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III.d. Magnetic Moments of Excited $9/2^+$ States around $A = 70$ Experimental Values for ^{67}Zn and ^{67}Ge

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Measurements of nuclear magnetic dipole moments of excited $9/2^+$ states by means of perturbed angular distribution following nuclear reactions were performed at the 7-MV van de Graaff accelerator of the Hahn-Meitner-Institut, Berlin. The moments are summarized in Table I. This paper gives a systematic compilation of these moments of $9/2^+$ states of odd neutron and odd proton nuclei in the mass region around $A = 70$. Among them the moments of the $9/2^+$ states in ^{67}Zn and ^{67}Ge are presented which have not yet been reported.

The aim of these investigations was to study the influence of additional proton and neutron pairs on the magnetic moments and to deduce appropriate configurations for these states by comparing measured values with theoretical predictions.

Experimental Determination of the Magnetic Moments of $9/2^+$ States of ^{67}Zn and ^{67}Ge

The $9/2^+$ states in ^{67}Zn and ^{67}Ge were populated and oriented by a 13-MeV α particle beam via the reactions ^{64}Ni(α, n) ^{67}Zn and ^{64}Zn(α, n)^{67}Ge. The repetition time of the pulsed beam was 1 μs. The observation of γ-rays was carried out with NaI(Tl) scintillation counters. In ^{67}Zn the ground statetransition of 605 keV was detected. In ^{67}Ge the γ-transition of

Table I. Magnetic moments of excited $9/2^+$ states.

	Nucleus	State [keV]	$T_{1/2}$[s]	μ_{exp}[n.m.]
Odd Neutron	^{67}Zn	605	$3.4(3) \times 10^{-7}$	-1.094 (20)[a]
	^{67}Ge	734(?)	$7.0(7) \times 10^{-8}$	-0.945 (30)[a]
	^{69}Ge	398	2.8×10^{-6}	$-1.0008(32)$[b]
	^{71}Ge	198	2.0×10^{-2}	$-1.0368(23)$[b]
Odd Proton	^{71}As	1000	2.0×10^{-8}	$+5.108$ (45)[b]
	^{73}As	426	5.8×10^{-6}	$+5.234$ (14)[b]
	^{77}As	473	1.16×10^{-4}	$+5.522$ (9)[b]
	^{81}Br	541	3.7×10^{-5}	{5.67 (5)[c] {5.84 (7)[d]

a) This work.
b) References see V. S. Shirley, in '*Hyperfine Interactions in Excited Nuclei*', ed. G. Goldring and R. Kalish (Gordon and Breach, New York, 1971), Vol. IV, p. 1255.
c) J. Christiansen, H. Ingwersen, H. G. Johann, W. Klinger, W. Kreische, W. Lampert, G. Schatz and W. Witthuhn: Phys. Letters **35B** (1971) 501.
d) N. Bräuer, B. Focke, B. Lehmann, K. Nishiyama and D. Rigel: Z. Phys. **244** (1971) 375.

$E_\gamma = 734(1)$ keV was observed which is expected to be a ground state transition, also. A rough measurement of the half lives yielded $T_{1/2} = 340(30)$ ns for ^{67}Zn and $T_{1/2} = 70(7)$ ns for ^{67}Ge. As targets we used solid ^{64}Ni heated above the Curie temperature and a molten alloy of natural Zn (90%) and In (10%), the latter in order to reduce the relaxation of the nuclear alignment.

By applying the time differential perturbed angular distribution (DPAD) technique to measure the g-factors the following values were deduced from the observed spin rotation pattern:

$$g(^{67}\mathrm{Zn}) = -0.243(4) \ ,$$
$$g(^{67}\mathrm{Ge}) = -0.210(7) \ .$$

Odd Neutron Nuclei

All experimental values display considerable deviations from the single particle value ($\mu_{sp} = -1.91$ n.m.). The description of nuclei around $A = 70$ is difficult because of the large number of nucleons outside neutron and proton closed shells. For the $9/2^+$ states a considerable fraction of single particle character and strong similarities among themselves can be assumed from nuclear reaction data.[1] Consequently we start with the single particle value and try to find corrections within the core polarization model.

The contributions due to core polarization are calculated by means of the theory of Noya *et al.*.[2] The experimental data of the magnetic moments of the $9/2^+$ states in odd mass neutron nuclei reveal a slight decrease of the moments from ^{67}Ge to ^{71}Ge with a significantly higher value for the stable ground state of ^{73}Ge.[3]

This behaviour is reproduced in the calculated values (see Table II). The neutron configurations used were chosen by simply filling up the single particle levels. Comparing ^{67}Zn and ^{69}Ge the influence of an additional proton pair on the magnetic moment is well described by the core polarization, a fact which is confirmed by the moments of the $5/2^-$ ground states of ^{67}Zn and ^{69}Ge.

Odd Proton Nuclei

Considering the magnetic moments of the $9/2^+$ states of odd mass proton nuclei (Table I) we find —comparing the experimental moments of ^{71,73,77}As and ^{81}Br with the theoretical values obtained by correcting the single particle value ($\mu_{sp} = +6.79$ n.m.) for core polariza-

Table II. Configurations for $9/2^+$ states in odd neutron nuclei.

Nucleus	Neutron configuration			μ_{cal}[n.m.]	μ_{exp}[n.m.]
	$2p_{3/2}$	$1f_{5/2}$	$1g_{9/2}$		
^{67}Zn	4	4	1	−0.99	−1.093
^{67}Ge	4	2	1	−0.64	−0.945
^{69}Ge	4	4	1	−0.93	−1.0008
^{71}Ge	4	6	1	−1.21	−1.0368
^{73}Ge	4	6	3	−0.98	−0.87922

Proton configuration Zn: $(2p_{3/2})^2$; Ge: $(2p_{3/2})^4$

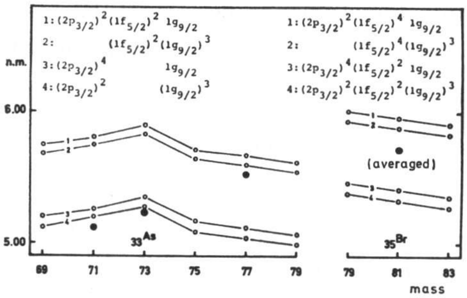

Fig. 1. Experimental magnetic moments (full circles) and calculated values for various proton configurations (open circles) using the core polarization model.

tion— a good agreement within the accuracy of the model using the proton configurations

$$^{71,73}\mathrm{As}: (2p_{3/2})^2(1g_{9/2})^3 \,,$$

$$^{77}\mathrm{As}: (1f_{5/2})^2(1g_{9/2})^3 \,,$$

$$^{81}\mathrm{Br}: (1f_{5/2})^4(1g_{9/2})^3 \,.$$

The neutron configurations are obtained using the usual assumptions of the single particle shell model, but the $2p_{1/2}$ shell empty for $N > 40$.

Figure 1 shows the systematics of these configurations. Other configurations with less consistency are omitted. This comparison suggests a rearrangement of proton pairs from the $2p_{3/2}$ shell to the $1f_{5/2}$ shell while passing over the quasi-magic neutron number $N = 40$. The preferential occupation of the $1f_{5/2}$ shell is in good agreement with the known ordering of the single particle states in the mass region around $A = 80$, which is $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$, and $1g_{9/2}$.[4)] In this respect the determination of the magnetic moment of the $9/2^+$ state in ^{75}As is of considerable interest as a test of the proton configuration in the direct neighborhood of $N = 40$.

The assumed proton configurations are supported by the interpretation of other known states in the As isotopes. Though the wave function of states with lower spins are expected to be of less purity,[5)] the magnetic moments are nevertheless well reproduced by the core polarization model. The ground state of ^{75}As, *e.g.*, has a spin parity assignment of $I^\pi = 3/2^-$ and a magnetic moment of $\mu_{exp} = +1.44$ n.m.,[3)] which is extremely small in comparison with the single particle value $\mu_{sp} = +3.79$ n.m. A proton configuration of $(1g_{9/2})^2(2p_{3/2})^3$ yields a calculated value of $\mu_{cal} = +1.53$ n.m., which supports the assumption of three protons in the $1g_{9/2}$ shell for the excited $9/2^+$ states. Furthermore, the rearrangement of a proton pair from the $2p_{3/2}$ shell to the $1f_{5/2}$ shell, observed in the 9/2 states, is consistent with the excited $5/2^-$ states in ^{73}As and ^{75}As:

$$^{73}\mathrm{As}: (2p_{3/2})^2(1g_{9/2})^2 1f_{5/2}$$

$$(\mu_{cal} = +1.75\ \mathrm{n.m.};\ \mu_{exp} = +1.62\ \mathrm{n.m.}^{3)}) \,,$$

$$^{75}\mathrm{As}: (1f_{5/2})^5$$

$$(\mu_{cal} = +0.96\ \mathrm{n.m.};\ \mu_{exp} = +0.908\ \mathrm{n.m.}^{3)}) \,.$$

The influence of four additional nucleons —especially of the additional proton pair— on the magnetic moment when going from ^{77}As to ^{81}Br is well predicted.

References

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