February 28–March 1: Entropy

Objectives

- Explain the tendency of matter and energy to spread out over time.
- Justify entropy changes in familiar processes.

What's the point?

- Why is the past different from the future?

Matter Disperses

Random thermal motions tend to move molecules away from regions where there are a lot of them and into regions where there are few of them. This is because where more molecules are present, more will move away, and where fewer molecules are present, fewer will move away.

Energy Disperses

When two objects can exchange energy, the tendency is for their energies to be more similar after the exchange than before. This is for the same reason that molecules spread out — more energy is available to transfer from an energetic object than from one that has little energy.

Entropy

Entropy is physically related to probability. If we label two states of a system 1and 2, and the number of ways to make the two states are Ω_1 and Ω_2, then the **entropy change** ΔS for the system to switch from state 1 to state 2 is

$$\Delta S = k_B \ln\left(\Omega_2/\Omega_1\right)$$

where $k_B = 1.38066 \times 10^{-23}$ J/K, and $\ln(A)$ is the natural logarithm (base e) of A.

If a change from state 1 to state 2 is likely to occur, $\Omega_2 > \Omega_1$, so $\Delta S > 0$. This is the **second law of thermodynamics**: *entropy increases for every process that actually occurs*.

Resolving Conflicting Tendencies

Many processes that actually occur make either matter or energy more concentrated somewhere. This can only occur if matter or energy becomes more spread out somewhere else, to a great enough degree to compensate for the concentration. Often this occurs by energy being dispersed when matter becomes more concentrated. Energy is almost always eventually converted to heat, which is about the most spread-out form of energy that there is.

For example, when water freezes, its molecules become less free to move about. This can occur because water releases heat when it freezes, so that the energy dispersed more than makes up for the confinement of matter.