Frontiers of NMR in Medicine and Chemistry:

Enforcing or Avoiding Thermal Equilibrium?

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Nuclear magnetic resonance (NMR) has found many applications as a non-invasive tool at the interface of physics, chemistry, and the life sciences. Macroscopic spin magnetization reveals, e.g., molecular structures in solution and provides anatomical information in medical MR imaging (MRI). All these experiments require an initial perturbation of the spin magnetization to generate an inductive signal. Many classical applications work with a moderate perturbation of the Boltzmann equilibrium in combination with spontaneous or enforced recovery during which the magnetization is subject to microscopic field variations. These allow analysis of molecular sub-units or generation of image contrast. Recently emerging techniques, however, use additional steps to enforce a different state of magnetization. These approaches include saturation or hyperpolarization of the spin system, or a combination of both, to achieve conditions outside the thermal equilibrium for retrieving additional information.

This talk will give an overview of the basic concepts of analyzing and manipulating different spin pools. Application examples for paramagnetic relaxation centers that enforce recovery towards the equilibrium will be compared to methods such as saturation transfer and transient spin hyperpolarization that avoid the Boltzmann equilibrium. The advantages and requirements related to hyperpolarized spin systems will be discussed as well, particularly in the context of biomedical MRI where the limited lifetime of the hyperpolarized state motivates accelerated acquisition techniques like the CAVKA method.