

Enhanced Biomedical ^{13}C NMR by Thermal Mixing with Hyperpolarized ^{129}Xe

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Here, we describe the first report of nuclear inter-molecular spin polarization transfer from hyperpolarized ^{129}Xe to ^{13}C accomplished by thermal mixing (TM) between hyperpolarized ^{129}Xe and a proton-containing molecule of biological relevance. The analytical potential of ^{13}C NMR spectroscopy and imaging is not exploited to its full capacity because of poor sensitivity. The low sensitivity of ^{13}C NMR is substantially improved by hyperpolarization techniques: DNP and PASADENA [6]. However, both methods have significant limitations. Alternatively, ^{13}C sensitivity can be enhanced by polarization transfer from hyperpolarized ^{129}Xe to ^{13}C by either Nuclear Overhauser Effect (SPINOE) [1] or low-field thermal mixing (TM) [2,3]. Our goal is to explore the TM procedure and to delineate the factors that limit the ^{13}C polarization enhancements. This approach is to bring in contact ^{13}C enriched molecules and hyperpolarized ^{129}Xe by mixing them in the **gas phase**. The equilibrated system is condensed to the solid state with liquid N_2 . The condensation is conducted in uniform magnetic field $B_0=900$ G T to prevent relaxation losses in the solid state. Following condensation, the field is decreased to the mixing magnetic field B_{mix} comparable to the local dipolar fields. This allows ^{129}Xe and ^{13}C spins to exchange their polarizations. After polarization transfer, the applied magnetic field is raised to B_0 and the system is brought to the liquid state.

Hyperpolarized ^{129}Xe is produced by spin exchange optical pumping, originally described by Driehuys et al. [4] and optimized by Ruset et al. [5]. The condensation procedure is conducted in the fringe field of a 4.7T magnet and utilized a compensation electromagnet to momentarily reduce the field to B_{mix} (0.1 - 5 mT) for spin transfer. The experimental setup is shown in Fig. 1.

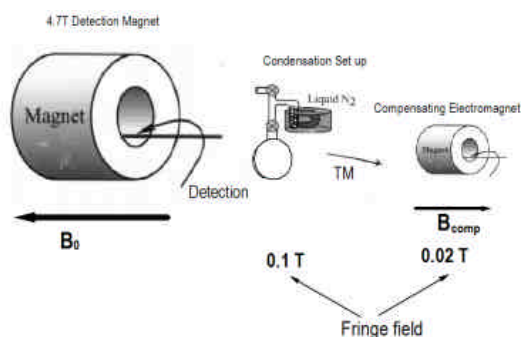


Figure 1. Experimental setup for TM procedure.

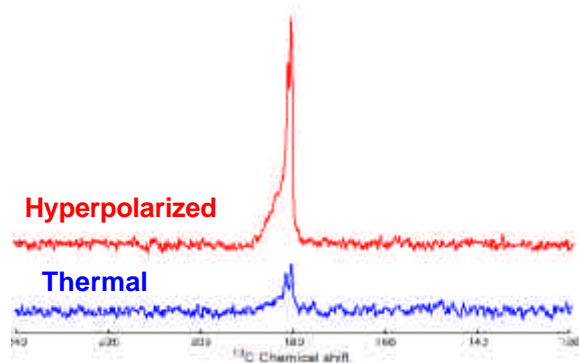


Figure 2. ^{13}C NMR spectra of hyperpolarized 1- ^{13}C -AcH (red) and 1- ^{13}C -AcH at Boltzmann polarization at 4.7T

The observed signal enhancement is expressed as the ratio of integral signal intensity of the hyperpolarized carbon signal relative to that of the reference spectrum at thermal polarization. It ranged from 3 to 5 and depended on the starting xenon polarization (20-40%) and $^{129}\text{Xe}/1\text{-}^{13}\text{C}\text{-AcH}$ molar ratio. Since we did not have the capability to monitor ^{13}C polarization build up in the solid state in situ, we account for relaxation losses during 40-60 second time interval between TM and NMR detection using 1- ^{13}C AcH T_1 of ~ 30 s. The resulting extrapolated enhancement varied between 11 and 20 fold. The theoretically predicted enhancement factor is $\sim 10^3$, more than one order of magnitude greater than the enhancement factors observed. The discrepancy between the theoretical limit and the experimental results could be because of inhomogeneous solid matrix and the other relaxation processes, which will be discussed. Work is in progress in our laboratory to overcome experimental limitations to achieve better ^{13}C hyperpolarization and extend this method to other biologically important compounds.

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