

## **Two state particles, mixing entropy and negative temperatures revisited**

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### **Abstract**

The interrelation of thermodynamics and statistical properties of quantum systems can be demonstrated with comparatively little mathematical effort using two state systems (or two state particles). Basic results are summarized for this model system. The entropy can be interpreted as the entropy of mixing particles in their low and high energy state. Thus, an apparent single component system can be considered as a two component system with variable particle numbers. This result has recently been generalized for elementary bosonic and fermionic systems or particles with many different excited states. In this case, one has to take into account as many components as different internal states of the particles are available. The numbers of particles of each component, however, are not constant but depend on the temperature at thermal equilibrium according to statistical principles.

In the literature, the concept of negative internal temperatures was previously introduced to characterize and describe special inverted occupation probabilities out of thermal equilibrium. This interpretation of inverted occupation numbers is revisited explicitly for nuclear spin systems. The interpretation of inverted occupancy by negative temperature is based on ignoring athermal contributions to the internal energy due to the inversion procedure. Accordingly, negative temperatures are not justified in the case of systems out of thermal equilibrium but seem to be misleading and confusing. Instead, the different states of the particles represent distinctive components possessing different chemical potentials, magnetic moments or other properties. The present paper intends to remove the confusion about negative temperatures. It shows how processes out of thermal equilibrium are described and understood without difficulties by balancing the different kinds of particles together with their energy and production of entropy within the framework of thermodynamics.