Additional Problem IV for Physics 102

This problem is part of your required homework for chapter 20.

Before the particle accelerator known as the Large Hadron Collider (LHC) started running, a number of people voiced concerns that the collider might produce miniature black holes that could potentially destroy the Earth. A lawsuit was even filed (and later dismissed). Particle physicists considered this fear unreasonable, both because of known characteristics of black holes (for example, they quickly decay by a process called Hawking radiation) and because the same processes produced in the LHC have been going on for billions of years when high-energy cosmic rays enter the Earth’s atmosphere. In fact, the LHC has now been up and running for some time, with no ill effects.

So what does this have to do with thermodynamics? In a *Discover* magazine article from August 2008, (http://discovermagazine.com/2008/aug/24-the-extremely-long-odds-against-the-destruction-of-earth) Brown University physicist Greg Landsberg gave an analogy to explain why we shouldn’t worry about the possible creation of black holes in the LHC: “The probability is never equal to zero in quantum mechanics, but you don’t worry about it if the probability is very small. There is some probability that all the air molecules in your room will suddenly cross over and end up on one half of the room and you won’t be able to breathe.” In this problem, we will estimate just how small this probability is.

a) Estimate the number of moles of air in a familiar room of your choice. Be sure to explain your assumptions and reasoning.

b) Use your answer from part (a) to get an estimate for the number of molecules of air in the room.

c) Suppose that the room you considered in part (a) is initially filled with air in the normal way, with air particles moving randomly and distributed throughout the room. Now, imagine that, just by chance, at some later time all the air molecules end up on one side of the room (i.e., only half of the room’s volume now contains air). You may assume that no work or heat transfer was involved in order to make this happen; the molecules just happened to end up where they did through their usual random paths and collisions. Use the microscopic interpretation of entropy to calculate the change in entropy between these two situations. (Example 20.11 in the textbook may be useful for reference.)
d) Estimate the **probability** that all the air molecules will end up on one side of the room as in part (c). This probability is the ratio (number of microstates with air in only half of the room)/(number of microstates with air in the full room)—the same ratio involved in the calculation of entropy in part (c). Using a calculator here will be very unhelpful! (Do you see why?) Instead, work out your answer in terms of exponents. Your final answer should be expressed as a power of 10. (Note that $10 \approx 2^{3.3}$.)}