ALTERED STATES OF SOLID XENON

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INTRODUCTION

Longitudinal relaxation (T_1) processes in solid Xe are studied using hyperpolarization of ^{129}Xe via spin-exchange from optically pumped Rb with a precision of %1 and unprecedented reproducibility. We find a difference in the measured T_1 values between snow and ice solid Xe, which contradicts the suggested bulk relaxation mechanism. After mapping temperature dependent ice data, we find a consistent discrepancy across the range of validity of the model that shows suggested the model does not fit.

METHODS

To prepare the solid Xe, a flow-through polarizer is utilized.[1] A gas mixture containing Xe is passed through a cell holding an optically pumped Rb vapor. The Rb vapor polarizes the ^{129}Xe nuclei via a Fermi-contact interaction. The gas mixture is flowed into a sample chamber at 77 K in a 2 T magnetic field, where the Xe is condensed directly from the gas mixture, creating a white polycrystalline hyperpolarized solid "snow" Xe. By monitoring phase transitions using the NMR frequency, we can conrollably liquify and re-freeze solid Xe as an "ice".

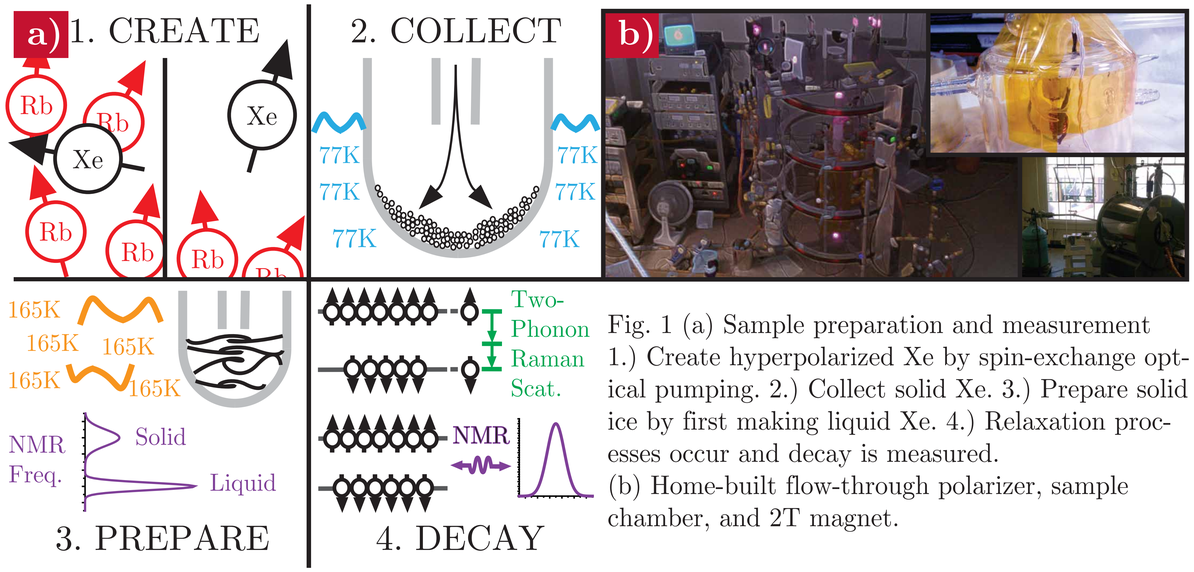

Fig. 1 (a) Sample preparation and measurement 1.) Create hyperpolarized Xe by spin-exchange optical pumping. 2.) Collect solid Xe. 3.) Prepare solid ice by first making liquid Xe. 4.) Relaxation processes occur and decay is measured.
(b) Home-built flow-through polarizer, sample chamber, and 2T magnet.

THEORY

In the regime of 77-120K and 2T, the dominate relaxation mechanism is supposed to be spin-rotation mediated by a two-phonon Raman-scattering.[2]

$$T_1^S \propto \frac{\Theta_D^3}{c_K T^2 \eta} \qquad (1)$$

is the predicted relaxation time, where the temperature-dependent parameters are the Debye temperature Θ_D, the spin-rotation coupling strength c_K, and η, which accounts for the available phonon modes.

RESULTS

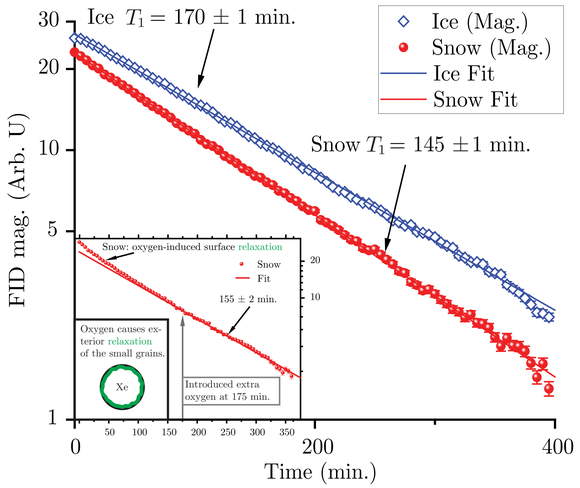

Fig. 2 Comparison between snow and ice ^{129}Xe T_1 data at 77K in a field of 2T. (inset) Oxygen was introduced, causing snow surface relaxation.

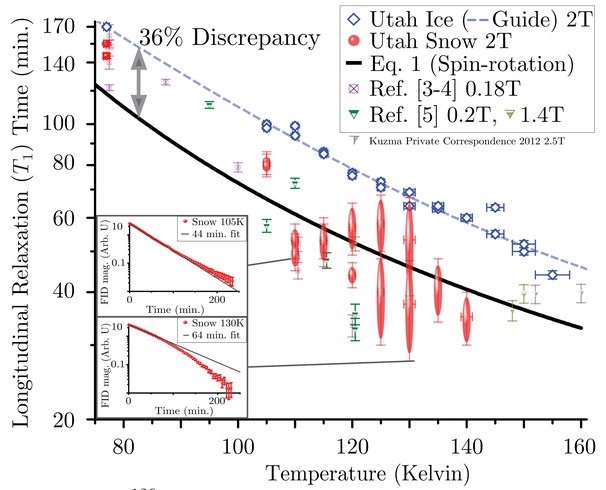

Fig. 3 ^{129}Xe T_1 data mapped against temperature. Data from Ref. [3-5] is also plotted.
(inset)Demonstration of anomolous snow data.

DISCUSSION

The difference of snow and ice T_1 values is unexpected because both are bulk solids: the phonon spectrum is approximately the same in each case. The theory produces a reasonable fit through the ice data only if the lattice spacing or the Debye temperature is altered enough to account for the 36% discrepancy. Any additional relaxation mechanisms will only decrease the predicted T_1. These results indicate that, unless fundamental parameters are altered from the reported values, the mechanism of two-phonon Raman-scattering as calculated does not account for our measured T_1 values.

DILUTE SPINS

By varying ^{129}Xe isotopic concentrations, we can rule out mechanisms of relaxation. In a separate convection cell experiment,[6] we prepare dilute spin lattices (0.1 - 10% ^{129}Xe) for T_1 measurements and for the study of dilute spin lineshapes. Our intial T_1 measurements corroborate previous enriched ^{129}Xe (90%) results which indicated no isotope dependence. This rules out isotope-dependent mechanisms e.g. dipolar relaxation.

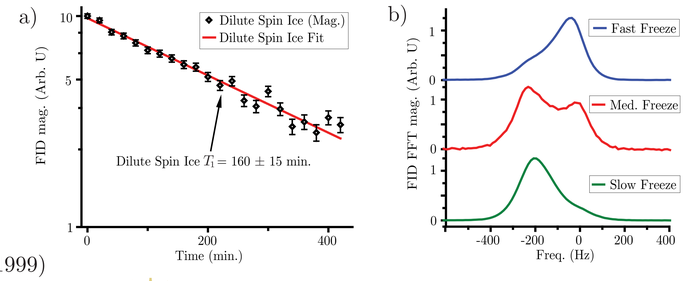

Fig. 4 a) Dilute Spin convection cell T_1 measurement (4.5% ^{129}Xe).
b) Freezing rate dependent frequency shift in a 5.5% Xe sample, where the characteristic freezing time is on the order of minutes.

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NSF PHY 0855482

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