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Kierownik: prof. dr hab. Stanisław Szpikowski

Anna SUPERSON, Krzysztof POMORSKI

Moments of Inertia, Giromagnetic Ratios and Decoupling Factors of Odd-A Rare-Earth Nuclei

Momenty bezwładności, czynniki giromagnetyczne i parametry odsprzężenia jąder ziem rzadkich o nieparzystym A

Моменты инерции, гиромагнитные факторы и параметры развязывания нечётных ядер редкоземельной области

INTRODUCTION

The aim of the present paper is to investigate the coupling of the single-particle motion of the odd-valence nucleon to the collective rotation of the even-even core. We will discuss the ground-state moments of inertia, giromagnetic ratios and the Coriolis decoupling parameters for the odd-Z nuclei and the odd-N nuclei in the rare earth region.

The energy $E_K(I)$ of rotating odd-A nuclei is given in the adiabatic approximation by the formula [1,2]:

$$E_K(I) = E_K + \hbar^2/2J \left\{ \left[I(I+1) - K^2 \right] + a(-1)^{I+1/2} (I+1/2)\delta \right\}_{K1/2} , \qquad (1)$$

where I is the total angular momentum of the nucleus and K is its Z component in the intrinsic coordinate frame. The quantity J is the moment of inertia and a is the decoupling parameter which appears in the $K = \frac{1}{2}$ bands.

All the theoretical results reported here are obtained in the frames of the Inglis cranking model [3,4]. The Nilsson single-particle potential is used in our calculations. The pairing correlations are included here by the BCS approximation. Our theoretical model is similar to that of Ref. [5], but we have taken into account the new version of the Nilsson model with the quadrupole and hexadecapole deformations and better approximation for the pairing forces [6].

The moment of inertia of the odd A nucleus J_{ODD} is the sum of the moments of inertia of proton (odd or even) and neutron (even or odd) systems:

$$J_{odd} = J_{Z(N)odd} + J_{N(Z)even} \tag{2}$$

All the quantities are obtained microscopically and we do not introduce any extra fenomenological parameters. We do not distinguish between the valence and core nucleons. We do not take into account the blocking effect, when solving the BCS equations, because the wave functions corresponding to the different excited states would not be ortogonal then, and they could not form a proper basis for the calculations of the moments of inertia.

All the calculations of the moments of inertia are performed in the ground-state equilibrium points on the $(\varepsilon, \varepsilon_4)$ plane. These equilibrium deformations for the odd-A rare-earth nuclei are taken from Refs [7-12]. The dependence of the moment of inertia on quadrupole and hexadecapole deformations and the pairing strength are discussed too.

THE METHOD OF THE CALCULATIONS

The Inglis cranking model gives the following expression for the moment of inertia [3]

$$I = 2\hbar^2 \sum_{i \neq 0} |\langle \Phi_i | \hat{j}_x | \Phi_o \rangle|^2 / (\mathcal{E}_i - \mathcal{E}_o) \tag{3}$$

were the sum runs over all the excited states $|\Phi_i\rangle$ with the energy $\mathcal{E}_i$ and $|\Phi_o\rangle$ is the ground-state wave function. $\hat{j}_x$ is the x component of the angular momentum operator and equals

$$\hat{j}_x = \sum_{\alpha\beta} \langle \alpha | \hat{j}_x | \beta \rangle a^+_\alpha a_\beta \tag{4}$$

Here a^+_α (a_β) is the creation (anihilation) operator of the single particle state $|\alpha\rangle (|\beta\rangle)$.

When we introduce the quasiparticle picture instead of the particle and hole operators we diagonalize approximately our Hamiltonian consisting of a single part (e.g. Nilsson energies) and the residual pairing interaction.

The ground state function $|\Phi_0\rangle$ of the odd particles system is described by

$$|\Phi_0\rangle = \alpha^+_\omega |BCS\rangle \tag{5}$$

where α^+_ω is the operator creating the quasiparticle in the state $|\omega\rangle$ with the energy e_ω closest to the Fermi surface. $|BCS\rangle$ is the BCS type function for the even core.
The excited states $|\Phi_i\rangle$ contributing to (3) are of the following form

$$\begin{gathered} \alpha^+_\nu |BCS\rangle, \ \nu \neq \omega \\ \alpha^+_\nu \alpha^+_{\nu'} \alpha^+_\omega |BCS\rangle, \ \nu \neq \omega, \ \nu' \neq \omega \end{gathered} \tag{6}$$

and they correspond to one and three quasiparticle excitations.

The angular momentum operator $\hat{J}_x$ could change the number of quasiparticles by 0 or 2 what could be immediately seen after performing in (4) the Bogolubov-Valatin transformation to the quasiparticle picture. It means that $\hat{J}_x$ in the formula (3) has the nonzero matrix elements between one quasiparticle states and between one and three quasiparticle states of the form (6).

Finally the formula (3) for the moment of inertia takes the form (13).

$$\begin{aligned} \mathcal{J} = \hbar^2 \Big\{ & \sum_{\nu \neq \omega} \sum_{\nu'} |\langle \nu | \hat{j}_+ | \nu' \rangle|^2 / (E_\nu + E_{\nu'}) (u_\nu v_{\nu'} - u_{\nu'} v_\nu)^2 \\ & + 1/2 \sum_{\mu \neq \omega} \sum_{\mu'} |\langle \mu | \hat{j}_+ | -\mu' \rangle|^2 / (E_\mu + E_{\mu'}) (u_\mu v_{\mu'} - u_{\mu'} v_\mu)^2 \\ & + 1/2 \sum_{\nu \neq \omega} |\langle \nu | \hat{j}_+ | \omega \rangle|^2 / (E_\nu - E_\omega) (u_\nu u_\omega + v_\nu v_\omega)^2 \\ & + 1/2 \sum_{\nu' \neq \omega} |\langle \omega | \hat{j}_+ | \nu' \rangle|^2 / (E_{\nu'} - E_\omega) (u_{\nu'} u_\omega + v_{\nu'} v_\omega)^2 \\ & + 1/2 \sum_{\mu \neq \omega} |\langle \mu | \hat{j}_+ | -\omega \rangle|^2 / (E_\mu - E_\omega) (u_\mu u_\omega + v_\mu v_\omega)^2 \Big\}, \end{aligned} \tag{7}$$

where $|\nu\rangle$ are the states with z projection of the angular momentum $K_\nu \geqslant 1/2$ and the states $|\mu\rangle$ have $K_\mu = 1/2$. E_α are the quasiparticle energies and u_α, v_α are the usual BCS occupation factors.

The terms in the first two lines of (7) represent the contributions to J coming from three quasiparticle excitations. The other terms origin from one quasiparticle excitations.

The terms in the second and last lines of (7) are due to the fact that the $\hat{j}_x$ operator has a nonzero matrix element between the states $|\mu\rangle$ and $|\mu'\rangle$ with the different sign of the z projection of the angular momentum $K_{\mu(\mu')} = \pm 1/2$.

The cranking model gives the following expression for the giromagnetic ratio

$$g_R = J_p/J + (g_s^p - 1)\,W_p/J + g_s^n\,W_n/J \quad , \tag{8}$$

where J_p and J are the moments of inertia of protons and the whole nucleus, respectively. The functions g_s^p and g_s^n are the proton and neutron giromagnetic ratios. The function W_p (or W_n) for an odd system is equal

$$W = 2\hbar^2 \Big\{ \sum_{\nu' \neq \omega} \sum_{\nu} \langle \nu | \hat{j}_x | \nu' \rangle \langle \nu' | \hat{s}_x | \nu \rangle / (E_\nu + E_{\nu'}) (u_\nu v_{\nu'} - u_{\nu'} v_\nu)^2 + \sum_{\nu \neq \omega} \langle \nu | \hat{j}_x | \omega \rangle \langle \omega | \hat{s}_x | \nu \rangle / (E_\nu - E_\omega)(u_\nu u_\omega + v_\nu v_\omega)^2 \Big\}, \tag{9}$$

where $\hat{S}_x$ is the operator of the x spin component.

The expression for the moment of inertia of the even particle system is simpler than (7) [4]

$$J = 2\hbar^2 \sum_{\nu\nu'} |\langle \nu | \hat{j}_x | \nu' \rangle|^2 / (E_\nu + E_{\nu'}) (u_\nu v_{\nu'} - u_{\nu'} v_\nu)^2 \tag{10}$$

The function W in this case is equal to

$$W = 2\hbar^2 \sum_{\nu\nu'} \langle \nu | \hat{j}_x | \nu' \rangle \langle \nu' | \hat{s}_x | \nu \rangle / (E_\nu + E_{\nu'}) (u_\nu v_{\nu'} - u_{\nu'} v_\nu)^2 \tag{11}$$

The equations (7-11) are basis of our numerical calculations, which are done in details in Ref. [14].

RESULTS OF THE CALCULATIONS

All the calculations are performed using the standard values of the single-particle potential parameters and the strength of the pairing interaction. The parameters μ and $\varkappa$ of the Nilsson potential are listed in Table 1 for different mass regions of the rare-earth nuclei. These parameters are taken from the references written in the lowest row of the table. These papers also include theoretical equilibrium deformations of the rare earth nuclei.

We assume the following pairing strength [6]

$$G_{p(n)} = \left[19.2 \pm 7.4\ (N-Z)/A\right] /A\ (\mathrm{MeV})$$

and we take $\sqrt{15Z(N)}$ levels above and below the Fermi level solving the BCS equation.

The internal-energy unit $\hbar \overset{\circ}{\omega}_0$ in the Nilsson potential is [6]

$$(\hbar\overset{\circ}{\omega}_0)_{p(n)} = 41/A^{1/3} \left[1 \mp (N-Z)/A\right]\ (\mathrm{MeV})$$

We take 9 oscillator shells for protons and 10 for neutrons. The coupling of the oscillator shells via the hexadecapole term in the Nilsson potential is taken into account.

The results of our calculations are presented in Table 2 for 51 odd-Z and in Table 3 for 63 odd-N nuclei. The equilibrium deformation (columns 2 and 3) are taken from Refs [a-d] listed in Table 1. The quantum numbers of the ground states are written in the column 5. The theoretical estimates of the moments of inertia J and the giromagnetic ratios g_R are compared with the experimental values (J_{exp} and g_R^{exp}) taken in most cases from the compilation made in Ref [2] and the others are obtained from the data listed in [15] using the formula (1).

In the cases when the theory predicts a ground state other than the experimental one we put the values of J and g_R in both cases (index T and E). Theoretical and experimental values of the decoupling parameter a are given in Table 4 for the nuclei having $K = \frac{1}{2}$ in the ground state. Agreement of the theoretical and experimental values is rather good. We have to stress that the magnitude of decoupling

Tab. 1. The parameters of the Nilsson potential

	a				b	c	d	
	Z							
	63-65	67-69	71-73	75	"A=161"	"A=178"	"A=165"	"A=187"
$\varkappa_p$	0.0648	0.0637	0.0628	0.0620	0.0641	0.0624	0.0637	0.0620
μ_p	0.591	0.600	0.608	0.614	0.597	0.609	0.600	0.614
$\varkappa_n$	0.0637	0.0637	0.0636	0.0636	0.0637	0.0636	0.0637	0.0636
μ_n	0.438	0.438	0.405	0.393	0.425	0.404	0.420	0.393
Ref.		7			8	9,10	11,12	

(a,b,c) - Z - odd (b,c,d) - N - odd

Tab. 2. The moments of inertia and the giromagnetic ratios for odd - Z nuclei

	ε^{eq}	ε_4^{eq}	Ref	$\Omega^{\pi}[Nn_z\Lambda]$	$\frac{2}{\hbar^2}J$ 1/MeV	$2/\hbar^2 J_{exp}$ 1/MeV	g_R	g_R^{exp}
1	2	3	4	5	6	7	8	9
^{153}Eu	0.235	-0.038	a	$5/2^+$ [413]	67.50*	84,03	0.41	0.47
^{155}Eu	0.245	-0.038	a	$5/2^+$ [413]	75.24*	89.29	0.36	
^{155}Tb	0.235	-0.028	a	$3/2^+$ [411]	58.49*	76.34	0.57	
^{157}Tb	0.250	-0.028	a	$3/2^+$ [411]	66.11*	81.97	0.50	
^{159}Tb	0.255	-0.024	a	$3/2^+$ [411]	67.43*	86.21	0.49	0.42
^{161}Tb	0.260	-0.015	a	$3/2^+$ [411]	69.70*	89.29	0.46	
^{155}Ho	0.155	-0.021	b	$5/2^-$ [532]E	60.62*	-	1.23	
				$7/2^+$ [404]T	38.42		0.50	
^{157}Ho	0.209	-0.018	b	$7/2^-$ [523]	150.41	-	1.13	
^{159}Ho	0.240	-0.019	a	$7/2^-$ [523]	116.56	92.31	0.94	
^{161}Ho	0.254	-0.012	a	$7/2^-$ [523]	107.05	90.91	0.86	
^{163}Ho	0.264	-0.002	a	$7/2^-$ [523]	104.11	98.04	0.80	
^{165}Ho	0.271	0.009	a	$7/2^-$ [523]	103,66	95.24	0.76	0.43
^{167}Ho	0.273	0.021	b	$7/2^-$ [523]	103.45	-	0.77	
^{169}Ho	0.276	0.030	b	$7/2^-$ [523]	105.66	-	0.76	
^{159}Tm	0.185	-0.020	b	$5/2^+$ [402]E	40.06*	-	0.75	
				$7/2^-$ [523]T	138.90		1.16	
^{161}Tm	0.218	-0.014	b	$7/2^+$ [404]	45.94	-	0.38	
^{163}Tm	0.245	-0.001	b	$1/2^+$ [411]	48.33	65.19	0.42	

Tab. 2. continued

1	2	3	4	5	6	7	8	9
^{165}Tm	0.261	0.006	a	1/2^{+} [411]	54.89	61.81	0.38	
^{167}Tm	0.270	0.017	a	1/2^{+} [411]	59.10	80.65	0.38	
^{169}Tm	0.276	0.029	a	1/2^{+} [411]	61.85	80.65	0.39	0.41
^{171}Tm	0.280	0.038	a	1/2^{+} [411]	66.09	83.33	0.38	
^{173}Tm	0.273	0.047	b	1/2^{+} [411]	66.13	-	0.39	
^{175}Tm	0.267	0.056	b	1/2^{+} [411]	64.64	-	0.40	
^{161}Lu	0.172	-0.010	c	5/2^{+} [402]	27.85	-	0.69	
^{163}Lu	0.203	-0.008	c	1/2^{+} [411]	35.69	-	0.41	
^{165}Lu	0.228	0.0	c	7/2^{+} [404]	45.61*	-	0.38	
^{167}Lu	0.244	0.007	c	7/2^{+} [404]	49.23	64.33	0.35	
^{169}Lu	0.259	0.016	a	7/2^{+} [404]	54.76	72.87	0.32	
^{171}Lu	0.265	0.028	a	7/2^{+} [404]	56.24	73.53	0.33	
^{173}Lu	0.269	0.038	a	7/2^{+} [404]	59.43	76.79	0.31	
^{175}Lu	0.266	0.047	a	7/2^{+} [404]	62.40	79.37	0.31	0.31
^{177}Lu	0.259	0.057	a	7/2^{+} [404]	60.17	76.92	0.33	0.35
^{179}Lu	0.254	0.068	c	9/2^{-} [514]	82.84	-	0.50	
^{181}Lu	0.244	0.071	c	9/2^{-} [514]	74.85	-	0.60	
^{171}Ta	0.264	0.012	c	7/2^{+} [404]T	55.87*	-	0.28	
^{173}Ta	0.269	0.022	c	7/2^{+} [404]T	57.08*	-	0.29	
^{175}Ta	0.254	0.034	c	7/2^{+} [404]E	55.09*	69.39	0.30	
				9/2^{-} [514]T	72.63		0.58	
^{177}Ta	0.254	0.046	a	7/2^{+} [404]E	58.58*	68.49	0.33	
				9/2^{-} [514]T	73.97		0.52	
^{179}Ta	0.247	0.057	a	7/2^{+} [404]E	57.64*	67.14	0.29	
				9/2^{-} [514]T	72.49		0.52	
^{181}Ta	0.241	0.067	a	7/2^{+} [404]	63.77*	66.23	0.25	0.29
^{183}Ta	0.230	0.072	a	7/2^{+} [404]	54.43*	62.89	0.32	
^{185}Ta	0.208	0.066	c	7/2^{+} [404]E	42.20*	-	0.36	
				9/2^{-} [514]T	65.60		0.70	
^{175}Re	0.249	0.017	c	5/2^{+} [402]T	50.14	-	0.30	
^{177}Re	0.249	0.027	c	5/2^{+} [402]T	50.88	-	0.29	
^{179}Re	0.228	0.039	c	5/2^{+} [402]	49.21	56.54	0.30	
^{181}Re	0.232	0.054	a	5/2^{+} [402]	52.89	59.52	0.28	
^{183}Re	0.225	0.064	a	5/2^{+} [402]	56.33	61.35	0.26	
^{185}Re	0.215	0.067	a	5/2^{+} [402]	49.90	55.87	0.32	0.42
^{187}Re	0.200	0.067	a	5/2^{+} [402]	44.00	52.08	0.40	0.41
^{189}Re	0.172	0.058	c	5/2^{+} [402]	37.43	47.95	0.49	
^{191}Re	0.151	0.056	c	5/2^{+} [402]	36.21	-	0.49	

Tab. 3. The moments of inertia and the giromagnetic ratios for the odd - N nuclei

	ε^{eq}	ε_4^{eq}	Ref	$\Omega^{\pi}[N n_z \Lambda]$	$\frac{2}{\hbar^2}J$	$2/\hbar^2 J_{exp}$	g_R	g_R^{exp}
					1/MeV	1/MeV		
1	2	3	4	5	6	7	8	9
^{153}Sm	0.217	-0.038	d	$3/2^+$ [651]	249.47	663.13	-0.18	
^{155}Sm	0.236	-0.037	d	$3/2^-$ [521]	76.18	100.00	-0.24	
^{157}Sm	0.243	-0.030	d	$5/2^+$ [642] T	141.04	-	-0.03	
^{153}Gd	0.184	-0.029	d	$3/2^-$ [521] E	70.68*	120.19	0.48	
				$1/2^+$ [660] T	452.10		-0.26	
^{155}Gd	0.222	-0.030	d	$3/2^-$ [521] E	86.90	83.33	0.15	0.32
				$3/2^+$ [651] T	290.61		-0.20	
^{157}Gd	0.239	-0.028	d	$3/2^-$ [521]	74.63	91.74	0.25	0.26
^{159}Gd	0.245	-0.022	d	$3/2^-$ [521] E	83.15*	99.60	0.31	
				$5/2^+$ [642] T	151.48	136.99	-0.06	
^{161}Gd	0.254	-0.011	d	$5/2^-$ [523]	75.72	96.15	0.33	
^{155}Dy	0.188	-0.027	b	$3/2^-$ [521] E	72.75*	126.90	0.48	
				$1/2^+$ [660] T	453.01*		-0.26	
^{157}Dy	0.215	-0.025	b	$3/2^-$ [521] E	88.60	81.91	0.13	
				$3/2^+$ [651] T	354.91		-0.23	
^{159}Dy	0.239	-0.025	b	$3/2^-$ [521]	73.89	88.50	0.24	
^{161}Dy	0.252	-0.016	b	$5/2^+$ [642]	157.82	158.72	-0.07	0.21
^{163}Dy	0.264	-0.005	b	$5/2^-$ [523]	76.19	95.24	0.34	0.27
^{165}Dy	0.270	0.008	b	$7/2^+$ [633]	123.46	107.53	0.02	
^{167}Dy	0.276	0.019	b	$1/2^-$ [521]	65.05	-	0.34	
^{157}Er	0.176	-0.023	b	$3/2^-$ [521] E	76.39*	-	0.45	
				$1/2^+$ [660] T	445.11		-0.27	
^{159}Er	0.206	-0.020	b	$3/2^-$ [521] E	90.56	84.55	0.12	
				$3/2^+$ [651] T	480.26		-0.25	
^{161}Er	0.233	-0.018	b	$3/2^-$ [521]	73.49	84.03	0.23	
^{163}Er	0.252	-0.007	b	$5/2^-$ [525] E	77.01*	83.33	0.41	
				$5/2^+$ [642] T	176.04		-0.11	
^{165}Er	0.261	0.003	b	$5/2^-$ [523]	74.61	90.91	0.34	
^{167}Er	0.270	0.016	b	$7/2^+$ [633]	130.11	113.64	0.0	0.18
^{169}Er	0.276	0.027	b	$1/2^-$ [521]	65.39	85.03	0.35	
^{171}Er	0.276	0.038	b	$5/2^-$ [512]	73.96	100.00	0.31	
^{173}Er	0.270	0.047	b	$7/2^-$ [514]	71.74	-	0.36	
^{159}Yb	0.151	-0.014	d	$3/2^-$ [521]	95.93*	-	0.28	
^{161}Yb	0.189	-0.013	d	$3/2^+$ [651]	602.85	-	-0.27	
^{163}Yb	0.226	-0.008	d	$3/2^-$ [521]	76.37	-	0.25	
^{165}Yb	0.239	-0.001	d	$5/2^-$ [523]	75.84*	79.91	0.42	
				$5/2^+$ [642]	214.38		-0.16	

Tab. 3. continued

1	2	3	4	5	6	7	8	9
^{167}Yb	0.245	0.007	d	5/2$^-$ [523]	71.70	88.97	0.34	
^{169}Yb	0.250	0.012	d	7/2$^+$ [633]	151.61	126.58	-0.07	
^{171}Yb	0.270	0.034	d	1/2$^-$ [521] 7/2$^+$ [633]	62.89 133.24	83.33	0.35 0.0	0.28
^{173}Yb	0.270	0.044	d	5/2$^-$ [512]	76.26	89.29	0.29	0.28
^{175}Yb	0.266	0.053	d	7/2$^-$ [514]	72.15	86.21	0.34	
^{177}Yb	0.261	0.065	d	9/2$^+$ [624]	92.43	89.29	0.17	
^{167}Hf	0.228	-0.003	c	5/2$^-$ [523] 5/2+ [642]	73.67* 247.86	-	0.42 -0.19	
^{169}Hf	0.249	0.004	c	5/2$^-$ [523]	69.30	89.97	0.31	
^{171}Hf	0.254	0.017	c	7/2$^+$ [633]	167.62	145.88	-0.11	
^{173}Hf	0.259	0.027	c	1/2$^-$ [521]	56.43	78.16	0.30	
^{175}Hf	0.264	0.039	c	5/2$^-$ [512]	71.66	86.21	0.25	
^{177}Hf	0.259	0.049	c	7/2$^-$ [514]	66.97	79.36	0.29	0.26
^{179}Hf	0.249	0.058	c	9/2$^+$ [624]	90.14	89.29	0.09	0.22
^{181}Hf	0.244	0.068	c	1/2$^-$ [510]	73.71	101.52	0.30	
^{183}Hf	0.228	0.071	c	3/2$^-$ [512] 1/2$^-$ [510]	39.55* 67.54	-	0.24 0.33	
^{171}W	0.228	0.002	c	5/2$^-$ [523]	66.90	-	0.30	
^{173}W	0.238	0.014	c	7/2$^+$ [633]	211.17	-	-0.17	
^{175}W	0.244	0.024	c	1/2$^-$ [521]	51.47	71.84	0.27	
^{177}W	0.244	0.034	c	1/2$^-$ [521] 5/2$^-$ [512]	53.15 72.40	67.55	0.35 0.23	
^{179}W	0.244	0.044	c	7/2$^-$ [514]	61.54	75.19	0.24	
^{181}W	0.238	0.056	c	9/2$^+$ [624]	90.35	97.07	0.03	
^{183}W	0.228	0.063	c	1/2$^-$ [510]	69.82	76.92	0.26	0.21a
^{185}W	0.208	0.063	c	3/2$^-$ [512] 1/2$^-$ [510]	33.71* 63.27*	75.76 47.39	0.15 0.30	
^{187}W	0.192	0.061	c	3/2$^-$ [512] 11/2$^+$ [615]	53.58* 56.50	64.60	0.45 0.16	
^{177}Os	0.228	0.022	c	1/2$^-$ [521]	47.13	-	0.27	
^{179}Os	0.228	0.029	c	1/2$^-$ [521] E 5/2$^-$ [512] T	48.56 71.44*	-	0.27 0.23	
^{181}Os	0.218	0.039	c	1/2$^-$ [521] E 7/2$^-$ [514] T	49.16 59.46	-	0.28 0.26	
$^{181}_{m}$Os	0.228	0.041	c	7/2$^-$ [514]	60.32	72.87	0.25	
^{183}Os	0.223	0.051	c	9/2$^+$ [624]	95.27	114.11	0.01	
$^{183}_{m}$Os	0.218	0.051	c	1/2$^-$ [510] E 9/2$^+$ [624] T	94.11 97.69	-	0.01 -0.01	
^{185}Os	0.213	0.058	c	1/2$^-$ [510]	68.34	81.74	0.26	

Tab. 3. continued

1	2	3	4	5	6	7	8	9
^{187}Os	0.197	0.058	c	1/2$^-$ [510]	62.93*	42.19	0.32	
^{189}Os	0.172	0.053	c	3/2$^-$ [512]	53.25*	71.84	0.52	
^{191}Os	0.151	0.051	c	9/2$^-$ [505]	36.95*	-	0.43	
^{193}Os	0.136	0.019	c	3/2$^-$ E 9/2$^-$ [505] T	51.66 38.56	-	0.52 0.36	

Tab. 4. The deccuping parameters for the odd - A rare-earth nuclei with K = $\frac{1}{2}$ in the ground state

			a	a_{exp}
1	2	3	4	5
	^{163}Tm	1/2$^+$ 411	+0.96	-0.71
	^{165}Tm	1/2$^+$ 411	+0.95	-0.76
	^{167}Tm	1/2$^+$ 411	+0.95	-0.72
	^{169}Tm	1/2$^+$ 411	+0.95	-0.77
	^{171}Tm	1/2$^+$ 411	+0.96	-0.86
	^{173}Tm	1/2$^+$ 411	+0.98	/-0.93/
	^{175}Tm	1/2$^+$ 411	+1.00	-
	^{163}Lu	1/2$^+$ 411	+1.01	-
	^{167}Dy	1/2$^-$ 521	0.94	-
	^{169}Er	1/2$^-$ 521	0.94	0.83
	^{171}Yb	1/2$^-$ 521 E	0.88	0.85
	^{173}Hf	1/2$^-$ 521	0.88	0.82
	^{181}Hf	1/2$^-$ 510	0.14	0.55
	^{175}W	1/2$^-$ 521	0.86	/0.80/
	^{177}W	1/2$^-$ 521 E	0.87	/0.80/
	^{183}W	1/2$^-$ 510	0.19	0.19
	^{177}Os	1/2$^-$ 521	0.84	-
	^{179}Os	1/2$^-$ 521 E	0.84	-
	^{181}Os	1/2$^-$ 521 E	0.80	-
	^{183}Os	1/2$^-$ 510 E	0.19	-
	^{185}Os	1/2$^-$ 510	0.23	0.02
	^{187}Os	1/2$^-$ 510	0.31	0.05

parameters is reproduced properly, there is no need for their renormalization as it was done in several previous papers. This is mainly due to taking the ε_4 deformation into account.

In most cases we reproduced properly the ground state quantum numbers. The theoretical estimates of the moments of inertia are on the average 20 % smaller than the experimental values.

It is very interesting to see how the moments of inertia of the odd-A nuclei are sensitive to the choice of ε, ε_4, G parameters.

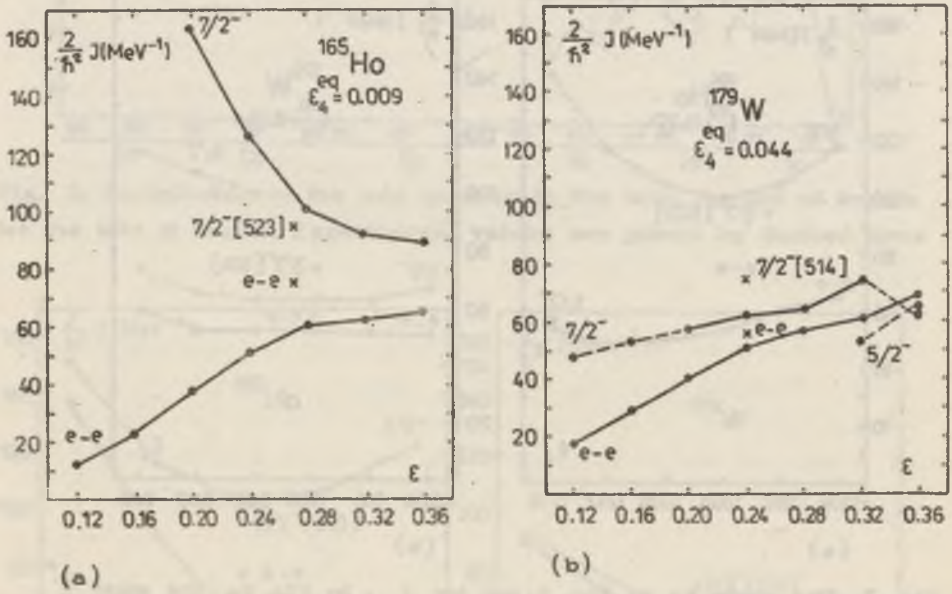

Fig. 1 . Dependence of the moments of inertia of ^{165}Ho (a) and ^{179}W (b) on the quadrupole deformation ε . The moment of inertia of the even-even core (e-e) is denoted by a thin solid line. Experimental values of J are marked by crosses

In Fig. 1 a and b the dependence of J on the quadrupole deformation is plotted for the odd Z nucleus ^{169}Ho and the odd N nucleus ^{179}W, respectively. The dependence of the moment of inertia of the even-even core (a thin solid line) is drawn too. In both pictures the hexadecapole deformation is assumed to be equal to the ground state deformation ε_4^{eq}. The similar Figs 2a and b show the dependence of J on $\varepsilon_4 (\varepsilon = \varepsilon^{eq})$. From these pictures we can learn that the dependence of J for odd A nucleus can be significantly different from the dependence for the even-even core.

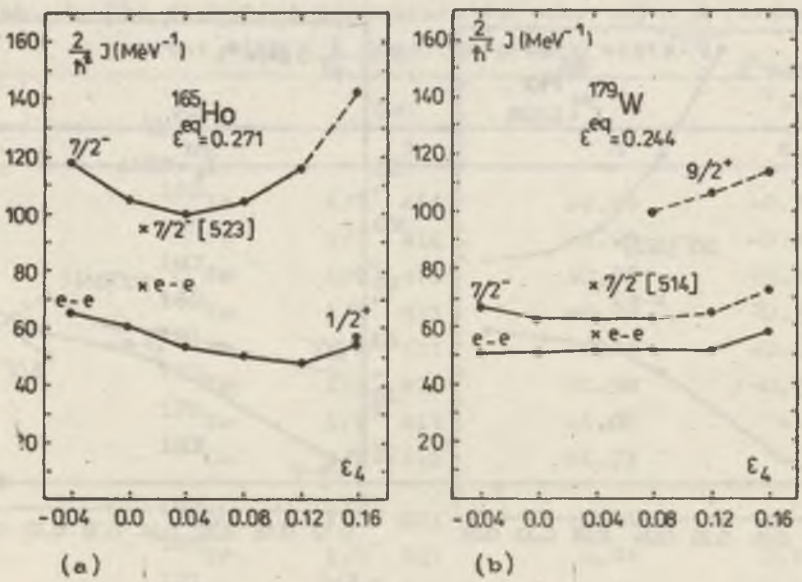

Fig. 2. The same as in Fig. 1 but for ε_4. In Fig. 2a the state $\frac{1}{2}^+$ instead of $\frac{7}{2}$ is a ground - state at the deformation $\varepsilon_4 = 0.16$

We can also estimate the average magnitude of the effect of an odd particle on the moment of inertia (ΔJ_{odd}). This effect is about 30 %. The quality ΔJ_{odd} estimated theoretically for the odd N nuclei is compared with its experimental value in Fig. 3. We can see that the effect of an odd particle on the moment of inertia is reproduced pretty well.

The dependence of the moments of inertia on the strength of the pairing interaction (and the pairing-energy gap Δ) is very large; we can observe it in Fig. 4 a and b for ^{165}Ho and ^{179}W, respectively. We can see that sometimes the moment of inertia of an odd nucleus grows with G what is never the case for an even nucleus.

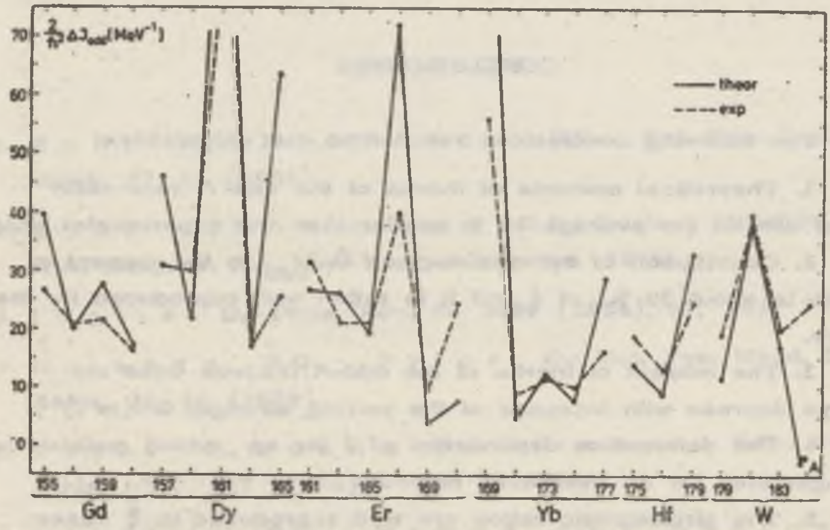

Fig. 3. Contribution of the odd nucleon to the total moment of inertia for the odd N nuclei. Experimental values are joined by dashed lines

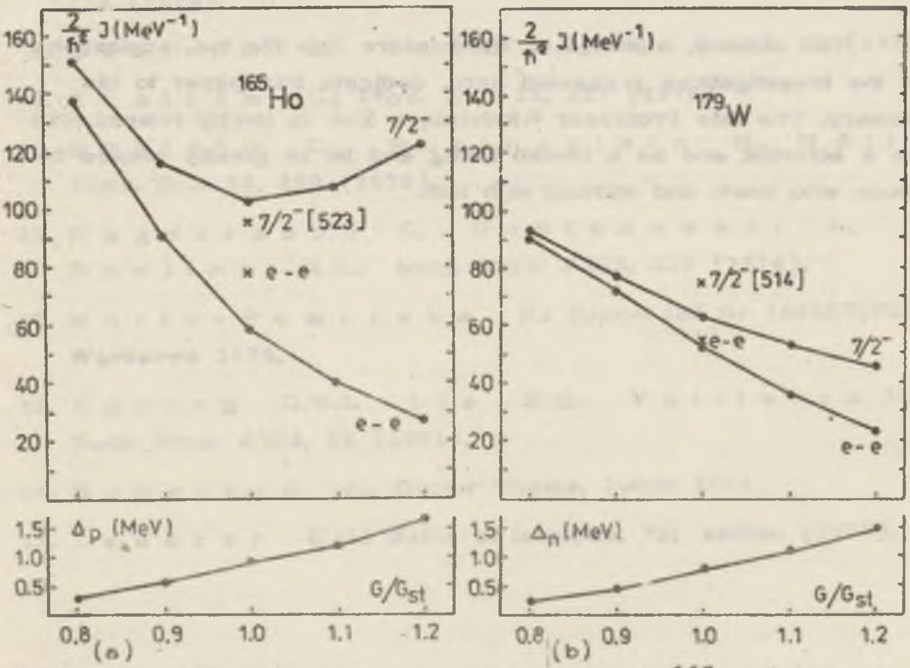

Fig. 4. Dependence of the moment of inertia of ^{165}Ho (a) and ^{179}W (b) on the pairing strength G. The corresponding values of the energy gaps Δ are plotted in the bottom parts of the diagrams

CONCLUSIONS

The following conclusions result from our calculations:

1. Theoretical moments of inertia of the odd- A rare-earth nuclei are on the average 20 % smaller than the experimental ones.

2. Contribution of the odd nucleon ΔJ_{odd} to the moment of inertia is about 30 % of J and it is rather well reproduced by the theory.

3. The moment of inertia of the odd-A nucleus does not always decrese with increase of the pairing strength G (or Δ).

4. The deformation dependence of J for an odd-A nucleus is stronger than for an even-even nucleus.

5. The giromagnetic ratios are well reproduced in $\frac{2}{3}$ cases.

6. Magnitudes of the decoupling parameters and their variances with A are surprisingly well reproduced. There is no need of their renormalisation.

The authors, indebted to Włodzimierz Żuk for the inspiration of the investigations presented here, dedicate this paper to his memory. The late Professor Włodzimierz Żuk is fondly remembered as a scientist and as a human being and he is greatly missed by those who knew and worked with him.

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STRESZCZENIE

Wyliczono momenty bezwładności, czynniki giromagnetyczne i parametry odsprzężenia w stanach podstawowych 51 jąder o nieparzystym Z i 63 jąder o nieparzystym N. W obliczeniach zastosowano model wymuszonego obrotu i przybliżenie adiabatyczne. Potencjał Nilssona o deformacjach ε i ε_4 był bazą rachunków. Siły pairing uwzględniono w przybliżeniu BCS.

РЕЗЮМЕ

Вычислено теоретические величины моментов инерции, гиромагнитных факторов и параметров развязывания основных состояний 51 нечетно-протонных и 63 нечетно-нейтронных ядер. Использовано модель принудительного вращения и адиабатическое приближение. Расчеты основаны на потенциале Нильссона с деформациями ε и ε_4. Парные взвимодействия включены в приближении БКШ.

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