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II-6 Measurement of the Spin and Nuclear Magnetic Moment of the 345 msec ^{36}K

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In recent years a number of magnetic moments of short-lived light nuclei which belong to $T=1/2$ mirror pairs have been measured. They were examined under the assumption that $\mu=\mu_0$(isoscalar) $+\mu_3$(isovector). Especially the isoscalar part was found to agree satisfactory with theoretical predictions.[1,2]

For the next higher isospin multiplets $T=1$ equivalent systematical information is much poorer. Only for the mass numbers $A=12$ and $A=20$ the moments of both the $T_3=\pm1$ members of the triplet could be measured.[3,4] Measurements in the very short-lived third state $T_3=0$ are completely missing. We report here on the determination of $\mu_I(^{36}\text{K})$ the missing $T_3=+1$ member of the $A=36$ triplet. Together with the measurement of $\mu_I(^{8}\text{B})$ which is reported by another group at this conference[3] the knowledge on isotriplet moments is considerably improved.

§1. Experimental

The experimental method is essentially similar to our previous works.[4,6] Figure 1 shows the principle of our apparatus. ^{36}K is produced by the reaction ^{36}Ar(p, n)^{36}K using an external 17 MeV proton beam from the Karlsruhe Isochronous Cyclotron. The target consists of a glass bulb filled with 200 Torr of enriched ^{36}Ar. Polarization of the ^{36}K nuclei ($T_{1/2}=345$ ms; $E_{\beta\max}=9.9$ MeV) is achieved by spin exchange scattering with optically pumped ^{87}Rb. The β-decay asymmetry of ^{36}K is used for detecting nuclear polarization. Rf transitions between hfs Zeeman levels of the electronic $^2S_{1/2}$ ground state manifest themselves in a decrease of nuclear polarization and thus in a decrease of β-asymmetry.

§2. Measurement

The particular choice of resonance experiment is

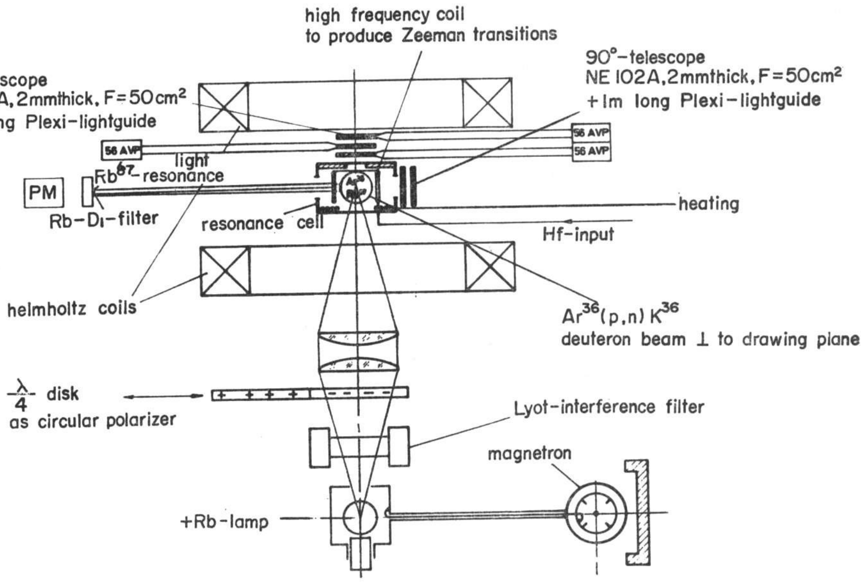

Fig. 1. Experimental arrangement.

guided by the Breit-Rabi formula.[7] Expanded up to second order in the Zeeman effect it yields for the transition frequencies $\Delta F = 0$, $\Delta m_F = \pm 1$ in the hfs of a $^2S_{1/2}$ state

$$\nu_{m_F, m_F - 1} = \frac{g_J \mu_B H_0}{(2I+1)h} \mp \frac{\mu_n I(2m_F - 1)(\mu_B g_J H_0)^2}{\mu_I H_e(0)(2I+1)^3 h} \qquad (1)$$

g_J: electron g-factor, I and μ_I: nuclear spin and magnetic moment respectively, μ_B and μ_n: Bohr's and nuclear magneton respectively, m_F: magnetic quantum number, $H_e(0)$: hyperfine field of the electrons, h: Planck's constant, H_0: static magnetic field.

Figure 2(a) shows the computer on-line display of the spin measurement. According to (1) the quadratic term vanishes for the low magnetic field of 3 Gauss. Thus the Zeeman transitions ν_{m_F, m_F-1} coincide and depend only on I. The asymmetry of about 1% is destroyed at two frequencies corresponding to $I = 3/2$ and $I = 2$. The first resonance is due to ^{87}Rb which is used for spin exchange. The second must be attributed to ^{36}K and we conclude

$$I(^{36}\mathrm{K}) = 2 \ .$$

If H_0 is increased the μ_I-sensitive quadratic term becomes observable and the transitions are no longer equidistant. In order to get a large nuclear depolarization we apply several transition frequencies ν_{m_F, m_F-1} simultaneously. At fixed magnetic field the frequencies are calculated as a function of the parameter μ_n/μ_I. The resonance pattern of Fig. 2(b) represents the β-asymmetry as a function of this parameter. A set of four frequencies was swept in order to saturate four out of five possible transitions. In the minimum at $\mu_n/\mu_I = 1.8$ resonance occurs for all these frequencies. At the small dip at $\mu_n/\mu_I = 1.0$ two out of the four frequencies happen to take the same value as in the deep minimum. The accuracy was improved by applying higher magnetic field. At $H_0 = 60$ Gauss we obtained

$$\mu_I/\mu_n = 0.547(3)$$

The result is not corrected for diamagnetic shielding nor hfs anomaly which are supposed to be smaller than the quoted error.

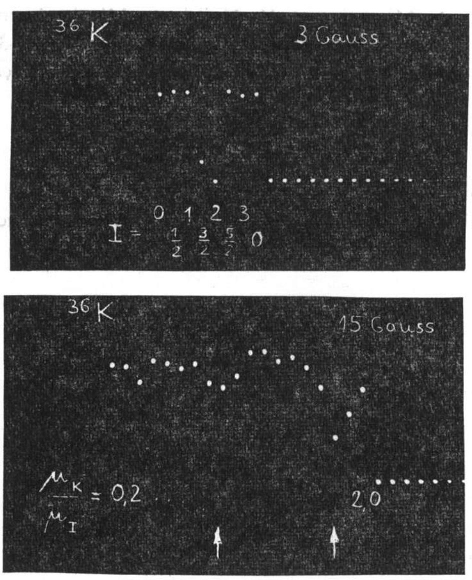

Fig. 2. Typical resonance patterns.
a) Spin measurement.
b) Measurement of magnetic moment.

§3. Discussion

The present experiment brings to four the number of $T = 1$ mirror pairs whose magnetic moments are known. Except for the lightest one ($A = 8$) they are discussed in pure *jj*-coupling. In this approximation the magnetic moment of an odd-odd nucleus is given by

$$\mu_I(Z, N) = 1/2(g_p + g_n)I + (g_p - g_n)\frac{I_p(I_p+1) - I_n(I_n+1)}{2(I+1)} \qquad (2)$$

with g_p, g_n representing the g-factors and I_p, I_n the total angular momenta of the odd proton and neutron groups respectively. We confine ourselves to discuss the isoscalar part of the moments of the $T = 1$ pairs

$$2\mu_0 = \mu_I(A/2 + 1, A/2 - 1) + \mu_I(A/2 - 1, A/2 + 1) \ . \qquad (3)$$

If the moment of the nucleus ($Z = A/2 \pm 1$, $N = A/2 \mp 1$) is composed of the g-factors of the neighbours ($Z \mp 1, N$) and ($Z, N \pm 1$) then by eqs. (2) and (3) the isoscalar moment of the isospin triplet is expressed by the isoscalar parts of the two neighbouring isospin doublets.

The following table shows that this coupling scheme works quite satisfactory. The measured magnetic moments as well as their sums are listed in the first column. The values of the second column are obtained by *jj*-coupling of free nucleon g-factors. Though the predictions of the individual moments

Table I. Magnetic moments of $T = 1$ mirror pairs.

Nucleus	μ Experimental	μ Computed using free nucleon g-factors	μ Computed using measured g-factors
^{12}B	1.003	2.84	1.89
^{12}N	0.457	−1.46	−0.64
Sum	1.460	1.38	1.25
^{20}F	2.094	1.152	1.967
^{20}Na	0.369	1.152	0.500
Sum	2.463	2.304	2.467
^{36}Cl	1.285	0.849	1.18 (13)
^{36}K	0.547	0.849	0.557
Sum	1.832	1.698	1.74 (13)

are rather bad the sums agree reasonably with experiment. Better agreement can be obtained by using the measured g-factors of the neighbours (third column), a semiempirical procedure which gives satisfactory results even for individual odd-odd nuclei.[8] The Table I shows that this simple model works excellently for the scalar moments of $A = 20$ and $A = 36$. The agreement is reasonable for the very light pair $A = 12$.

Our coupling scheme demands that the whole neighbourhood of the mirror pair in question should be known from experiment. In the present case there is indeed one weak point, the moment of ^{37}Ar which is very roughly known.[9] This manifests itself in the large error of the semiempirical value of $A = 36$. As Talmi[2] pointed out the ^{37}Ar moment, quoted as 0.95 (20) μ_n, is probably rather close to the upper limit of the error interval. This assumption is supported by the present discussion. In our coupling scheme the best fit of experimental data is obtained by using 1.09 as the magnetic moment of ^{37}Ar.

References

1) R. Leonardi and M. Rosa-Clot: Phys. Rev. Letters **21** (1968) 377.
2) I. Talmi: *Proc. Intern. Conf. on Hyperfine Interactions detected by nuclear radiation, Rehovot and Jerusalem, 1970.*
3) K. Sugimoto, K. Nakai, K. Matuda and T. Minamisono: J. Phys. Soc. Japan **25** (1968) 1258.
4) J. Bonn, E. W. Otten, Ch. von Platen, W. Linder, H. Müller and H. Schweickert: *Proc. Intern. Conf. on the properties of nuclei far from the region of β-stability, Leysin, 1970.*
5) T. Minamisono, Y. Nojiri, A. Mizobuchi and K. Sugimoto, presented at this conference II–3.
6) U. Köpf, H. J. Besch, E. W. Otten and Ch. von Platen: Z. Phys. **226** (1969) 297.
7) P. Kusch and V. W. Hughes: *Handbuch der Physik* (Berlin, 1959) Vol. XXXVII/1, p. 96.
8) H. M. Schwartz: Phys. Rev. **89** (1953) 1293.
9) M. M. Robertson, J. E. Mack and V. W. Cohen: Phys. Rev. **140** (1965) B820.