Recapitulate: The second law

When two large systems interact they will evolve toward the macrostate with the highest entropy.

- Not a fundamental law,
- only a consequence of the mathematics of very large numbers,
- but the probabilities as so overwhelming that we can treat the second law as fundamental.

Plan for what follows

- Figure out how entropy is related to other variables as temperature and pressure.
- Use these relations together with formulas for entropy to predict thermal properties of some realistic systems.

Temperature

New understanding of thermal equilibrium...

Second law

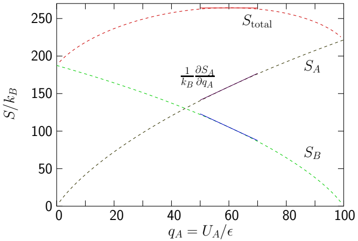
When two objects are in thermal equilibirium, their total entropy has reached its maximum possible value.

which we will use to understand temperature!

From chapter one

Temperature is the thing that is the same for objects when they are in thermal equilibrium.

Two Einstein solids: $N_A = 300$, $N_B = 200$



$$\left(\frac{\partial S_{\text{total}}}{\partial U_A}\right) = 0 \quad \Rightarrow \quad \left(\frac{\partial S_A}{\partial U_A}\right) + \left(\frac{\partial S_B}{\partial U_A}\right) = 0$$

$$dU_A = -dU_B \quad \Rightarrow \quad \left(\frac{\partial S_A}{\partial U_A}\right) = \left(\frac{\partial S_B}{\partial U_B}\right).$$

Temperature is the thing that is the same for objects when they are in thermal equilibrium

$\Rightarrow$ Temperature is related to $\partial S_A/\partial U_A$... but how?

Definition of temperature

Reformulate: equal temperature if

$$\left(\frac{\partial S_A}{\partial U_A}\right) = \left(\frac{\partial S_B}{\partial U_B}\right).$$

- Assume we are at $q_A = 40$
- Approach to equilibrium means that system B gives away energy to system A
- This implies that $T_B > T_A$ when $q_A = 40$.
- At $q_A = 40$: Bigger slope of system A
- Bigger slope $\Leftrightarrow$ lower temperature
- Check units: $[S/U] = \mathrm{J/K/J} = 1/\mathrm{K}$.

$$\Rightarrow \frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)_{N,V} \quad \text{with possible prefactors}$$