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^{8}Li Magnetic Dipole Moment*

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Polarized ^{8}Li nuclei recoiling from the reaction ^{7}Li$(d,p)^8$Li were implanted in Au, Pd, and Pt foils, and the Knight-shifted values of the ^{8}Li magnetic dipole moment in these metals were measured by a resonant depolarization technique. From measurements of the spin-lattice relaxation times of ^{8}Li implanted in Au, Pd, and Pt, the Knight shifts of ^{8}Li in these metals were estimated. A corrected value for the magnetic dipole moment of ^{8}Li was found to be $\mu(^8\text{Li}) = (1.653\,35 \pm 0.000\,35)\mu_N$. Attempts were also made to measure the quadrupole couplings of ^{8}Li in single crystals of Be and Mg. While the resonance lines could not be distinctly resolved, upper and lower limits have been deduced for $|e^2qQ/h|$ in these two metals.

The magnetic moment of ^{8}Li has been measured by Connor[1] and Gul'ko, Trostin, and Hudoklin[2] using resonant depolarization of the nuclear recoils resulting from thermal neutron capture by ^{7}Li in a crystal of LiF. These experimenters found $\mu(^8\text{Li}) = 1.6530 \pm 0.0008$, which when corrected for the slight diamagnetism of LiF yields[3] $\mu(^8\text{Li}) = 1.6532 \pm 0.0008$. This paper reports the measurements[4] of the Knight-shifted values of $\mu(^8\text{Li})$ in Au, Pd, and Pt. Estimates of the ^{8}Li Knight shifts in these metals based on nuclear spin-lattice relaxation measurements lead to a corrected value of $\mu(^8\text{Li}) = 1.653\,35 \pm 0.000\,35$. Since similar Knight-shift estimates have been used to obtain values of $\mu(^{12}\text{B})$[5] and $\mu(^{13}\text{B})$[6] from the Knight-shifted effective moments in Au, Pd, and Pt, it is gratifying that the values of $\mu(^8\text{Li})$ obtained by the two different methods agree so closely. However, since the error assigned to the value of Connor and Gul'ko, Trostin, and Hudoklin includes the three Knight-shifted values of $\mu(^8\text{Li})$ in Au, Pd, and Pt, the agreement is only a qualified check on the validity of the Knight-shift analysis.

Polarized ^{8}Li recoils were produced at the Brookhaven National Laboratory Van de Graaff facility using the reaction ^{7}Li$(d,p)^8$Li. The ^{8}Li decay scheme is $^8\text{Li} \rightarrow {}^8\text{Be} + \beta^- + \bar{\nu}$ where the ^{8}Be nucleus subsequently decays into two α particles. The ^{8}Li half-life is 838 msec and the β end-point energy is 13.1 MeV. Since the initial and final states in ^{8}Li and ^{8}Be possess parity and angular momentum of 2^+, the decay is a mixture of Fermi and Gamow-Teller transitions. Hence, the resulting asymmetry in the distribution of the emission directions of the decay electrons may reflect only partially the polarization of the nuclear recoils. The experimental technique employed in measuring $\mu(^8\text{Li})$ was simply resonant depolarization of the recoil nuclei and will be described briefly.

A thin layer of LiF is deposited on Au foil and bombarded with 2.0-MeV deuterons. The polarized recoiling nuclei are collimated so that the fraction centered about a laboratory recoil angle of 32° is allowed to strike a foil of Au, Pd, or Pt. A large (~2-kG) vertical magnetic holding field is applied normal to the reaction plane. The subsequent decay β's are detected by two coincidence telescopes, one positioned directly above and one directly below the metal stopping foil. Each telescope contains one totally depleted silicon surface-barrier detector and one lithium-drifted silicon detector. The background counting rate is kept low by electrostatically chopping the deuteron beam and counting only when the beam is off. Typical beam times are 900 msec on and 1500 msec off, while counts are recorded for the first 900 msec of the beam-off period. Since the recoils are partially polarized perpendicular to the reaction plane, this polarization can be detected by observing the asymmetry in the counting rates of the telescopes. Resonance lines are obtained by varying in discrete steps the frequency of a weak (~1-G) horizontal magnetic field, while keeping the large vertical magnetic field constant. The destruction of the nuclear polarization at a particular frequency is manifested as a change in the up-down β asymmetry. The frequency changed approximately once each second so that random drifts in any part of the system are rapidly averaged out.

The data presented in Fig. 1 were fitted by computer to Gaussian resonance lines in order to obtain values for the ^{8}Li resonant frequencies and their standard deviations in Au, Pd, and Pt. Table I lists the ^{8}Li resonant frequencies and their standard deviations as well as values for the proton resonant frequencies, the deduced effective g factors in each metal, and the deduced effective magnetic moment in each metal. The uncertainties listed for the proton resonant frequencies represent the sum in quadrature of the uncertainties due to nonuniformity in $|\vec{B}|$ over the stopping material and over the time duration of the resonance experiment.

In order to obtain estimates of the Knight shifts, the spin-lattice relaxation times T_1 were measured at room temperature[7] for ^{8}Li implanted in Au, Pd, and Pt. Using the nominal T_1 values given in Table II, approximate Knight shifts for $\mu(^8\text{Li})$ in Au, Pd, and Pt were calculated from the Korringa relation,[8] $K^2T_1T = \hbar/4\pi k(\gamma_e/\gamma_N)^2$, where γ_e and γ_N are the electronic and nuclear gyromagnetic ratios, respectively.

Next, it was noted that the Knight shifts of the moments of Au, Pd, and Pt in their respective metal lattices are positive,[9] negative,[10] and negative,[11] respectively. Further, the corresponding empirical enhancement factors are 1.4, 9, and 7.0, respectively. It was assumed that the enhancement factors for ^{8}Li implanted in Au, Pd, and Pt are not likely to exceed these empirical enhancement factors for Au, Pd, and Pt in their respective lattices by more than a factor of 2. Hence, maximum values for the enhancement factors for ^{8}Li in Au, Pd, and Pt were taken to be 4, 16, and 16, respectively.

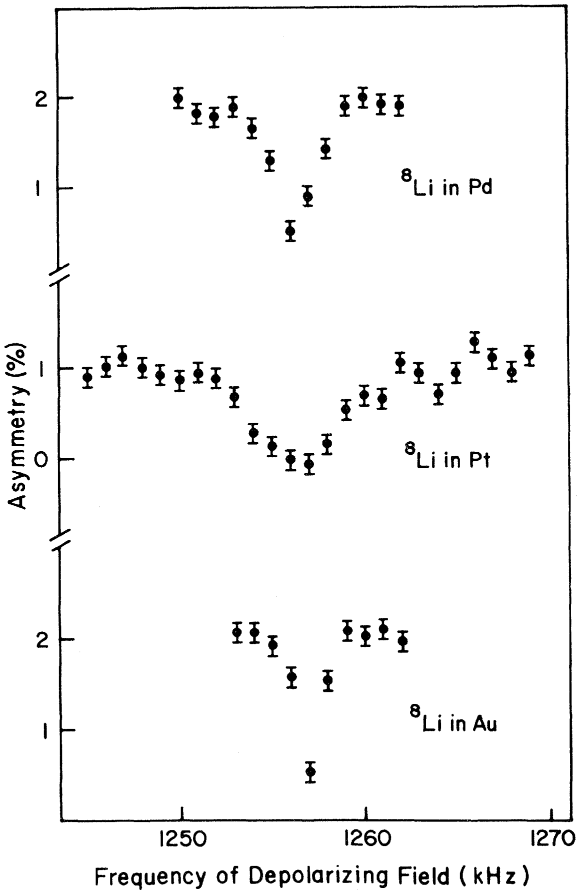

FIG. 1. ^{8}Li magnetic resonances in Pd, Pt, and Au.

Using these maximum values for the enhancement factors, and taking minimum values for T_1 to be the measured values minus one standard deviation, σ, maximum values for the Knight shifts of $\mu(^8\text{Li})$ in Au, Pd, Pt were calculated and are listed in Table II. It is clear that these calcu-

TABLE I. ^{8}Li effective magnetic moments in Au, Pd, and Pt.

	ν_{Li} (kHz)	ν_p (kHz)	g_{Li}	μ_{Li} (μ_N)
Au	1257.03 ± 0.11	8491.7 ± 0.7	0.826 81 ± 0.000 12	1.653 62 ± 0.000 24
Pd	1256.26 ± 0.08	8491.2 ± 0.7	0.826 35 ± 0.000 10	1.652 70 ± 0.000 20
Pt	1256.40 ± 0.19	8491.2 ± 0.7	0.826 44 ± 0.000 17	1.652 88 ± 0.000 34

lated maximum Knight shifts together with the Knight-shifted effective moments of ^{8}Li in Au, Pd, and Pt are consistent only with the assumption that the Knight shifts are negative in Pd and Pt, and positive in Au.

A minimum value for the corrected $\mu(^8\text{Li})$ can be obtained by considering the Knight-shifted effective moment of ^{8}Li in Au and $K(\text{max})$ in Au:

$$\begin{aligned}\mu(\text{min}) &= [\mu \text{ in Au}] - \sigma \text{ of } [\mu \text{ in Au}] \\ &\quad - [\mu \text{ in Au}][K(\text{max}) \text{ in Au}], \\ &= (1.653\,62 - 0.000\,24 - 0.000\,40)\mu_N, \\ &= 1.652\,98\mu_N.\end{aligned}$$

A maximum value for the corrected $\mu(^8\text{Li})$ can be obtained by a similar manipulation with the Pd values:

$$\begin{aligned}\mu(\text{max}) &= [\mu \text{ in Pd}] + \sigma \text{ of } [\mu \text{ in Pd}] \\ &\quad + [\mu \text{ in Pd}][K(\text{max}) \text{ in Pd}], \\ &= (1.652\,70 + 0.000\,20 + 0.000\,92)\mu_N, \\ &= 1.653\,82\mu_N.\end{aligned}$$

A corrected value with standard deviation including all reasonable values is then $\mu(^8\text{Li}) = (1.653\,35 \pm 0.000\,35)\mu_N$. The corresponding values of the enhancement factors are 2.5, 5.5, and 9.6 for Au, Pd, and Pt.

TABLE II. Calculations for Knight-shift analysis.

	T_1 (sec)	K (KORRINGA)	a (max)	T_1(min) (sec)	K (max)
Au	4.0 ± 1.1	1.0×10^{-4}	4	2.9	2.4×10^{-4}
Pd	2.3 ± 0.3	1.3×10^{-4}	16	2.0	5.6×10^{-4}
Pt	2.7 ± 0.7	1.2×10^{-4}	16	2.0	5.6×10^{-6}

An attempt was made to measure the ^{8}Li nuclear quadrupole couplings in single crystals of Be and Mg. The experimental procedure was similar to previous measurements made of the ^{12}B and ^{13}B quadrupole couplings in single crystals of Be and Mg.[12,13] The metal stopping foils used in the magnetic moment measurements were simply replaced by single crystals of Be or Mg, and mountings were devised to hold the c axis of the crystal at well-defined angles with respect to the magnetic holding field. Unfortunately the ^{8}Li quadrupole splittings in Be and Mg were too small to allow resolution of the four ^{8}Li quadrupole-resonance lines. However, reversal of the polarity of the magnetic holding field resulted in a shift in frequency of the smeared resonance line. This shift enables one to place upper and lower limits on the quadrupole couplings.[14] For ^{8}Li in Be, 1.3 kHz $\leq |e^2qQ/h| \leq 16$ kHz. For ^{8}Li in Mg, 5.3 kHz $\leq |e^2qQ/h| \leq 24$ kHz.

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