LBL-36608
UC-413

Magnetic Moment of Proton Drip-line Nucleus ^9C

K.Matsuta[a], M. Fukuda[a], M.Tanigaki[a], T.Minamisono[a], Y.Nojiri[a], M.Mihara[a], T.Onishi[a], T.Yamaguchi[a], A.Harada[a], M.Sasaki[a], T.Miyake[a], S.Fukuda[b], K.Yoshida[b], A.Ozawa[b], T.Kobayashi[b], I.Tanihata[b], J.R.Alonso[c], G.F.Krebs[c], and T.J.M.Symons[c]

[a] *Osaka University, Toyonaka, Osaka 560, Japan*
[b] *RIKEN, Wako, Saitama 351-01, Japan*
[c] *Lawrence Berkeley Laboratory, Berkeley, California 94720, USA*

October 1994

MASTER

This work was supported in part by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098 and by a National Aeronautics and Space Administration Research Training Grant (NGT-50783) and the University of California.

RWR

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Magnetic moment of proton drip-line nucleus ^{9}C

K. Matsuta,[a] M. Fukuda,[a] M. Tanigaki,[a] T. Minamisono,[a] Y. Nojiri,[a] M. Mihara,[a] T. Onishi,[a] T. Yamaguchi,[a] A. Harada,[a] M. Sasaki,[a] T. Miyake,[a] S. Fukuda,[b] K. Yoshida,[b] A. Ozawa,[b] T. Kobayashi,[b] I. Tanihata,[b] J.R. Alonso,[c] G.F. Krebs[c] and T.J.M. Symons[c]

[a]Osaka University, Toyonaka, Osaka 560, Japan
[b] RIKEN, Wako, Saitama 351-01, Japan
[c] Lawrence Berkeley Laboratory, Berkeley, California 94720, USA

The magnetic moment of the proton drip-line nucleus ^{9}C(I^π=3/2$^-$,$T_{1/2}$=126 ms) has been measured for the first time, using the β-NMR detection technique with polarized radioactive beams. The measured value for the magnetic moment is $|\mu(^9C)|$=1.3914±0.0005 μ_N. The deduced spin expectation value $<\sigma>$ of 1.44 is unusually larger than any other ones of even-odd nuclei.

1. INTRODUCTION

In the light mass region, most of the magnetic moments of isospin T=1/2 mirror pairs are known up to mass number A=41. All the magnetic moments of T=1 mirror pairs in the p-shell are also known. However, none of the magnetic moment measurements for T=3/2 pairs has been completed up until now, although some of the magnetic moments of neutron-rich partners are known. This is mainly due to the difficulty in the production of these nuclei especially on the proton rich side. Actually, some of these nuclei lie on the proton drip line.

The technique of polarized radioactive beams has proven its effectiveness in the study of nuclear moments for nuclei far from stability[1-4]. In the present experiment, this powerful technique has been applied to the β-NMR study of the proton drip-line nucleus ^{9}C(I^π=3/2$^-$,$T_{1/2}$=126 ms), a T=3/2 mirror pair with ^{9}Li. As a result, we have been able to measure the magnetic moment of ^{9}C for the first time.

2. EXPERIMENTAL PROCEDURE

^{9}C nuclei were produced through the 67 A MeV ^{12}C+^{12}C collision using ^{12}C beam from the K540 cyclotron at RIKEN. ^{9}C nuclei emerging from the target at 5°±2° were selected by a slit and were separated by the RIPS (RIKEN Projectile Fragment Separator). In the RIPS separator, ^{9}C nuclei which have the momentum 5%±1% larger than the one corresponding to the beam velocity were selected. These selection criteria for the angle and the momentum help ensure a high degree of polarization for the ^{9}C nuclei. They were then slowed down by an energy degrader and were implanted in a cooled Pt catcher foil (T=30K) placed in a strong magnetic field (H_0=4.0 kOe) to maintain the polarization. Beta rays emitted from the stopped ^{9}C were observed by two sets of plastic scintillation counter telescopes placed above and below the catcher relative to the polarization axis. Nuclear Magnetic Resonance (NMR) was observed for ^{9}C by means of asymmetries in these beta-ray counters.

3. RESULTS AND DISCUSSION

3.1. Magnetic moment

NMR spectrum obtained from the polarization destruction method is shown in Figure 1. By fitting a Lorentzian to the NMR spectrum, the resonance frequency was obtained as ν_L=2827.3±0.4 kHz. The external magnetic field was calibrated by NMR on ^{8}B in Pt, as H_0=3.9997±0.0010 kOe. From the frequency and the magnetic field, the uncorrected value for the magnetic moment of ^{9}C was obtained to be 1.3910±0.0004. Correction for the diamagnetism was taken from ref. [5] as σ=2.67x10^{-4}. Knight shift was estimated to be K<2.5 x 10^{-4} from the relaxation time T_1 of ^{23}Mg polarization implanted in Pt, i.e., T_1 ~ 1000 Ks[6]. This Knight shift was not corrected, but was included in the error. Finally, the magnetic moment of ^{9}C was determined as;

$$|\mu(^{9}C)| = 1.3914 \pm 0.0005\ \mu_N.$$

The sign of the $\mu(^{9}C)$ can be reasonably assumed to be negative, since all the predicted values, including the Schmidt value, are negative. The obtained magnetic moment is very much quenched from the Schmidt value -1.91 μ_N. Compared with the theoretical values listed in Table 1, the absolute value of the observed magnetic moment is smaller than any theoretical values. The value predicted by multi-cluster model seems to fit best, but is still 0.1 μ_N larger than the present experimental value.

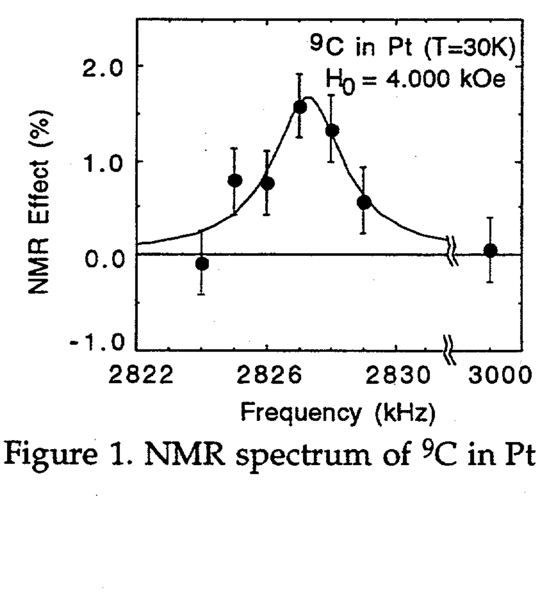

Figure 1. NMR spectrum of ^{9}C in Pt

Table 1. Comparison of experimental magnetic moments and theoretical predictions. Magnetic moments are in the unit of μ_N.

	exp.	Simple[c]	Shell model[d]	Cluster model[e]
$\mu(^9C)$	(-)1.3914(5)[a]	-1.62	-1.59	-1.50
$\mu(^9Li)$	+3.4391(6)[b]	-	+3.48	+3.57
$<\sigma>$	1.44	0.84	1.03	1.50

[a] present result, [b] Ref. [7], [c] based on Ref. [8], [d] Ref. [9], [e] Ref. [10]

3.2. Isoscalar moment

Using the isoscalar-moment analysis summarized by the relation[11];

$\mu(T_z=-3/2)+\mu(T_z=+3/2)=J+(\mu_p+\mu_n-1/2)<\sigma>$,
where $\mu_p+\mu_n-1/2=0.380$,

with the known magnetic moment $\mu(^9Li)=3.4391\pm0.0006\mu_N$ [7], the spin expectation value is found to be $<\sigma>=1.44$. This value is unusually large compared with $T=1/2$ mirror nuclei as clearly shown in Figure 2. As listed in Table 1, the simple model from systematics predicts a much smaller $<\sigma>$ value. This present large $<\sigma>$ value cannot be well explained by the shell model calculation, either. This discrepancy may be attributed to unknown anomalous structure of the proton drip-line nucleus, since the above mentioned discussions are based on the systematics come from $T=1/2$ mirror pairs which lie in a much more stable region.

The $<\sigma>$ value deduced for the multi-cluster model using above discussed isoscalar formula seems to fit best to the present experimental value, as shown in Table 1. What this implies, however, is not known yet.

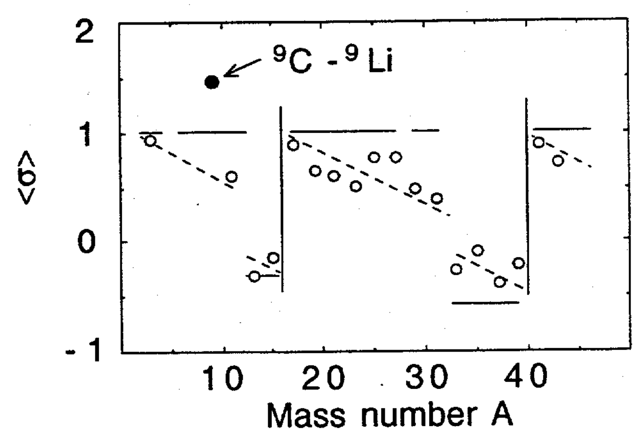

Figure 2. Spin expectation values for mirror nuclei.

3.3. Odd-even analysis

Ignoring the contribution from the even nucleon group, the g-factors of mirror pairs g(p) and g(n) are expressed as follows according to Buck and Perez[8];

$$g(\mathrm{p}) = g_l^p + (g_s^p - g_l^p)\, S_z/J,$$
$$g(\mathrm{n}) = g_l^n + (g_s^n - g_l^n)\, S_z/J,$$

where g(p) and g(n) are the nuclear g-factors for odd-proton nucleus and odd-neutron nucleus. Connecting these two equations at the same S_z/J value, the g(p) and g(n) can be mapped on a straight line as;

$$g(\mathrm{p}) = \mathrm{a}\, g(\mathrm{n}) + \mathrm{b},$$
where $\mathrm{a}=(g_s^p-g_l^p)/(g_s^n-g_l^n)$ and $\mathrm{b}=(g_l^p g_s^n-g_s^p g_l^n)/(g_s^n-g_l^n)$.

Using the free nucleon g-factors, parameters a and b are given as a=-1.199 and b=1. Magnetic moments of T=1/2 mirror pairs fall on a straight line slightly different from the one with the free nucleon g-factors. The most suitable parameters a and b for this line are -1.154 and 1.046, respectively. However, the present ^{9}C-^{9}Li pair moments deviate from this line. If the deviation is interpreted by the difference in S_z values between the mirror nuclei, the difference ΔS_z should be 0.09. This absolute $|\Delta S_z|$ value is much larger than seen in any other mirror pairs; typical $|\Delta S_z|$ values are less than 0.03.

If ΔS_z is really non zero, this would imply violation of the mirror symmetry. Two more reasonable explanations are: a slight difference in the effective g-factors for T=3/2 mirror pairs, and a significant contribution from the even nucleon group.

REFERENCES

1. K. Matsuta et al., Hyperfine Interactions 78 (1993) 123.
2. K. Asahi et al., Proc. 2nd Int. Conf. on Radioactive Nuclear Beams, Louvain- la Neuve, Belgium, 1991, ed. Th Delbar (IOP Publishing, London 1992) 155.
3. H. Okuno et al., Hyperfine Interactions 78 (1993) 97.
4. H. Izumi, Proc. of Symp. on Science with Short Lived Nuclear Beams '93, Dec. 16-18, 1993, Tokyo Japan, ed. S. Kubono and T. Ohtsuka :(JHP-Suppl.-15, 1994) 49.
5. Table of Isotopes, 7th ed., ed. C.M. Lederer and V.S. Shirley, (John Wiley & Sons Inc., New York, 1978) Appendices 43.; F.D. Feiock and W.R. Johnson, Phys. Rev. 187 (1969) 39.
6. measured by present authors; being considered publication.
7. For 3.4391=0.0006: F.D. Correll et al., Phys. Rev. C28 (1983) 862; For 3.4335±0.0052: E. Arnold et al., Z. Phys. A331 (1988) 295.
8. B. Buck and S.M. Perez, Phys. Rev. Lett. 50 (1983) 1975.
9. H. Sagawa and H. Kitagawa, private communication.
10. K. Varga, Y. Suzuki, et al., to be submitted to Phys. Rev. C
11. K. Sugimoto, J. Phys. Soc. Jpn. 34 suppl. (1973) 197.