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NUCLEAR SPIN OF A NEW ISOMER IN ^{119}Cs AND MAGNETIC MOMENT OF ^{120}Cs -EVIDENCE FOR STRONGLY DEFORMED NUCLEAR SHAPES OF THE LIGHT CESIUM ISOTOPESC. Ekström¹

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ABSTRACT

The nuclear spin, $I = 3/2$, of a new isomer in ^{119}Cs and the magnetic moment, $\mu_I = 3.92(5)$ n.m., of ^{120}Cs have been determined in on-line ABMR experiments at the ISOLDE Facility, CERN. The experimental data give evidence for strongly deformed nuclear shapes of the light cesium isotopes.

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In a recent paper [1] we reported the results from spin and moment measurements on cesium isotopes in the mass range $A = 120-135$. The data indicated a gradual change to deformed nuclear shapes with decreasing mass number. Here, we present further results on the light cesium isotopes; the nuclear spin of a new isomer in ^{119}Cs and the magnetic moment of ^{120}Cs , giving evidence for strongly deformed nuclear shapes in this mass region.

The radioactive cesium isotopes studied in this work were obtained as spallation products in a target of lanthanum irradiated by 600 MeV protons from the CERN synchro-cyclotron. Following on-line mass separation in the ISOLDE isotope separator [2], the cesium ions were directed to the oven section of the ABMR apparatus, in which an atomic-beam was formed by continuous evaporation from a heated foil of tantalum covered by a layer of yttrium. The design and operation of the on-line ABMR apparatus are described in detail in ref. [3].

The experimental procedure used for the spin and moment determinations follows closely that described in ref. [1]. The measurements were made in the $^2S_{1/2}$ atomic ground state, limiting us to the study of the magnetic dipole hyperfine structure interaction.

The spin measurements were performed in weak external magnetic fields by observing the Zeeman transitions changing the sign of the magnetic quantum number associated with the electronic angular momentum. In this operation mode, the ABMR apparatus may be regarded as a spin or isomer separator with the potential of discovering new isomers. Actually, the spin $I = 9/2$ isomer in ^{121}Cs was first identified in this way [1]. In our continued systematic investigations of the light cesium isotopes we discovered a new isomer in ^{119}Cs with the nuclear spin $I = 3/2$ in addition to the previously known ground state with $I = 9/2$ [4]. The spin resonances were observed at two different settings of the external magnetic field; 0.23 and 0.39 mT. The half-life of the isomer has subsequently been measured to be 28(1) sec. [5]. Experiments were also made in an attempt to measure the nuclear spins of $^{118}, ^{118\text{m}}\text{Cs}$, $^{120\text{m}}\text{Cs}$ and $^{123\text{m}}\text{Cs}$. However, no resonances were observed, probably because of too low production yields of these states for our applications.

In order to determine the magnetic moment of the $I = 2$ state in ^{120}Cs , the deviations from the "linear" Zeeman-frequencies were determined in successively stronger external magnetic fields. The resonances recorded at the field settings 0.72 and 1.42 mT showed a slight negative deviation, indicating that we were dealing with a nucleus with a large positive magnetic moment. At 2.85 mT we obtained a broad, ≈ 100 kHz FWHM, resonance curve due to a multiplet of unresolved multiple-quantum transitions. These were completely resolved at the field strengths 5.86 and 11.48 mT; the separations being ≈ 70 and ≈ 275 kHz, respectively,

with line widths of 20-40 kHz FWHM. Because of the large hyperfine structure separation, the magnetic fields of the focusing magnets were not sufficiently strong to give a complete decoupling of the nuclear and electronic angular momenta, resulting in a decreased transmission for the low-quantum transitions [6].

In table 1 we give the experimentally observed resonance frequencies together with the only consistent set of multiple-quantum assignments. The residuals, $\nu_{\text{res}} - \nu_{\text{fit}}$, obtained in a fitting of the resonances to the Breit-Rabi formula are shown in column 3. The fitting procedure gave a hyperfine structure separation of 15250 (125) MHz, from which a nuclear magnetic moment of 3.916 (32) n.m. was extracted using the methods of ref. [1]. Allowing for a 1% hyperfine anomaly we obtain as a final result for the magnetic moment of the $I = 2$ state in ^{120}Cs :

$$\mu_I = 3.92 (5) \text{ n.m.}$$

A systematic discussion of the nuclear structure in the cesium region was presented in ref. [1] in connection with our hyperfine structure measurements in the mass range $A = 120-135$. Of particular interest is the gradual change to deformed nuclear shapes with decreasing mass number, as evidenced by the experimental data on nuclear spins and moments. The results of the present work add further pieces of evidence to this picture.

Experimental data on half-lives, spins and magnetic moments of the ground and isomeric states in $^{119-123}\text{Cs}$, together with probable Nilsson model assignments, are collected in table 2. The ground state spin sequence $I = \frac{1}{2}$ (^{123}Cs), $I = \frac{3}{2}$ (^{121}Cs) and $I = \frac{9}{2}$ (^{119}Cs) is reproduced by the orbitals $[420 \frac{1}{2}]$, $[422 \frac{3}{2}]$ and $[404 \frac{9}{2}]$ of the 55th proton in the Nilsson diagram, indicating an increasing deformation with decreasing mass number (cf. ref. [1]). The $I = \frac{3}{2}$ and $I = \frac{9}{2}$ isomeric states in ^{119}Cs and ^{121}Cs , respectively, may thus be given the assignments $[422 \frac{3}{2}]$ and $[404 \frac{9}{2}]$. The excitation energy of the isomeric state in ^{121}Cs is about 40 keV [7], while it is not known in ^{119}Cs . The level order of the $\frac{9}{2}$ and $\frac{3}{2}$ states in ^{119}Cs is based on the observation of the $\frac{9}{2}$ state in the β -RADOP experiment [4]. The small rotation parameter, $\hbar^2/2\mathcal{J} \approx 22$ keV, of the rotational bands built on the $\frac{9}{2}$ states in $^{119,121}\text{Cs}$ [7] is consistent with the interpretation above; i.e. a strong nuclear deformation of the states.

The large magnetic moment of the doubly-odd nucleus ^{120}Cs , $\mu_I = 3.92 (5) \text{ n.m.}$, clearly shows that the proton contribution comes from the orbital $[404 \frac{9}{2}]$. The configuration assignment suggested on basis of the measured nuclear spin [1] evidently has to be revised. At deformations $\epsilon = 0.25-0.30$, two orbitals are available for the 65th neutron; $[532 \frac{5}{2}]$ and $[413 \frac{5}{2}]$. Coupled to the $[404 \frac{9}{2}]$ proton, both may explain the nuclear spin $I = 2$, the latter, however, with

coupling according to the rules of Gallagher and Moszkowski [8]. As shown in fig. 1, the configuration $2^+ \{p[404 \frac{9}{2}] \ n[413 \frac{5}{2}]\}$ also gives the closest agreement between the experimental and theoretical magnetic moments in ^{120}Cs .

In fig. 1, we also compare experimental and theoretical magnetic moments of the nuclides ^{122}Cs and ^{124}Cs . It is seen that the difference between the moments is well reproduced. The theoretical absolute values are, however, somewhat too large.

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REFERENCES

- [1] C. Ekström, S. Ingelman, G. Wannberg and M. Skarestad, Nucl. Phys. A292 (1977) 144.
- [2] H.L. Ravn, L.C. Carraz, J. Denimal, E. Kugler, M. Skarestad, S. Sundell and L. Westgaard, Nucl. Instr. and Meth. 139 (1976) 267.
- [3] C. Ekström, S. Ingelman and G. Wannberg, Nucl. Instr. and Meth. 148 (1978) 17.
- [4] H. Fischer, P. Dabkiewicz, P. Freilinger, H.-J. Kluge, H. Kremmling, R. Neugart and E.-W. Otten, Z. Physik A284 (1978) 3.
- [5] A. Charvet, J. Genevey-Rivier, A. Huck, G. Klotz, A. Knipper, G. Marguier, C. Richard-Serre and G. Walter, Contr. to the Nucl. Phys. Conf., Edinburgh (1978).
- [6] C. Ekström, M. Olsmats and B. Wannberg, Nucl. Instr. and Meth. 103 (1972) 13.
- [7] U. Garg, T.P. Sjoreen and D.B. Fossan, Proc. Int. Conf. on Nucl. Structure, Tokyo (1976).
- [8] C.J. Gallagher Jr. and S.A. Moszkowski, Phys. Rev. 111 (1958) 1282.
- [9] Karlsruher Nuklidkarte, 4. Auflage (1974).
- [10] J. Genevey-Rivier, A. Charvet, G. Marguier, C. Richard-Serre, J. D'Auria, A. Huck, G. Klotz, A. Knipper and G. Walter, Nucl. Phys. A283 (1977) 45.

Table 1 : Resonance transitions observed in ^{120}Cs

Transition (F, m_F) $\rightarrow$ ($F', m_{F'}$)	Resonance frequency ν_{res} (MHz)	Residual (MHz)
$(^5/2, ^3/2) \rightarrow (^5/2, -^5/2)$	32.851(5) a)	0.000
	64.496(6) b)	0.002
$(^5/2, ^1/2) \rightarrow (^5/2, -^5/2)$	32.921(7) a)	-0.001
	64.767(7) b)	0.000
$(^5/2, -^1/2) \rightarrow (^5/2, -^5/2)$	32.992(8) a)	-0.001
	65.044(9) b)	-0.001
$(^5/2, -^3/2) \rightarrow (^5/2, -^5/2)$	33.065(10) a)	-0.001

External magnetic field : a) 5.8603(7) mT

b) 11.4820(6) mT

Table 2 : Nuclear properties of $^{119-123}\text{Cs}$.

	^{119}Cs	^{120}Cs	^{121}Cs	^{122}Cs	^{123}Cs
Isomeric state	$T_{1/2}$ I μ n.m. p-conf. n-conf.	57 sec [10]	2.9 min $9/2$ [404 $9/2$]	4.2 min [9] 8 [404 $9/2$] [523 $7/2$]	1.6 sec [9]
Ground state	$T_{1/2}$ I μ n.m. p-conf. n-conf. N	64 sec [10] 2 3.92(5) α [404 $9/2$] [413 $5/2$] 65	2.1 min $3/2$ 0.785(16) [422 $3/2$] 66	21 sec [9] 1 0.133(2) [422 $3/2$] [411 $1/2$] 67	5.9 min $1/2$ 1.389(16) [420 $1/2$] 68

α) This work.

FIGURE CAPTION

Fig. 1 : Comparison between experimental and theoretical magnetic moments of some doubly-odd cesium isotopes. The theoretical moments are calculated within the Nilsson model using the "extrapolated" shell parameters; $\kappa_p = 0.0662$, $\mu_p = 0.540$ and $\kappa_n = 0.0637$, $\mu_n = 0.450$ (cf. ref. [1]). Two different g_s -factors have been used in the calculations; $g_s = g_s^{\text{free}}$ and $g_s = 0.6 g_s^{\text{free}}$. The corresponding magnetic moments are given by dashed and solid lines.

Fig. 1