1. Consider a "rigid rotator." This is a system with a fixed moment of inertia, I, and angular momentum $L = \ell\hbar$ where $\ell = 0, 1, 2, 3, \ldots$. The energy of this system is

$$E = L^2/2I\ ,$$

From quantum mechanics, we know that L^2 takes on the values $\ell(\ell+1)\hbar^2$ and there are $2\ell + 1$ states with $L = \ell\hbar$.

(a) Evaluate the partition function, the thermal average energy, and the entropy for a rigid rotator when the temperature is large, $\tau \gg \hbar^2/2I$. Hint: you can approximate the sum by an integral.

(b) Evaluate the partition function, the thermal average energy, and the entropy for a rigid rotator when the temperature is small, $\tau \ll \hbar^2/2I$. Hint: in this case you might want to truncate the sum after just a couple of terms. Are the rotational modes "frozen out" at low temperatures?

(c) Look up whatever you need to know to estimate I for a nitrogen (N_2) molecule. Then estimate the temperature which divides low temperatures from high temperatures for the rotational modes of a nitrogen molecule.

2. K&K, chapter 6, problem 1.

3. K&K, chapter 6, problem 3. Note that the two occupancies are **not** the same. You might want to plot the occupancies versus $x = \exp[(\mu - \epsilon)/\tau]$ in order to see the difference.

4. K&K, chapter 6, problem 4. You really don't need to know relativity to work this problem. You just need to use $E = pc$ rather than $E = p^2/2m$ as the relation between energy and momentum.

5. K&K, chapter 6, problem 9.

6. K&K, chapter 6, problem 10.

7. K&K, chapter 6, problem 11. Also, food for thought (not to be handed in): Suppose the atmosphere is in a state of isentropic convective equilibrium in the morning. Now the sun heats the ground, which heats the air, which starts to rise. (There will be rising and falling patches due to uneven heating). So a blob of air rises. What effect does the water vapor and especially the cooling of water vapor through its condensation point have on this process?

8. K&K, chapter 6, problem 15. Note that you get high temperatures even before the fuel burns. This might have something to do with making pollutants like nitrous-oxide, etc.

You might find K&K, chapter 6, problem 8 amusing, but you don't need to hand it in!