Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

βNMR study of Isolated $^8Li^+$ in the Enhanced Paramagnet Pt

Oren Ofer, K. H. Chow, I. Fan, M. Egilmez, T. J. Parolin, M. D. Hossain, J. Jung, R. F. Kiefl, C. D. P. Levy, G. D. Morris, M.R. Pearson, H. Saadaoui, Q. Song, D. Wang and W. A. MacFarlane

Introduction

Enhanced Paramagnetism is often observed as a large temperature dependent paramagnetic susceptibility detected using various measurement techniques. Platinum is an enhanced paramagnet that has magnetic properties unlike elemental noble metals such as Au, Ag or Cu. Instead, it is closely related to Pd. Pt has a strong electron exchange interaction that results in an enhanced paramagnetic susceptibility. Here we report on a βNMR resonance and relaxation rates measurements in annealed high purity (5N) Pt foil.

Our main finding is a linear temperature dependence on both the 8Li relaxation rate and the 8Li Knight shift measurements, despite that the Pt bulk susceptibility is not linear in this temperature range. This result point to an intrinsic untainted measurement of the Pt susceptibility.

$^8Li^+$ and μ^+ Knight-Shifts in Pt

A single interstitial site is observed at all measured temperatures, 3<*T*<300 K, indicated by a single resonance peak, close to the Larmor frequency of the applied field, unlike previous studies on Ag, Au, Cu[1] and Pd[2]. The resonance spectra are well described by a Lorentzian lineshape (see figure below),

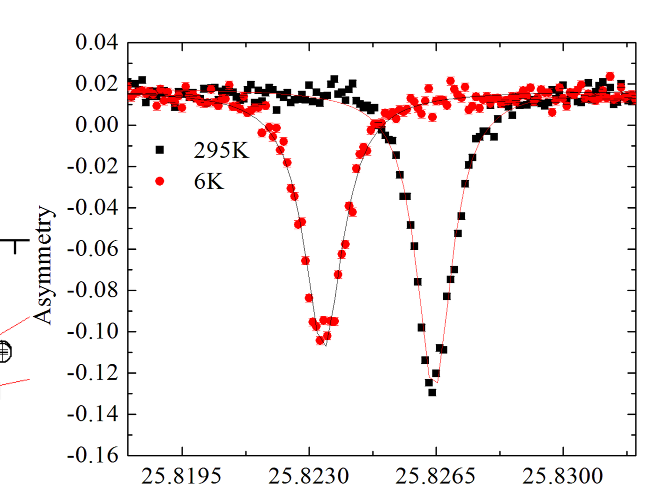
$$A = \frac{A_0}{2\pi} \frac{\omega}{(\nu - \nu_{Pt})^2 + \omega^2}$$

Where is the amplitude, is the frequency and is the FWHM. Does not exhibit any temperature dependence, confirming a single site occupancy. The shift,

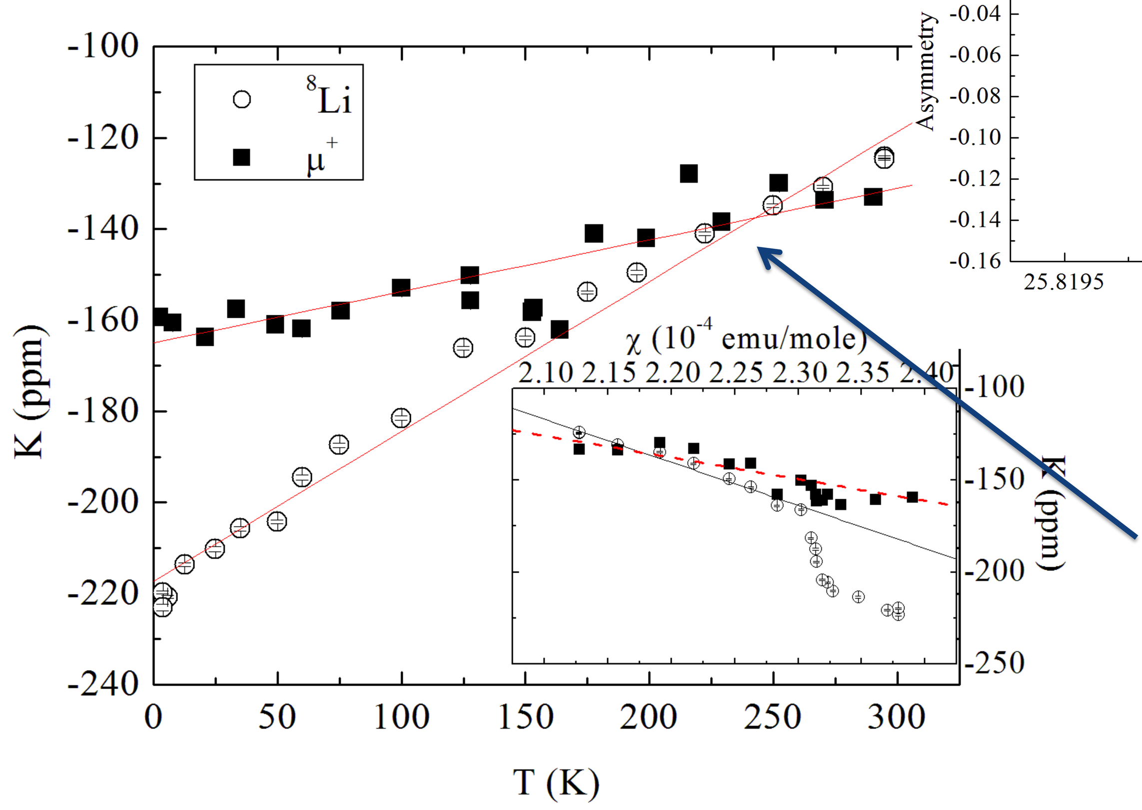
$$K = \frac{\nu_{Pt} - \nu_{MgO}}{\nu_{MgO}}$$

is calculated compared to the insulating reference MgO.

Unlike the bulk susceptibility (see figure), dominated by contact interaction with some impurity at low *T*, the ^{8}Li *K* exhibits linear temperature dependence indicating core interactions.



The raw resonance data taken at 6 and 295K, showing *K*.

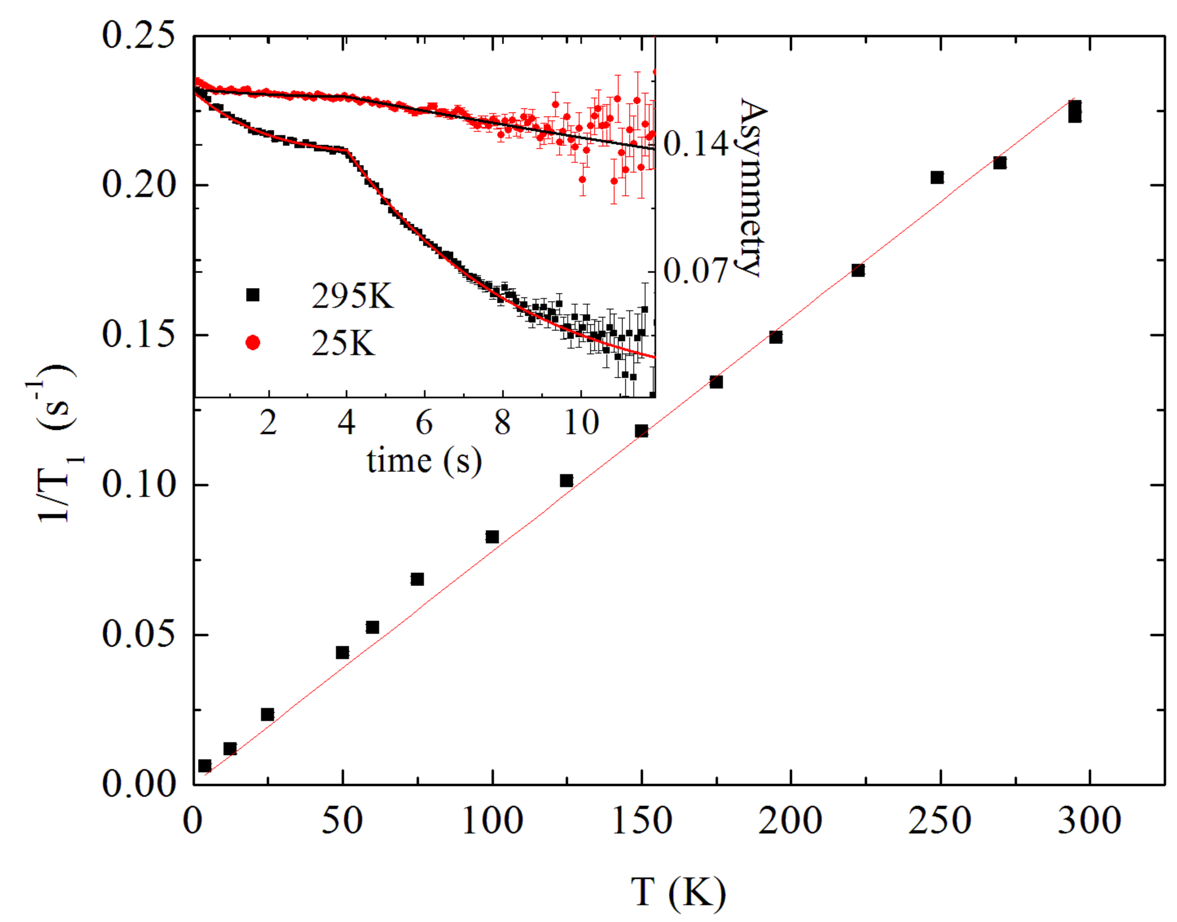


The μ^+ shift is weaker than the 8Li, as expected from a lighter Z nuclei.

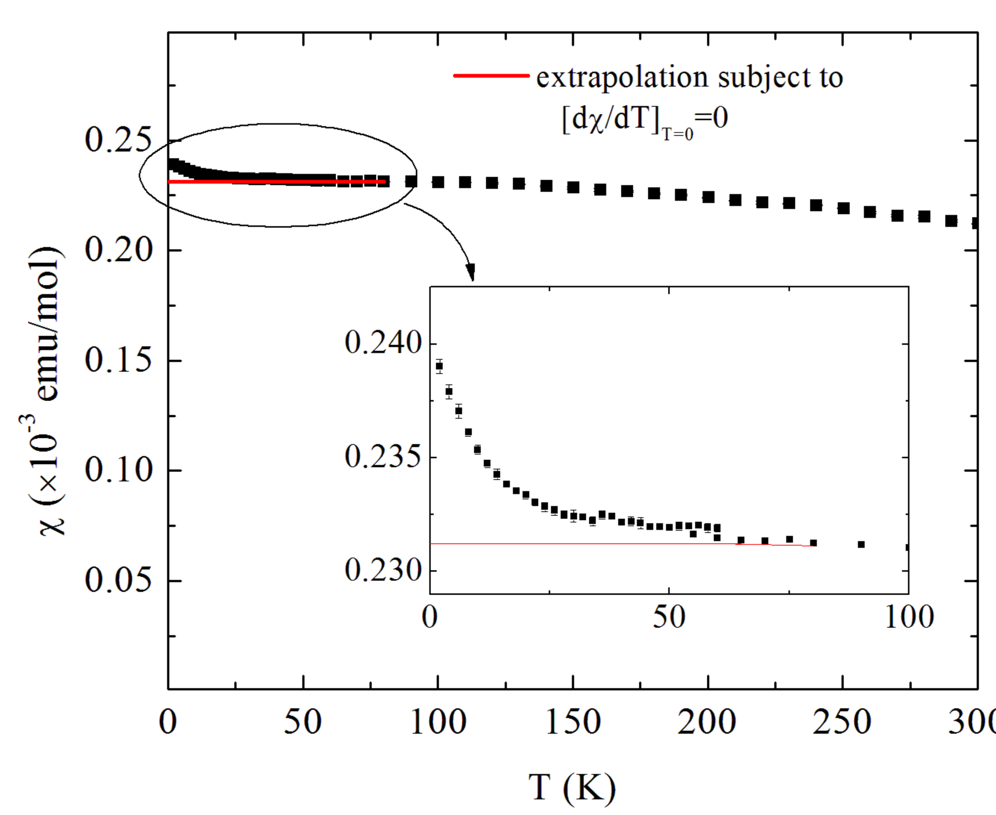
The Temperature dependence of the frequency shift (corrected for demagnetization effects) in an applied field of H=4.1 T. The inset shows the shift vs the bulk susceptibility.

T_1 Measurements

The T1 is measured using a pulsed ^{8}Li beam: a 4 sec beam-on, followed by a 12 sec beam-off. No RF is applied and the time dependence of the asymmetry is observed with applied field of H=4.1 T. The relaxation rate extracted revealing a linear temperature dependence, yet the relaxation rate is dominated by contact interactions hence the similarity to other noble metals.



The spin-lattice relaxation rate vs the temperature. Inset shows the raw data demonstrating the slowing down of fluctuations with decreasing *T*.



The almost temperature-independent bulk susceptibility (χ≡M/H). Inset shows the blow-out of the low-T affected by impurities.

Discussion and Summary

In normal metals, the free-electron-like local susceptibility is characterized by Korringa relaxation,

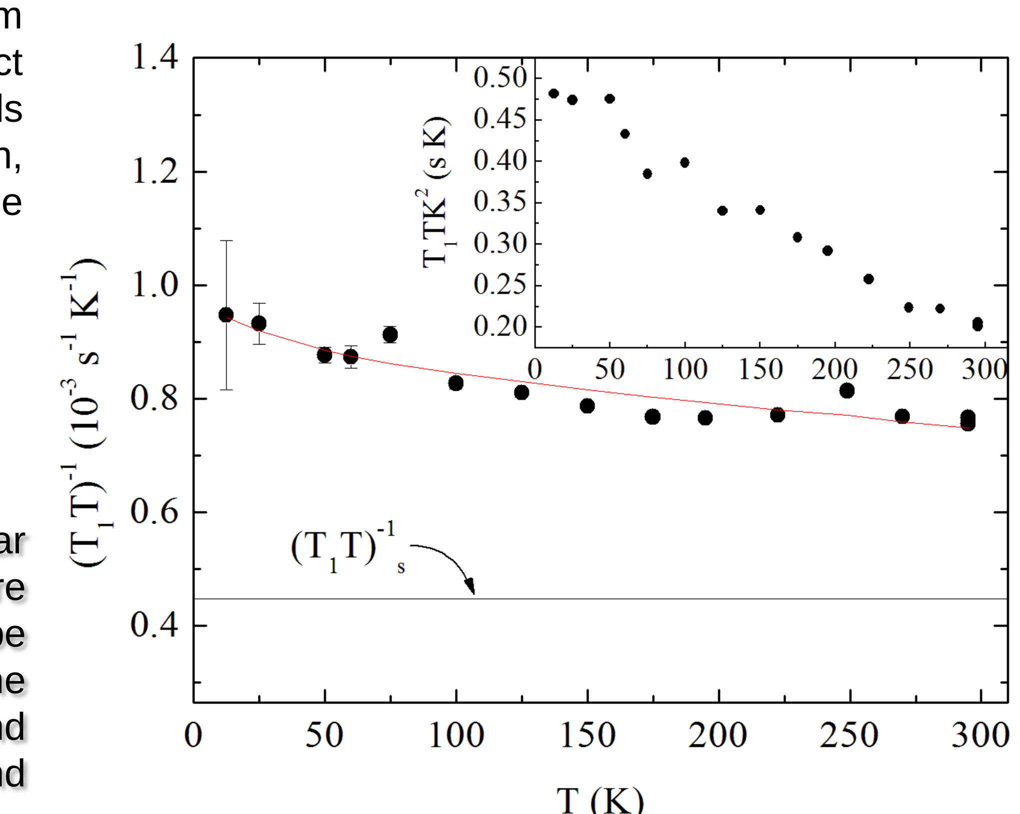
$$T_1 T K_2 = \frac{h\gamma_e^2}{4\pi k_B \gamma_n^2}$$

Obviously, this is not the case here since (see figure). Deviations are expected from electronic correlation and were observed elsewhere as well. The product , $(T_1T)^{-1}$ can be described as a sum of contact, orbital and core contributions,

$$(T_1T)^{-1} \propto \sum_i \frac{\pi k_B}{\hbar} (\gamma_n \hbar N_A \mu_B \frac{K_i}{\chi_i})^2 [N_i(\varepsilon_F)]^2$$

Hence the T-dependence is controlled by the core and orbital contributions,

and a constant term originating from the contact term. The fit reveals negligible orbital contribution, the contact is shown as the horizontal line.



The temperature normalized relaxation rate, $(T_1T)^{-1}$, vs the temperature. Inset shows the Korringa law T_1TK^2 removing the possibility of a Korringa-like behavior.

To summarize, *K(T)* linear dependence, influenced by core contributions, is found to be unaffected with impurities at the low *T*. The linear $T_1(T)$ is found to be contributed by contact and core terms.

Further reading

[1] Z. Salman et. al., Phys. Rev. B **75**, 073405 (2007).
[2] T. J. Parolin et. al., Phys. Rev. Lett. **98**, 047601 (2007).
[3] Oren Ofer et. al., submitted.

Acknowledgments

We acknowledge the staff of TRIUMF for technical assistance and R. Liang at UBC for helping in sample preparations. This research is partially funded by NSERC of Canada (through TRIUMF) by NRC of Canada.