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LOW TEMPERATURE NUCLEAR ORIENTATION OF ^{239}Np IN GADOLINIUM HOST

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1. INTRODUCTION

The ^{239}Pu nucleus belongs to heavy nuclei with A>225 which have been found to exhibit pronounced spheroidal deformations. The observed energy levels have been classified according to the level diagrams calculated by Nilsson for nuclei with spheroidal deformations /1/. The levels of ^{239}Pu have been characterized in terms of four intrinsic Nilsson states and rotational excitation of these states /2,3/.

The low-lying levels and gamma-transitions in ^{239}Pu have been investigated in EC decay of ^{239}Am /4/, in alpha-decay of ^{243}Cm /5/ and in beta-decay of ^{239}Np. The results of measurements of the energies and intensities of gamma-transitions from the beta-decay of ^{239}Np are summarized in Nuclear Data Sheets /3,6/.

The γ-γ coincidence study of the transitions in ^{239}Pu was performed by Pate et al. /7/. The beta-decay of ^{239}Np and electron capture branching to the levels of ^{239}Pu was investigated by Hollander /8/. The assignment of multipolarities was performed by measurement of conversion coefficients /4,9/. The multipole mixing ratios were studied by Patel et al. /10/ in γ-γ angular correlation measurements of the decay of ^{239}Np and by Krane /11/ in nuclear orientation studies of ^{239}Np polarized in $(U_xZr_{1-x})Fe_2$. Except for this study hyperfine interactions on ^{237}Np and ^{239}Np implanted into copper and nickel /12/ were investigated.

An attempt to perform a low temperature nuclear orientation of neptunium in gadolinium host was done based on the analogy of 5f electron shape in heavy actinide elements with the 4f shape in the rare earth elements /13/. The measurement of angular distribution of gamma radiation was aimed to complete and to improve the precision of the earlier measured data for multipole mixing ratios and some of the earlier proposed spin/parity assignments of the levels at ^{239}Pu.

2. EXPERIMENTAL

The ^{239}Np radionuclide ($T_{1/2}$= 2.35 d, I^{π}= $5/2^+$) was produced by milking a ^{243}Am - ^{239}Np generator /14/. 5 μg of the mother nuclide ($T_{1/2}$= 7370 y) was sorbed on a microchromatographic column filled with HDEHP fixed on polytetrafluorethylene. The daughter activity was washed out using 0.05M nitric acid. The final purification of the radionuclide was done by anion exchange on Dowex 1x8 resin /15/. The ^{239}Np<u>Gd</u> sample was prepared by melting the radionuclide with pure gadolinium metal in a vacuum furnace.

The sample was soldered to the thermal support base of the top-loading ^{3}He-^{4}He dilution refrigerator of the nuclear facility SPIN /16/. An external magnetic field of 1.3 T was applied to the sample to polarize the domains of the gadolinium host.

The measurement of gamma-spectra was performed using two spectrometers with true coaxial Ge(Li) detectors having resolution of 1.9 keV and 2.3 keV FWHM at 1.3 MeV gamma-ray energy. The detectors were placed at emission angles $\theta=0^{\circ}$ and $\theta=90^{\circ}$ relative to the direction of the external magnetic field. "Cold" gamma-spectra were taken after cooling the sample down to the temperature of ~16 mK.

The normalization of the spectra measured was performed using the spectra taken at a sample temperature of ~800 mK, when the source ensemble was considered to be fully random. Typical "cold" and "warm" spectra are shown in Fig. 1. Peak areas and their mean-square deviations were evaluated by the Gaussian line shape fitting routine KATOK /17/ using PP04 mini-computer.

3. RESULTS AND DISCUSSION

The normalized intensities of 12 gamma-transitions in ^{239}Pu have been calculated after correcting all the measurements for the decay of the source. The results obtained are listed in Table 1.

Table 1
The normalized intensities of gamma-transitions in ^{239}Pu (in %)

E_γ[keV]	W(0)-1	1-W(90)	E_γ[keV]	W(0)-1	1-W(90)
106.1	8.1(3)	4.0(18)	272.8	1.2(14)	0.0(23)
181.7	-28.1(16)	-16.0(33)	277.5	1.52(9)	0.70(11)
209.7	3.1(2)	1.2(16)	285.4	-14.0(2)	-9.3(3)
226.4	6.4(12)	4.8(16)	315.8	-10.6(2)	-5.6(2)
228.1	-11.8(1)	-6.5(1)	334.3	7.7(2)	3.6(2)
254.4	-22.9(9)	-13.2(16)	434.7	-0.5(43)	-6.2(40)

The analysis of the results was performed using a multiparameter fitting routine WHIM /18/. The routine enables simultaneous fitting of orientation parameters B_k, multipole mixing ratios δ and attenuation

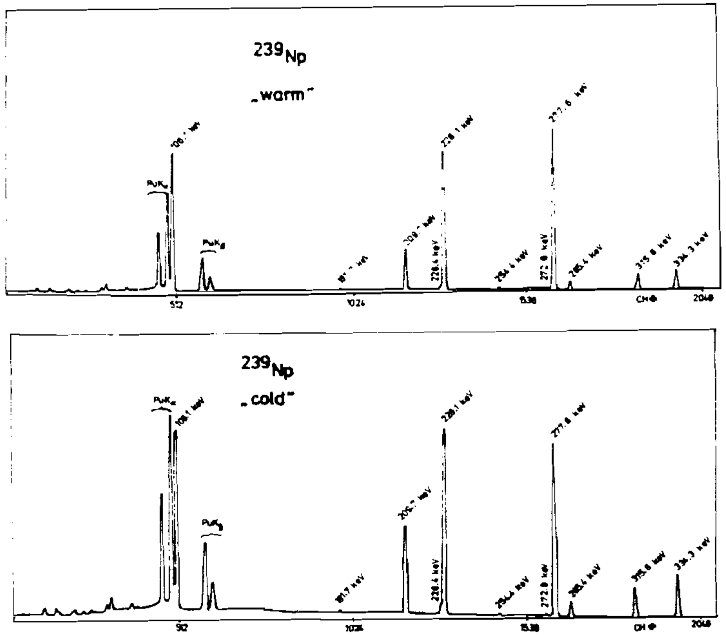

Fig. 1 The gamma-ray spectra of ^{239}Np measured at ≈ 800 mK and at 15 mK

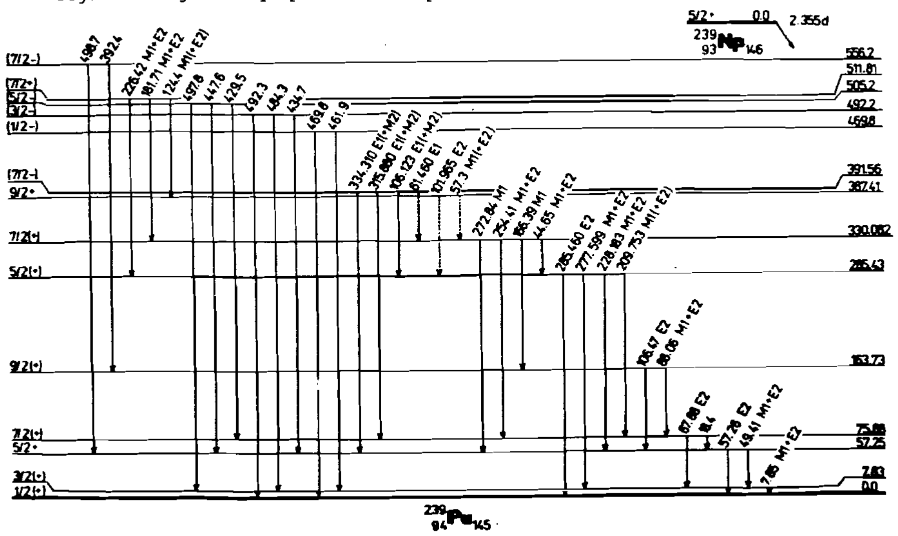

Fig. 2 The decay scheme of ^{239}Np /3/

parameters G_k to the experimental data and the given decay scheme. The decay scheme used in our calculations is shown in Fig. 2. The values of B_2 calculated from the anisotropy of 434.7 keV transition which should be E1 and $G_2(392)$ calculated using the 315.9 keV E1-transition were used together with the first approximations of the δ values as the starting parameters of the optimization.

The orientation parameters for ^{239}NpGd were fitted as

$B_2 = 1.09(15)$ and $B_4 = 0.005(5)$.

The attenuation factors determined for the long living states at 391.56 keV ($I^\pi = 7/2^-$, $T_{1/2} = 193$ ns) and 285.43 keV ($I^\pi = 5/2^+$, $T_{1/2} = 1.12$ ns) are

$G_2(392) = 0.263(3)$ and $G_2(286) = 0.310(2)$.

Similar attenuations were observed by Krane /11/ for ^{239}Np in intermetallic compound $(U_xZr_{1-x})Fe_2$ [$G_2 = 0.53(15)$ and $G_2 = 0.25(5)$].

Deorientation parameters U_2 and U_4 were calculated according to the decay scheme /3/, reorientation of long-living levels was included in the calculation.

The angular distribution coefficients A_2 and A_4 calculated for eleven gamma-transitions in the ^{239}Pu nucleus are given in Table 2.

Table 2
Angular distribution coefficients for gamma-transitions in ^{239}Pu

E_i [keV]	E_γ [keV]	I_i^π	I_f^π	A_2	A_4
511.81	226.4	$7/2^+$	$5/2^+$	0.075(12)	0.011(1)
	181.7	$7/2^+$	$7/2^+$	-0.311(16)	-0.010(3)
492.2	434.7	$3/2^-$	$5/2^+$	0.097(2)	0.000
391.56	334.3	$7/2^-$	$5/2^+$	0.316(7)	0.000
	315.9	$7/2^-$	$7/2^+$	-0.443(6)	0.000
	106.1	$7/2^-$	$5/2^+$	0.340(12)	0.000
330.08	272.8	$7/2^+$	$5/2^+$	0.014(17)	0.017(2)
	254.4	$7/2^+$	$7/2^+$	-0.302(11)	-0.012(2)
285.43	277.6	$5/2^+$	$3/2^+$	0.054(3)	0.019(1)
	228.2	$5/2^+$	$5/2^+$	-0.428(1,-9)	0.000
	209.8	$5/2^+$	$7/2^+$	0.129(1,-33)	0.000

The multipole mixing ratios δ for some E2/M1 and M2/E1 transitions in ^{239}Pu and their comparison with the results of the earlier work of

Krane /11/ are shown in Table 3. In agreement with EC data, the lower values of the roots of the quadratic equation for δ were chosen.

Table 3
Multipole mixing ratios for gamma-transitions in ^{239}Pu

E_i [keV]	E_γ [keV]	I_i^π	I_f^π	Mult.	δ our work	δ Krane /11/
511.81	226.4	$7/2^+$	$5/2^+$	E2/M1	0.133(6)	
	181.7	$7/2^+$	$7/2^+$	E2/M1	-0.150(17)	-0.12(8)
492.2	434.7	$3/2^-$	$5/2^+$	M2/E1	-0.002(2)	
391.56	334.3	$7/2^-$	$5/2^+$	M2/E1	0.006(4)	0.02(3)
	315.9	$7/2^-$	$7/2^+$	M2/E1	0.008(7)	-0.10(12)
	106.1	$7/2^-$	$5/2^+$	M2/E1	-0.007(7)	0.05(3)
330.08	272.8	$7/2^+$	$5/2^+$	E2/M1	0.165(9)	
	254.4	$7/2^+$	$7/2^+$	E2/M1	-0.159(12)	-0.12(6)
285.43	277.6	$5/2^+$	$3/2^+$	E2/M1	0.165(2)	0.16(3)
	228.2	$5/2^+$	$5/2^+$	E2/M1	0.001(9,-1)	-0.07(3)
	209.8	$5/2^+$	$7/2^+$	E2/M1	-0.004(1,-24)	-0.02(2)

As can be seen from these results all the E1-transitions are practically pure, as could be expected. The admixture of E2 to M1-transitions is relatively small, the maximum admixtures do not exceed 2.5 %. Our results are in a very good agreement when compared to those of Krane /11/. However, our precision is much better.

4. CONCLUSIONS

The orientation of neptunium in gadolinium host was found to be relatively high. This fact is in agreement with the analogy between the 5f electron shell configuration of Np and the 4f configuration of lanthanides which are known to exhibit rather high hyperfine interactions. The values of the orientation coefficients found are similar to those measured by Krane /11/ for a $(U_xZr_{1-x})Fe_2$ matrix.

The angular distribution coefficients of the 434.7 keV E1-transition depopulating the level at 492.2 keV and for the 334.3 keV, 315.9 keV and 106.1 keV E1-transitions depopulating the level at 391.6 keV enabled us to support the earlier proposed assignement of spins of these levels as $3/2^-$ and $7/2^-$, respectively.

The multipole mixing ratios δ obtained for the M1-transitions depopulating the level at 511.8 keV do not contradict the earlier proposed spin assignment $7/2^+$.

REFERENCES

/1/ F.S. Stephens, F. Asaro, and I. Perlman, Phys. Rev. 113(1959)212.
/2/ D.W. Davies and J.M. Hollander, Nucl. Phys. 68(1965)161.
/3/ M.N. Schmorak, Nucl. Data Sheets 40(1983)95.
/4/ F.T. Poster, I. Ahmad, M.S. Freedman, R.F. Barnes, R.K. Sjoblom, F. Wagner Jr. and P.R. Fields, Phys. Rev. C5(1972)1738.
/5/ B.S. Dzhelepov, R.B. Ivanov, V.G. Nedovesov and V.P. Checkev, Zh. Eksperim. Teor. Fiz. 45(1963)1360.
/6/ A. Astma-Cohen, Nucl. Data Sheets B6(1971)577.
/7/ J.C. Pate, K.R. Baker, R.W.Fink, D.A. McClure and N.S. Kendriak, Jr., Z. Physic A272(1975)169.
/8/ J.M. Hollander, Phys. Rev. 105(1957)1518.
/9/ G.T. Ewan, J.S. Geiger, R.L. Graham and D.R. McKenzie, Phys. Rev. 116(1959)950.
/10/ S.B. Patel, A.P. Agnihotry, P.N. Tandon, K.P. Gopinathan, Phys. Rev. C9(1974)1515.
/11/ K.S. Krane, C.E. Olsen and W.A. Steyert, Phys. Rev. C5(1972)1671
/12/ E.J. Ansaldo and L. Grodkins, Phys. Lett. 32B(1970)479.
/13/ E.J. Ansaldo and L. Grodkins, Phys. Lett. 34B(1971)43.
/14/ C.W. Sill, Anal. Chem. 38(1966)802.
/15/ J. Garraway and P.D. Wilson, J. Less Com. Met. 91(1983)13.
/16/ M. Finger et al., Hyp. Int. 22(1985)461.
/17/ V. Gadjokov, Particles and Nuclei 11(1980)1474 (in russian).
/18/ D. Nosek, Preprint JINR, in press.

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