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Magnetic Moment of β-Emitter ^8B

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Measurements on the mirror moments of isospin multiplets have been continued. For the $T=1$, two pairs of nuclear magnetic moments have been determined previously.[1,2] In the isospin triplet of $A=8$ ($I^\pi=2^+$, $T=1$), the magnetic moment of ^{8}Li was known,[3] and a measurement on $^8B(T_{1/2}=0.77\ s)$ was undertaken in the present work.

The method used in the present measurement was essentially the same to the previous works on ^{12}B and ^{12}N; NMR utilizing a recoil polarization through a nuclear reaction and the asymmetric β-decay from the polarized nuclei. In the course of the experiment, the ^{6}Li(^{3}He, n)^{8}B reaction was employed. It was largely limited to look for optimum conditions for polarization and counting rates because the maximum recoil angle of ^{8}B was $\theta\sim15°$ around 4 MeV of incident energy due to the reaction kinematics. Only a few percent of β-decay asymmetry was found. Thus it was desirable if the detectable NMR effect in the β-decay asymmetry could be increased. A polarization reversal by the adiabatic-passage method was utilized in which the rf frequency was swept in a definit range while the magnetic field was held constant. The resultant observable change in the β-decay asymmetry was twice compared with the initial asymmetry, which corresponded to four times increase in the effective counting rates. It was also sufficient to apply the rf for a short period and the disturbing effect due to the rf was minimized. The necessary conditions for the adiabatic passage are known as $(\gamma H_1)^2\gg\Delta\omega/\Delta t$, and $(\gamma H_1)\gtrsim2\pi D$, where $(\Delta\omega/\Delta t)$ is the sweep rate of the rf frequency and D is the dipolar broadening due to the surrounding nuclear magnetic moments.

The target was ^{6}LiF of $\sim$40 μg/cm^2 evapolated on a thick copper backing, and the backing was attached on a supporting rod of good heat conduction, which was cooled by a water flow. The glancing angle of the target was 5° to the incident beam and the recoil ^{8}B ejected from the same surface into $\theta\sim13°$ were implanted in a recoil stopper. A good production rate of ^{8}B was possible by employing an incident beam of high intensity ($\sim$50 μA). The polarization of the recoil ^{8}B during the flight in the vacuum was preserved by a strong magnetic field ($\sim$7 kG) which was parpendicular to the reaction plane formed by the directions of the incident beam of particles and of the recoil ^{8}B. The β particles were counted during every 3 sec after 1 sec of a beam bombardment period. The rf was applied once in every two beam cycles during 10 ms between the counting and the beam period. In the actual measurement each counting period was further divided into two sections and the rf was applied at the end of the first section (I) to make the effect in the second section (II) reversed from the first.

The observable asymmetry changes $\Delta_I(H)$, $\Delta_{II}(H)$ for both sections with the magnetic field H and the sweep range from ω_i to ω_f are $\Delta_I=A(1+S)$ and $\Delta_{II}(H)=-A'S(1+S)$, where A and A' are the initial detectable β-decay asymmetry in the both sections and S is given by

$$S=(\omega\ -\gamma H)(\gamma H-\omega_f)\cdot[\{(\omega_i-\gamma H)^2+(\gamma H_1)^2\}\times\{(\omega_f-\gamma H)^2+(\gamma H_1)^2\}]^{-1/2}\,.$$

A Pt foil was found to be suitable to preserve the polarization during the nuclear lifetime of about one second. However, the useful lifetime as a good stopper depended rather critically on each sample and its annealing treatment.

The initial search for the resonance conditions in the NMR was made with a sweep range of 3% in the rf frequency at $E(^3\mathrm{He})=3.8$ MeV, and an asymmetry change of about 3% was observed. The observable β-decay asymmetry was measured as a function of the incident energy and the result is shown in Fig. 1. It is noted, for example, that the asymmetry change obtained by the polarization destruction method at $E(^3\mathrm{He})=4.0$ MeV was $\sim$3.5%. This is almost a half of the asymmetry change obtained by the adiabatic passage method at the energy.

A final resonance spectrum was obtained with a sweep range of 0.5% of the rf frequency at $E(^3\mathrm{He})=4.0$ MeV as shown in Fig. 2 and in Table I. A slight decrease was found in the asymmetry change in the §II compared with the §I as shown in Fig. 2, this is due to the finite spin-lattice-relaxation time. The relaxation time was deduced to be $\sim$3.4 sec

Table I. Magnetic moment of ^{8}B.

Counting section		I	II
H_0 in unit of proton$^+$ res. freq. (MHz)		20.5493 (55)	20.5434 (100)
Rf sweep range (MHz)		1.89980~1.90896	
	center	1.90438	
$\mu_{uncorrected}$(nm)		1.03526 (29)	1.03553 (50)
$\mu_{corrected}$(nm)*		1.03545 (29)	1.03573 (50)
	average	1.03551 (25)	

$^+$ Diamagnetism of proton in water was corrected ($2.56 \cdot 10^{-5}$).
* Diamagnetism of boron was corrected ($1.99 \cdot 10^{-4}$).

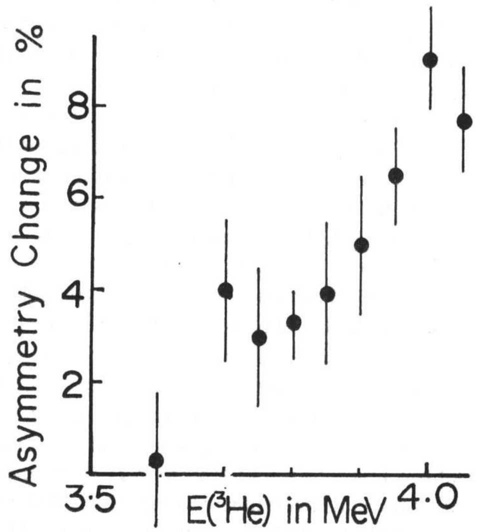

Fig. 1. β-decay asymmetry as a function of the incident energy of ^{3}He. The asymmetry change was detected by the adiabatic passage method.

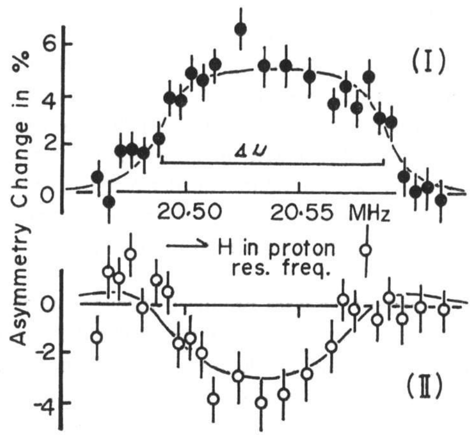

Fig. 2. NMR spectra of ^{8}B in Pt by the adiabatic passage method.

at room temperature, which was longer than the nuclear lifetime $T_{1/2} = 0.77$ *s*. The most uncertain correction to the moment value might come from the Knight shift. In this respect it is known that the Knight shift of Al(III) in Pd to be ($-1/20$) times smaller than the estimated value by the Korringa relation.[4] Considering the character of Pt metal in comparison with Pd metal, it could be said at least that the Knight shift of B(III) in Pt sample do not exceed the value estimated by the Korringa relation, 1.7×10^{-4} which was smaller than the experimental error. The magnetic moment of ^{8}B was determined to be $\mu(I^\pi = 2^+) = 1.0355 \pm .0003$ nm without the correction due to the Knight shift.

The magnetic moment of ^{8}Li is known to be $\mu(^8\text{Li}) = +1.6532 \pm .0008$ nm.[3] Kurath predicted values using their wave function as $\mu(^8\text{Li}) = +1.556$ nm and $\mu(^8\text{B}) = +1.095$ nm with the $(6-16)$2B interaction.[5] The predicted values are rather in good agreement to the experimental values in this pair of the magnetic moments.

References

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