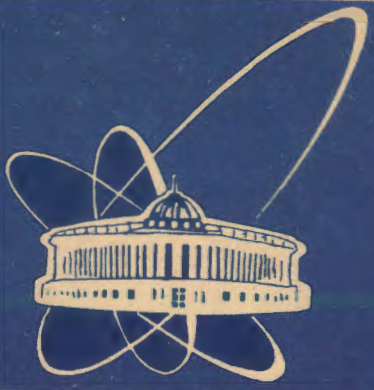

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

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LEVEL STRUCTURE IN ^{213}Bi

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In our studies of $(\alpha-\gamma)$-coincidences at the decay of ^{225}Ac and its daughter products [1,2,3] we had a possibility of obtaining some experimental data on α-decay of ^{217}At to levels of $^{213}_{83}Bi_{130}$ which is expected to be a good example of the nucleus described by the shell model.

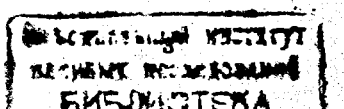
The available data on the ^{213}Bi levels are scanty and somewhat contradictory [4]. On the basis of the results of Liang [5] and Dzhelepov et al. [6] levels of ^{213}Bi with energies 258 keV, 465 keV and 593 keV were introduced. A few more γ-transitions were ascribed to ^{217}At decay [4] but not placed in the decay scheme. Last year we established that the 6810 keV α-line earlier ascribed to the ^{217}At decay belonged to ^{221}Ra arising in the ^{225}Ac decay chain in the weak β-decay branch of the ^{221}Fr decay [3] and therefore the 465 keV level does not exist in ^{213}Bi.

We separated ^{225}Ac ($T_{1/2}$=10 days) [7] from 30 μCi activity of ^{229}Th ($T_{1/2}$ = 7340 years). The samples obtained were vacuum evaporated on a thin Al foil. The ^{225}Ac sources were placed between the α and γ detectors in the 180° close geometry. The Si(Au)-α-detector, 100 mm^2 in area, has a 20 keV resolution. The HPGe γ-detector, 84 cc in volume, has a 1.0 keV resolution at the energy 150 keV. Single α and γ spectra were taken together with 4096 x 4096 channel coincidence measurements [8]. The (E_α, E_γ, T)-coincidence events were written in a list mode. In the course of the analysis of the experimental data on very weak ($\sim 0.01\%$ per decay) branches of the ^{217}At α-decay it was necessary to take into account relatively weak instrumental effects caused by ^{225}Ac, ^{221}Fr and ^{213}Bi nuclei from the ^{225}Ac decay chain the decay of which is accompanied by intense α and γ radiation. These effects are: a) random summation of the amplitudes of the α-pulses resulting in coicidences of intense γ-peaks throughout the α-spectrum (for example weak coincidences with γ218 keV ^{221}Fr are observed up to $E_\alpha > 10$ MeV); b)summing of the pulses from the α-particles and conversion electrons; c)summation of the pulses from cascade γ and χ-rays in γ-spectra; d) remnants of the random coincidence peaks. The majority of the random events is eliminated in the process of sorting the coincidence events. We identified γ-rays with ^{217}At decay by observing the changes in the area of the γ-peaks in the set α-gates (Fig. 1a). For example maxima of the γ258 keV peak area are observed at the energies $\sim$ 6810 keV and $\sim$ 6480 keV. The maxima of the

area of the 335 keV and 593 keV γ-peaks manifest themselves only at the energy $\sim$ 6480 keV. Thus the ^{213}Bi 258 keV and 593 keV levels (Fig.1b) proposed in [5,6] are confirmed. Besides, we observed 759 keV γ-rays with the area maximum in the E_α=6340 keV gate. This gate energy is the energy of the intense α_0-line at the ^{221}Fr decay ($E_{\alpha 0} = 6343keV, I_{\alpha 0}$= 85 %)

but we cannot attribute coincidences with γ759 keV to the remnant of the random coincidences because in the ^{217}At $E\alpha_0$=7069 keV gate this peak is absent (Fig. 1.). The energy of α particles calculated for the population of the ^{213}Bi 759 keV level is equal to 6322 keV. This allowed us to confirm excitation of the ^{213}Bi 759 keV level in the ^{217}At α-decay. In the γ spectra measured in the gates of Fig.1 we observed a few more weak γ peaks. The analysis similar to the one in Fig.1 excludes their belonging to the ^{217}At decay. For example, the 150 keV γ-peak area showed the maximum at E_α=6610 keV. These α-particles, as mentioned above, arise from the ^{221}Ra decay after the ^{221}Fr β^--decay. The 440 keV ^{213}Bi and 465 keV ^{209}Tl γ-peak areas have maxima in the ^{221}Fr $E_{\alpha 0}$ and ^{217}At $E_{\alpha 0}$ gates and therefore are connected with the random $(\alpha-\gamma)$-coincidences. In the gated γ-spectra we also observed weak peaks of the most intense γ-rays of ^{225}Ac and ^{221}Fr: 218 keV, 100 keV, 172 keV, 188 keV, etc. We ascribe them to the effect of random summation of the α-particle pulses.

For determination of the exact values of the γ-ray energy and intensity (Table 1) the single γ-spectrum of the ^{225}Ac equilibrium chain and the spectrum of γ-rays coinciding with α-particles of energy $E_\alpha = 5.9 \div 7.2$ MeV were used. The determination of the intensity of γ-rays in per cent per decay was made using the known data on the 218.2 keV γ-transition at the decay of ^{221}Fr. According to [9] the 218.2 keV γ-transition is of E2 type. Its total intensity is 15.1% per decay [5,9]. Thus, using the calculated [10] conversion coefficients, we found the intensity of 218.2 keV γ-rays to be 11.2(2)% per decay. The upper limits estimated for the γ-ray intensity of the possible unobserved 501 keV and 166 keV γ-transitions from the 759.0 keV level are given in Table 1. Relative intensities of 258 keV γ-rays and $K\chi$-rays in the spectrum gated by $E_{\alpha 258}$=6810 keV were used to determine α_{K258}=0.45(4). Comparison of this value with the calculated ones [10] allows the conclusion that the 258 keV γ-transition is of the (75% M1 + 25% E2) type.



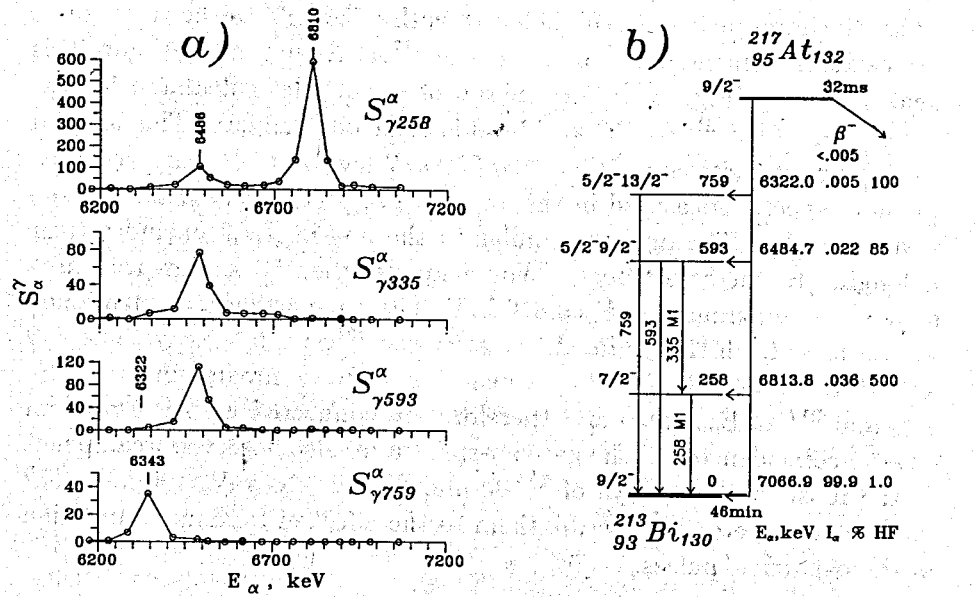


Fig. 1. a) $(\alpha-\gamma)$-coincidence at the decay of ^{217}At. Gamma peak areas S_{γ} in the alpha gated spectra as a function of the gate middle energy E_{α}. Statistical errors do not exceed the size of the points. b) Decay scheme of ^{217}At.

Table 1. Alpha-decay of ^{217}At (32 ms) on the levels of $^{213}_{83}Bi_{130}$

Energy	(keV)	of	Intensity	(% per decay	^{217}At) of	HF
γ-ray	level	α-particle	γ-ray	γ-transition	$\alpha-decay^{a)}$	
-	-	7066.9(16)	-	-	99.9	1.0
257.88(4)	257.88(4)	6813.8(16)	0.0287(7)	0.0450(25)	0.036(3)	500
335.33(10)	593.10(10)	6484.7(16)	0.0062(3)	0.0090(9)	0.021(2)	85
593.10(10)	- " -	- " -	0.0115(5)	0.012(1)		
758.9(1)	758.9(1)	6322.0(16)	0.0049(4)	0.005(1)	0.005(1)	100
(165.8)	- " -	- " -	<0.0002			
(501.0)	- " -	- " -	<0.0002			

[a)] Intensities of the α-decay branches are calculated on the assumption of the absence of the level population from higher lying unknown levels.

The quantitative analysis of the $(\alpha-\gamma)$-coincidence spectra confirms the population of the ^{213}Bi 257.9 keV, 592.9 keV and 759.0 keV levels at the ^{217}At α-decay. The total intensity of the 335 keV transition is determined to be 0.0090(9)% per decay. This value is consistent with M1 multipolarity of the 335 keV γ-transition. Weak population of the 592.9 keV and 759 keV levels by transitions from higher so far unknow levels of ^{213}Bi is not excluded. The experimental data on the $^{217}At \rightarrow {}^{213}Bi$ decay (Fig.1b) are summed up in Table 1. Energies of α-particles for the decay to excited ^{213}Bi levels are calculated using the energy value for the ground-ground α-transition $E_{\alpha 0}$=7066.9(16) keV recommended by Rytz [11] and our values for the ^{213}Bi level energies. The new fine structure line $E_{\alpha 759}$=6322.0 keV, $I_{\alpha 759}$=0.005 % is discovered at the ^{217}At decay. On the basis of more precise values for the α-decay intensity hindrance factors for the α-decay to ^{213}Bi levels are determined. The experimental data allow the following interpretation of the excited states of ^{213}Bi. The value of HF for the α-transition between the ^{217}At and ^{213}Bi ground states shows that the following configurations must be ascribed to ground states of these nuclei: $^{217}_{85}At$ - $(\pi h^3_{9/2}, \nu g^6_{9/2})_{9/2^-}$ and $^{213}_{83}Bi$ - $(\pi h_{9/2}, \nu g^4_{9/2})_{9/2^-}$. The high value HF=500 for the 258 keV level shows that this state has a configuration that includes shell model proton states $f_{7/2}$ or $i_{13/2}$. The M1 character of the 258 keV transition excludes the latter possibility. Thus we ascribe the configuration $(\pi f_{7/2}, \nu g^4_{9/2})_{7/2^-}$ to the 258 keV state. The majority of the wave functions of the 592.9 keV and 759 keV states is apparently connected with the coupling of the

ground state configuration with the 2^+ state of the even-even core 805 keV in $^{212}_{82}Pb$ and 609 keV in $^{214}_{84}Po$.

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