distribution to show that one of the 3 modes will not be populated at typical Earth temperatures.

3. Assume air is made of 79% N_2, 20% O_2 and 1% Ar.
   a. Calculate C_v and C_p of dry air (no water in the air) in J/kg/K using the simple molar specific heats, C_v', for diatomic molecules (5/2 R*) and monatomic molecules (3/2 R*).
   b. Find the actual heat capacity of air and compare your result to it.

4. Assume water is present in the atmosphere at a mixing ratio of 1%. Assume all of the water condenses out and that resulting the latent heat energy is transferred to the heat capacity energy storage of the air.
   a. How much will the temperature of the air increase?
   (For simplicity, ignore the heating of the condensed water droplets.)
   b. What is the fractional change in the air density? State any assumptions you make in determining the fractional density change.

5. Calculate the dry adiabatic temperature lapse rate of the atmosphere of Titan in K/km. Assume the atmosphere is made of 97% N_2 and 3% methane.

6. Consider air at 250 mb with a temperature of 225K.
   a. What is its potential temperature?
   b. Suppose an airliner flies at this altitude and needs to pressurize the cabin while simultaneously circulating air in from the outside, will the airliner need an air conditioner? Why?
   c. Based on the previous two answers, provide an explanation as to why do airliners don't fully pressurize the cabins to sea level pressure.

SHOW ALL WORK