Example 1. Table IIIA-8 summarized the results of the 30-particle example. Use this table to determine the entropy of the most, 10th most, 20th most, and least probable macrostates. Also determine the relative change in entropy as the system goes from the 10th, 20th, and least probable macrostates to the most probable.

From Table IIIA-7 we find $W = 2.648 \cdot 10^{29}$ and that $p_{mp} = 0.0639$; $p_{10} = 0.0271$, $p_{20} = 0.0162$; $p_{\ell p} = 1.13 \cdot 10^{-22}$. This allows us to determine W_i for each of these macrostates.

$$W_{mp} = p_{mp} W = 1.69 \cdot 10^{28}, \quad W_{10} = 0.718 \cdot 10^{28}, \quad W_{20} = 0.429 \cdot 10^{28}, \quad W_{\ell p} = 0.299 \cdot 10^{8}.$$

The entropies are

$$S_{mp} = k \ln W_{mp} = 1.38 \cdot 10^{-23} \text{ J/K} \cdot \ln (1.69 \cdot 10^{28}) = 8.97 \cdot 10^{-22} \text{ J/K}$$

$$S_{10} = 8.85 \cdot 10^{-22} \text{ J/K}, \quad S_{20} = 8.78 \cdot 10^{-22} \text{ J/K}, \quad S_{\ell p} = 2.37 \cdot 10^{-22} \text{ J/K}$$

The percent changes between these and the most probable macrostate are

$$\frac{S_{mp} - S_{10}}{S_{mp}} = \frac{(8.97-8.85)\cdot 10^{-22}}{8.97 \cdot 10^{-22}} = 1.45\%, \quad \frac{S_{mp} - S_{20}}{S_{mp}} = 2.12\%, \quad \frac{S_{mp} - S_{\ell p}}{S_{mp}} = 73.6\%$$

This illustration reaffirms our hypothesis; the changes in entropy among the probable macrostates are small. But the change from the least to the most significant macrostate is quite pronounced.

Exercise 1. Examine the definition of the entropy, eqn. IIIB-1, and determine the lowest possible value of entropy. Using the perspective of this answer, reflect on the idea of increasing entropy being synonymous with increasing disorder. How ordered is the state that corresponds to the lowest possible entropy?

The formulation of the second law as $dS_{isol} \geq 0$ (eqn. IIIB-4) appears limited since it applies only to isolated systems (closed systems without work or heat interaction). However, the equation can be immediately generalized by recognizing that the universe is an isolated system.[4] For application we divide the universe into a system (the subject of attention) and its surroundings. Thus

[4]The specification of the entire universe (as opposed to immediate surroundings) as an isolated system has interesting philosophical implications. From this perspective, all processes tend to maximize the entropy of the universe, i.e., to drive it toward equilibrium. Any approach to equilibrium in turn, decreases the driving potential that causes the process to occur. The driving potential for our planet is the energy of the sun which sustains all life, either directly or indirectly. However, the sun is continually approaching equilibrium with the other bodies in the solar system; it is burning out. Therefore, the sun's energy is being distributed uniformly within the solar system. Similarly, a universe, considered as an isolated system, is eventually destined to an "entropy death" (though the time required for this to happen is virtually beyond our conception).

One can relate our concepts of these processes to a perspective of a supreme being through a number of questions. How was the universe arranged in its original nonequilibrium condition? Is the universe isolated, such that it obeys eqn. IIIB-4? Or is there an interaction with something outside the universe, which could periodically or continuously restore the universe to, or toward, its original low-entropy nonequilibrium condition?