# Entropy defect in thermodynamics

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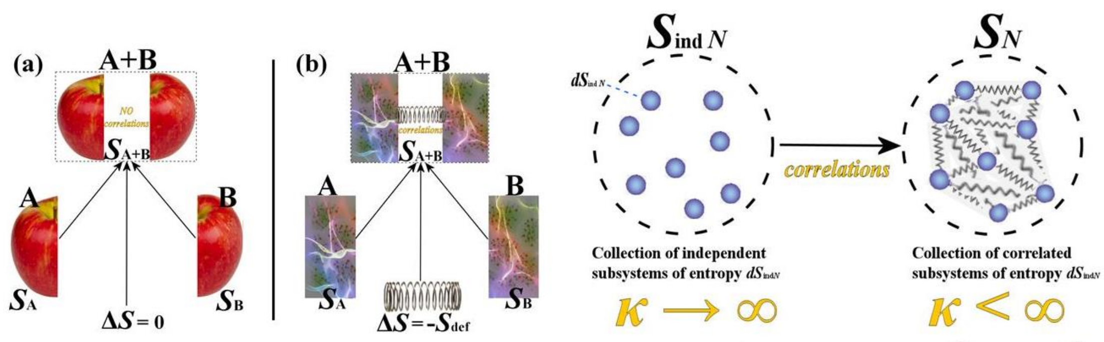
We describe the physical foundations of the newly discovered “entropy defect” as a basic concept of thermodynamics. The entropy defect quantifies the decrease in entropy caused by the order induced in a system through the additional correlations among its constituents when two or more subsystems are assembled. This defect is closely analogous to the mass defect that arises when nuclear particle systems are assembled. The entropy defect determines how the entropy of the system compares to its constituent’s entropies. In particular, the existence of long-range correlations between the constituents adds order to the whole system and thus decreases its total entropy, leading to the entropy defect, a term that reduces the simple summation of the constituent entropies. The entropy defect stands on three fundamental properties: each constituent’s entropy must be (i) separable, (ii) symmetric, and (iii) bounded. We show that these properties provide a solid foundation for the entropy defect and for generalizing thermodynamics to describe systems residing out of the classical thermal equilibrium, both in stationary and nonstationary states.

- In stationary states, the consequent thermodynamics generalizes the classical framework, which is based on the Boltzmann-Gibbs entropy and Maxwell-Boltzmann canonical distribution of particle velocities, into the respective entropy and canonical distribution associated with kappa distributions. The generalized statistical framework is suitable for describing the thermodynamics of systems residing in stationary states out of the classical thermal equilibrium, such as plasma particle populations from laboratory plasmas under extreme conditions and space plasmas throughout the heliosphere and beyond.

- In nonstationary states, the entropy defect similarly acts as a negative feedback, or reduction of the increase of entropy, preventing its unbounded growth toward infinity.




$$W = \exp(S_{\mathrm{ind}\,N}) = \exp_{\kappa}\left[S_N(\kappa)\right]$$

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