^{13}B Nuclear Magnetic Dipole Moment*

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Polarized ^{13}B nuclei have been produced through the ^{11}B$(t,p)^{13}$B reaction using the 3.5-MeV Van de Graaff accelerator at Brookhaven National Laboratory. The recoiling nuclei were stopped in Au, Pd, and Pt foils, and the effective dipole moments of ^{13}B in these metals were measured by a resonant depolarization technique. From earlier measurements of the spin-lattice relaxation times of ^{12}B in the same metals, the magnetic effects of the stopping foils were estimated. Using a common enhancement factor for the three metals, the ^{13}B magnetic dipole moment was found to be $\mu(^{13}\text{B}) = +3.17712(51)\mu_N$, the plus sign being inferred from the Schmidt limits for odd-proton spin $\frac{3}{2}$ nuclei.

I. INTRODUCTION

This paper reports the work done at Brookhaven National Laboratory using the unstable isotope ^{13}B, which is produced in the reaction ^{11}B$(t,p)^{13}$B and which decays according to the scheme $^{13}\text{B} \rightarrow {}^{13}\text{C} + \beta^- + \bar{\nu}$. The half-life of ^{13}B is 17.3 msec, and the β end-point energy is 13.4 MeV. The angular momenta and parities of the ^{13}B and ^{13}C nuclear ground states are $\frac{3}{2}^-$ and $\frac{1}{2}^-$, respectively, so that the transition is pure Gamow-Teller, and the greatest possible asymmetry in the decay electrons is available. A brief review of the experiment will now be given. The reader is asked to refer to earlier papers[1-3] for more details.

A thin layer of ^{11}B was deposited on Au foil and was bombarded with 2-MeV tritons. The recoiling ^{13}B nuclei were collimated so that the fraction centered about a laboratory recoil angle of 23° was allowed to strike a metal stopping foil. A large magnetic field was applied normal to the reaction plane. The subsequent β decays were detected by two coincidence telescopes, respectively, above and below the reaction plane and with their axis normal to it. Since the recoils are partially polarized perpendicular to the reaction plane by the nuclear reaction, this polarization can be detected by observing the asymmetry in the β-decay counting rates. The largest nuclear polarization thus far observed with ^{13}B, averaged over a 30-msec counting interval, is about 5%.

The resonance lines were obtained by varying the frequency of a perturbing rf field in discrete steps, holding the external magnetic-field constant and measuring the resulting up-down asymmetry at each frequency. The frequency changed approximately once each sec so that random drifts in any part of the system were rapidly averaged out. Figure 1 shows, for example, the ^{13}B resonance in Pd foil.

Field measurements were made with a proton-resonance probe and a crystal-controlled frequency standard. No correction was made for diamagnetism of the probe sample because it is too small to contribute materially to the experimental error. In the example of Fig. 1, the ratio of the ^{13}B resonance frequency to the proton-resonance frequency is 0.379 104(25).

II. RESULTS

The effective g factors obtained for ^{13}B implanted in three fcc metals are given in Table I. The assigned errors include contributions arising from field measurement, field drift, and curve fitting. Any variation in the strength of the perturbing

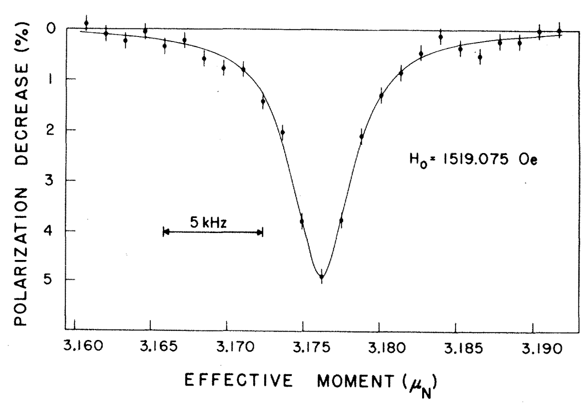

FIG. 1. Typical line shape obtained by the resonant depolarization method for ^{13}B implanted in Pd foil.

TABLE I. Effective g factors and approximate Knight shifts for ^{13}B in each stopping material. The nominal T_1T values for ^{12}B are used to determine the approximate ^{13}B Knight shifts.

Stopping metal	Effective g factor	^{12}B nominal T_1T (sec°K)	Knight shift (Korringa) (units of 10^{-4})	Knight shift (corrected) (units of 10^{-4})
Au	2.119 11(17)	70	3.4	5.4
Pt	2.117 58(16)	300	−1.6	−2.5
Pd	2.117 45(12)	200	−2.0	−3.0

field as a function of its frequency produces effects which are considerably smaller than the other uncertainties.

The effective g factors stand in about the same relation to each other as do the factors previously reported for ^{12}B in the same metals.[3,4] Since the Knight shifts are identical for the two boron isotopes, magnetic corrections were based on our previous measurements of T_1T, the product of spin-lattice relaxation time and absolute temperature, for ^{12}B in these metals.[3] Using the nominal T_1T values given in Table I, approximate Knight shifts were calculated from the Korringa relation.[5] Note that two of these Knight shifts were assumed to be negative as in the ^{12}B case.

Next, values were assumed for the enhancement factors in these metals. In the ^{12}B case it was found that,[3] because of the magnitude of the T_1T values, all reasonable assumptions about the relative sizes of the enhancement factors led to values of the corrected moment of ^{12}B which were within about 100 ppm of the value obtained using the nominal T_1T's of Table I and a common enhancement factor of 2.3. Thus, the corrected Knight shifts of Table I were obtained by multiplying the Korringa values by $(2.3)^{1/2}$. Then, these corrected shifts were multiplied by the approximate value of the ^{13}B g factor, and the products were subtracted from the corresponding effective g factors. The results cluster about the final value of the ^{13}B g factor, namely, $g(^{13}B) = 2.118\,08(34)$. For a nuclear spin of $\frac{3}{2}$, $\mu(^{13}B) = 3.177\,12(51)\mu_N$. If the sign of μ is assumed to be positive, then μ lies near the upper Schmidt limit for an odd-proton nucleus of spin $\frac{3}{2}$. The error assigned to the final values was obtained by adding in quadrature the 100 ppm mentioned above and the three measurement errors of the effective g factors.

An effort is being made to measure the ^{13}B electric quadrupole moment. This is difficult, however, because the large dipolar broadening tends to obscure any asymmetry in the resonance line.

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