ENTROPY AS A MICROSCOPIC QUANTITY

A microscopic view of entropy

To understand why the second law of thermodynamics is always true, we need to see what entropy really means at the microscopic level. An example that is easy to visualize is the free expansion of a monoatomic gas. Figure a/1 shows a box in which all the atoms of the gas are confined on one side. We very quickly remove the barrier between the two sides, a/2, and sometime later, the system has reached equilibrium, a/3. Each snapshot shows both the positions and the momenta of the atoms, which is enough information to allow us in theory to extrapolate the behavior of the system into the future, or the past. However, with a realistic number of atoms, rather than just six, this would be beyond the computational power of any computer.[2]

But suppose we show figure a/2 to a friend without any further information, and ask her what she can say about the system's behavior in the future. She doesn't know how the system was prepared. Perhaps, she thinks, it was just a strange coincidence that all the atoms happened to be in the right half of the box at this particular moment.

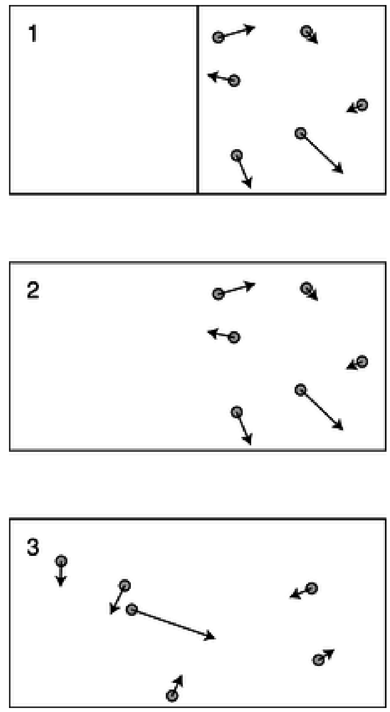

Figure a: A gas expands freely, doubling its volume.

In any case, she knows that this unusual situation won't last for long. She can predict that after the passage of any significant amount of time, a surprise inspection is likely to show roughly half the atoms on each side. The same is true if you ask her to say what happened in the past. She doesn't know about the barrier, so as far as she's concerned, extrapolation into the past is exactly the same kind of problem as extrapolation into the future. We just have to imagine reversing all the momentum vectors, and then all our reasoning works equally well for backwards extrapolation. She would conclude, then, that the gas in the box underwent an unusual fluctuation, b, and she knows that the fluctuation is very unlikely to exist very far into the future, or to have existed very far into the past.

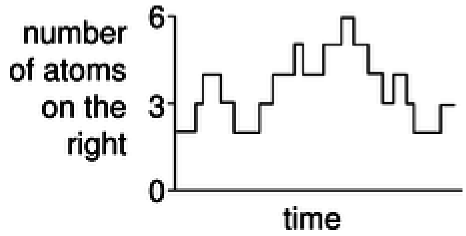

Figure b: An unusual fluctuation in the distribution of the atoms between the two sides of the box. There has been no external manipulation as in figure a/1.

What does this have to do with entropy? Well, state a/3 has a greater entropy than state a/2. It would be easy to extract mechanical work from a/2, for instance by letting the gas expand while pressing on a piston rather than simply releasing it suddenly into the void. There is no way to extract mechanical work from state a/3. Roughly speaking, our microscopic description of entropy relates to the *number of possible states*. There are a lot more states like a/3 than there are states like a/2. Over long enough periods of time --- long enough for equilibration to occur --- the system gets mixed up, and is about equally likely to be in any of its possible states, regardless of what state it was initially in. We define some number that describes an interesting property of the whole system, say the number of atoms in the right half of the box, R. A high-entropy value of R is one like R=3, which allows many possible states. We are far more likely to encounter R=3 than a low-entropy value like R=0 or R=6.

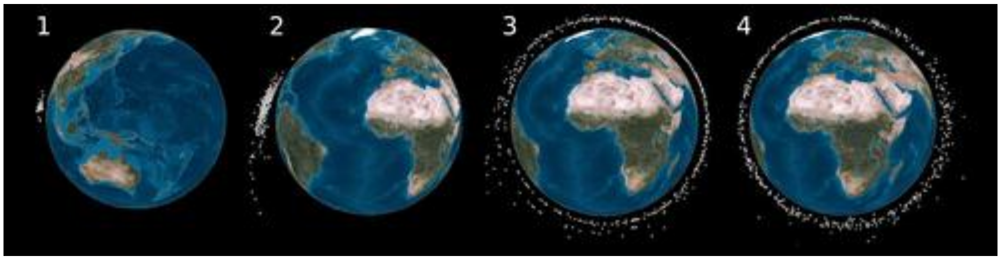

Figure c: Earth orbit is becoming cluttered with space junk, and the pieces can be thought of as the “molecules” comprising an exotic kind of gas. These image shows the evolution of a cloud of debris arising from a 2007 Chinese test of an anti-satellite rocket. Panels 1-4 show the cloud five minutes, one hour, one day, and one month after the impact. The entropy seems to have maximized by panel 4.

Source: http://physwiki.ucdavis.edu/Fundamentals/05._Thermodynamics/5.4_Entropy_As_a_Microscopic_Quantity