Thermal Relaxation of ^{3}He Droplets in Solid ^{4}He

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Introduction

Studies of clusters of ^{3}He in either liquid or solid form have revealed a rich variety of new phenomena for both the magnetic properties and the dynamics at low temperatures. The properties of these systems differ considerably from those for bulk systems because the range of the inter-particle interactions is smaller than the DeBroglie wavelength at low temperatures, and the interface interactions play an important role due to the confined geometry.

Experimental

The experiments used NMR pulse techniques to study the relaxation of ^{3}He impurities for low concentrations in solid ^{4}He. At low temperatures the ^{3}He impurities will bind together in small clusters and for the densities of the solid ^{4}He in these experiments, the ^{3}He atoms form a degenerate Fermi liquid. This degeneracy leads to a temperature independent nuclear magnetic susceptibility below the phase transition, typically 100 mK for low ^{3}He concentrations, 50< x_3<2000 ppm [1].

Results and Discussion

The relaxation can be understood in terms of a three-stage process: (i) fast spin diffusion through the core of the droplet, (ii) a slow coupling of the interior bulk atoms with the atoms at the wall, followed by (iii) a strong coupling of the wall atoms to the phonons of the ^{4}He lattice. The overall relaxation time is given by $T_1 = (1 + M_{core}\backslash M_{wall})\tau_x$ where τ_x represents the intrinsic 3He core – 3He wall relaxation time at the wall. Assuming $\tau_x = J_3\backslash M_2$, where J_3 is the rapid ^{3}He exchange frequency and M_2 is the effective NMR second moment we estimate T_1 = 170 s. in reasonable agreement with the observed rates.

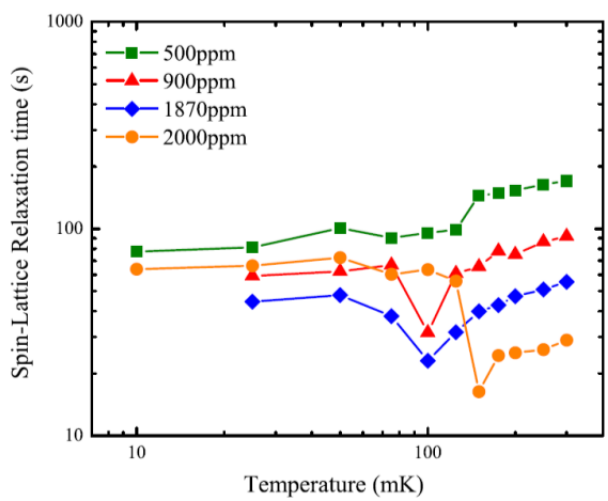

Figure 1. Temperature dependence of the nuclear spin-lattice relaxation of ^{3}He droplets in solid ^{4}He at low temperatures, showing the characteristic temperature independence for the relaxation for a degenerate system.

Conclusions

The magnitude of the relaxation rate and the temperature independence of the observed relaxation of the ^{3}He droplets suggest that the interface ^{3}He atoms responsible for thermal relaxation are degenerate, and not solid-like.

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References

[1] C. Huan, S.S. Kim, L. Yin, J.S. Xia and N.S. Sullivan, J. Low Temp. Phys. **162**, 167-173 (2013).