ON THE INFLUENCE OF CHANGES IN NUCLEAR STRUCTURE ON THE PROBABILITY OF β-DECAY

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Abstract

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ON THE INFLUENCE OF CHANGES IN NUCLEAR STRUCTURE ON THE PROBABILITY OF β-DECAY

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In the article ([1]) it was pointed out that the properties of the odd-proton nuclei of the transitional region Eu^{147}, Eu^{149}, Eu^{151}, Pm^{145}, Pm^{147}, Pm^{149} can be understood on the assumption that they have small equilibrium deformations. Further study of the level spectra and electromagnetic properties of nuclei of the transitional region ([2]) confirms the assumption adopted.

In the present article we shall show that β-transitions between the indicated odd-proton nuclei and neighboring odd-neutron spherical nuclei are systematically characterized by large values of $\log ft$, which is connected with a change in the nuclear shape in these β-transitions.

In Table 1 the values of $\log ft$ for β-transformations in the transitional region are compared with $\log ft$ for other nuclei, where no change of structure occurs in β-decay, i.e., either both the parent and daughter nuclei are spherical, or both nuclei are deformed.

In Table 1A are presented first-forbidden transitions with $\Delta I = 1$, namely, for comparison the transitions are grouped according to the spins of two states: ${}^{7}/_{2}\pm \leftrightarrow {}^{5}/_{2}\mp$; ${}^{5}/_{2}+ \rightarrow {}^{3}/_{2}-$. It is seen that the values of $\log ft$ for the transitional region exceed by 2–3 units the mean value of $\log ft$ in other regions. The cases of absence of β-transformation in the transitional region ($Nd^{149} \rightarrow Pm^{149}$, $Pm^{149} \rightarrow Sm^{149}$) mean that the values of $\log ft$ are very large (low-intensity transitions), for competing β-transitions with $\Delta I = 0$ are observed, also with large values of $\log ft$ (7.3 and 7.1, respectively). The values of $\log ft$ in the last column most often lie within the range from 6 to 7 ([3], [4]) (for deformed nuclei, transitions allowed by the asymptotic quantum numbers are given). The relatively large values of $\log ft$ for the transformations $Eu^{145} \rightarrow Sm^{145}$, $Ce^{141} \rightarrow Pr^{141}$, $Pm^{143} \rightarrow Nd^{143}$, are probably connected with the fact that one of the nuclei in each of these transformations has a filled neutron shell $N = 82$: it may be expected that the overlap of wave functions in these transitions should be smaller than in other cases. In the last line of Table 1A the case of β-decay

$Sm^{151} \rightarrow Eu^{151}$, belonging to the transitional region, is singled out; for it $\log ft = 7.5$, which is considerably smaller than for other transitions in this region. However, according to our calculations ([2]), the nucleus Sm^{151} is deformed and $\delta \simeq 0.17$, which is close to the deformation of Eu^{151} ($\delta \simeq 0.14$). Thus, in this case β-decay is not accompanied by a substantial change in nuclear structure. For analogous transitions of the type ${}^3/_2 - [521] \leftrightarrow {}^5/_2 + [413]$ (forbidden by the asymptotic quantum numbers) between strongly deformed nuclei: $Sm^{153} \rightarrow Eu^{153}$, $Eu^{155} \rightarrow Gd^{155}$, $Eu^{157} \rightarrow Gd^{157}$, the values of $\log ft$ are respectively 7.3; 7.7 and > 6.8, i.e., approximately the same as in the case under discussion. Conversely, in electron capture $Gd^{151} \rightarrow Eu^{151}$, accompanied by a change of structure (a transition of the type ${}^7/_2- \rightarrow {}^5/_2+$), $\log ft > 9$ (Table 1A).

In Table 1B an analogous comparison is made for transitions of the type $\Delta I = 0$, namely (${}^7/_2+ \leftrightarrow {}^7/_2-$ and ${}^5/_2+ \leftrightarrow {}^5/_2-$), in which the value of $\log ft$

less than for transitions with $\Delta I = 1$, yes. If in the right-hand column one excludes the transitions $Ba^{139} \rightarrow La^{139}$ and $Ce^{141} \rightarrow Pr^{141}$, in which nuclei with $N = 82$ participate, then for transitions of the type ${}^7/_2+ \rightleftarrows {}^7/_2-$ the mean value of $\log ft$ in the region of nuclei studied by us proves to be one unit larger than in other regions. For transitions of the type ${}^5/_2+ \rightleftarrows {}^5/_2-$, the mean value of $\log ft$ in the region studied

Table 1

Values of $\log ft$ for β-transitions

Transition	Nuclei of the transition region	$\log ft$	Spherical and deformed nuclei	$\log ft$
A. β-transitions of type $\Delta I = \pm 1$, yes				
${}^7/_2\pm \rightleftarrows {}^5/_2\mp$	$Pm^{145} \rightarrow Nd^{145}$	~ 7.8	$Kr^{89} \rightarrow Rb^{89}$	6.5
${}^7/_2\pm \rightleftarrows {}^5/_2\mp$	$Sm^{145} \rightarrow Pm^{145}$	9.0	$Ba^{139} \rightarrow La^{139}$	7.1
${}^7/_2\pm \rightleftarrows {}^5/_2\mp$	$Nd^{147} \rightarrow Pm^{147}$	> 10 or no decay	$Ce^{141} \rightarrow Pr^{141}$	7.7
${}^7/_2\pm \rightleftarrows {}^5/_2\mp$	$Pm^{147} \rightarrow Sm^{147}$	~ 10.4	$Pr^{143} \rightarrow Nd^{143}$	7.6
${}^7/_2\pm \rightleftarrows {}^5/_2\mp$	$Eu^{147} \rightarrow Sm^{147}$	8.4	$Pm^{143} \rightarrow Nd^{143}$	8.2

Transition	Nuclei of the transition region	log ft	Spherical and deformed nuclei	log ft
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$	$Gd^{147} \rightarrow Eu^{147}$	9.3	$Eu^{145} \rightarrow Sm^{145}$	8.2
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$	$Nd^{149} \rightarrow Pm^{149}$	no decay	$Re^{183} \rightarrow W^{183}$	6.7
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$	$Pm^{149} \rightarrow Sm^{149}$	no decay	$Np^{235} \rightarrow Pu^{235}$	6.6
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$	$Eu^{149} \rightarrow Sm^{149}$	8 or no decay	$Pu^{237} \rightarrow Np^{237}$	6.8
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$	$Gd^{149} \rightarrow Eu^{149}$	> 7.7	$Np^{239} \rightarrow Pu^{239}$	6.7
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$	$Gd^{151} \rightarrow Eu^{151}$	> 9	$Pu^{243} \rightarrow Am^{243}$	6.2
${}^{7}/_{2}\pm \rightleftarrows {}^{5}/_{2}\mp$			$Am^{245} \rightarrow Cm^{245}$	~ 6.2
${}^{5}/_{2}+ \rightarrow {}^{3}/_{2}-$	$Pm^{145} \rightarrow Nd^{145}$	~ 8.0	$Se^{75} \rightarrow As^{75*}$	7.5
${}^{5}/_{2}+ \rightarrow {}^{3}/_{2}-$	$Eu^{147} \rightarrow Sm^{147}$	8.0	$Sr^{91} \rightarrow Y^{91}$	(8.4)
${}^{5}/_{2}+ \rightarrow {}^{3}/_{2}-$			$Re^{183} \rightarrow W^{183}$	7.4
${}^{3}/_{2}- \rightleftarrows {}^{5}/_{2}+$	$Sm^{151} \rightarrow Eu^{151}$	7.5	$Sm^{153} \rightarrow Eu^{153}$	~ 7.3
${}^{3}/_{2}- \rightleftarrows {}^{5}/_{2}+$			$Eu^{155} \rightarrow Gd^{155}$	7.7
${}^{3}/_{2}- \rightleftarrows {}^{5}/_{2}+$			$Eu^{157} \rightarrow Gd^{157}$	> 6.8
${}^{3}/_{2}- \rightleftarrows {}^{5}/_{2}+$			$Er^{161} \rightarrow Ho^{161*}$	< 7.0
${}^{3}/_{2}- \rightleftarrows {}^{5}/_{2}+$			$Dy^{159} \rightarrow Tb^{159}$	~ 7.5
B. β-transitions of type $\Delta I = 0$, yes				
${}^{7}/_{2}+ \rightleftarrows {}^{7}/_{2}-$	$Sm^{145} \rightarrow Pm^{145}$	7.4	$Ba^{139} \rightarrow La^{139}$	7.0
${}^{7}/_{2}+ \rightleftarrows {}^{7}/_{2}-$	$Pm^{147} \rightarrow Sm^{147}$	7.4	$Ce^{141} \rightarrow Pr^{141}$	6.9

Transition	Nuclei of the transition region	$\log ft$	Spherical and deformed nuclei	$\log ft$
$^7/_2+ \rightleftarrows {}^7/_2-$	$Gd^{147} \rightarrow Eu^{147}$	7.9	$Pr^{145} \rightarrow Nd^{145}$	< 6.9
$^7/_2+ \rightleftarrows {}^7/_2-$	$Pm^{149} \rightarrow Sm^{149}$	(7.1)	$Dy^{165} \rightarrow Ho^{165}$	6.2
$^7/_2+ \rightleftarrows {}^7/_2-$	$Gd^{149} \rightarrow Eu^{149}$	7.4	$Ho^{167} \rightarrow Er^{167}$	6.0
$^7/_2+ \rightleftarrows {}^7/_2-$	$Gd^{151} \rightarrow Eu^{151}$	7.7	$Yb^{175} \rightarrow Lu^{175}$	6.4
$^7/_2+ \rightleftarrows {}^7/_2-$			$Ta^{175} \rightarrow Hf^{175}$	6.2
$^7/_2+ \rightleftarrows {}^7/_2-$			$Ta^{175} \rightarrow Hf^{175*}$	6.4
$^7/_2+ \rightleftarrows {}^7/_2-$			$Lu^{177} \rightarrow Hf^{177}$	6.7
$^7/_2+ \rightleftarrows {}^7/_2-$			$Ta^{177} \rightarrow Hf^{177}$	6.4
$^5/_2+ \rightleftarrows {}^5/_2-$	$Pm^{145} \rightarrow Nd^{145}$	~ 8.1	$Kr^{87} \rightarrow Rb^{87}$	< 7.5
$^5/_2+ \rightleftarrows {}^5/_2-$	$Nd^{147} \rightarrow Pm^{147}$	7.5	$Sr^{91} \rightarrow Y^{91}$	6.0
$^5/_2+ \rightleftarrows {}^5/_2-$	$Eu^{147} \rightarrow Sm^{147}$	8.7	$Er^{171} \rightarrow Tm^{171}$	6.3
$^5/_2+ \rightleftarrows {}^5/_2-$	$Nd^{149} \rightarrow Pm^{149}$	7.3	$Hf^{175} \rightarrow Lu^{175}$	6.6
$^5/_2+ \rightleftarrows {}^5/_2-$	$Eu^{149} \rightarrow Sm^{149}$	~ 8.2	$Pb^{199} \rightarrow Tl^{199}$	6.9
$^5/_2+ \rightleftarrows {}^5/_2-$			$Am^{239} \rightarrow Pu^{239}$	6.0
$^5/_2+ \rightleftarrows {}^5/_2-$			$Am^{239} \rightarrow Pu^{239*}$	6.3
$^5/_2+ \rightleftarrows {}^5/_2-$			$Pu^{241} \rightarrow Am^{241}$	5.6
$^5/_2+ \rightleftarrows {}^5/_2-$			$Am^{245} \rightarrow Cm^{245}$	~ 6.2

region of nuclei is greater by 2 units than in other regions (except for the transition $Pb^{199} \rightarrow Tl^{199}$, involving a nucleus with a filled proton shell with $Z = 82$). Let us note that if the values of $\log ft$ for β-transformations of the type $\Delta I = 0$,

yes in the transition region are compared with $\log ft$ for transitions between states with the purest shell wave functions, the difference proves to be still more substantial. Thus, for transitions···

$Hg^{205} \to Tl^{205}$, $Tl^{207} \to Pb^{207}$, $Pb^{209} \to Bi^{209}$, the values of $\log ft$, respectively, are ≥ 5.3; $= 5.1$; $= 5.9$. One should expect that large values of $\log ft$ will always be observed when β decay occurs between nuclei of different shape.

Table 2

Transition	Nuclei	$\log ft$
$5/2+ \to 5/2-$	$Ru^{103} \to Rh^{103}$	~ 9
$5/2+ \to 5/2-$	$Pd^{109} \to Ag^{109}$	~ 9.9
$5/2+ \rightleftarrows 3/2-$	$Ru^{103} \to Rh^{103}$	8.9
$5/2+ \rightleftarrows 3/2-$	$Pd^{109} \to Ag^{109}$	~ 10.4
$5/2+ \rightleftarrows 3/2-$	$Se^{75} \to As^{75}$	no decay
$3/2+ \rightleftarrows 1/2-$	$Au^{195} \to Pt^{195}$	> 8.3 or no decay
$3/2+ \rightleftarrows 1/2-$	$Hg^{195} \to Au^{195}$	no decay
$3/2+ \rightleftarrows 1/2-$	$Hg^{197} \to Au^{197}$	no decay
$3/2+ \rightleftarrows 1/2-$	$Pt^{197} \to Au^{197}$	no decay

Table 2 gives data relating to β transitions that include individual deformed nuclei (Rh^{103}, Ag^{109}, As^{75}), as well as some β transitions of the second transition region, in which the nuclear shape may change. In the level spectra of nuclei in transition regions there may be states of both spherical and ellipsoidal shape. Since information on the shape of nuclei in their ground states is more definite, Table 2 gives data on transitions only between ground states. It is evident that the values of $\log ft$ are also large.

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CITED LITERATURE

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Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.