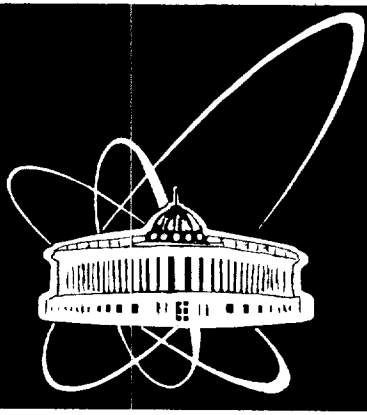

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

BD

E6-97-189

V.G.Chumin, V.I.Fominikh, T.A.Furyaev, K.Ya.Gromov,
J.K.Jabber, K.V.Kalyapkin, S.A.Kudrya,
V.V.Tsupko-Sitnikov

STUDIES OF α-SPECTRA IN ^{221}Fr, ^{217}At, ^{213}Bi AND ^{213}Po DECAYS

Submitted to «Известия РАН, серия физическая»

Sw9749

1997

1. Introduction

In the last ten years several investigations on the decays of nuclides from the ^{225}Ac equilibrium decay chain (Fig. 1) have been published. New data on the structure of the ^{217}At, ^{213}Bi, ^{213}Po and ^{209}Pb nuclei close to double magic ^{208}Pb have been gained. It is expected that the ^{225}Ac α-decay studies can reveal some new information on the presense of the static octupole deformation in the ^{221}Fr nucleus.

To study nuclear radiations of the above nuclei, ^{225}Ac is separated from ^{229}Th. The daughter nuclides are rapidly accumulated in the prepared source. Complex α-, β- and γ-radiation spectra and relatively short half-lives of the daughter nuclei hinder the identification of specific transitions with the decay of appropriate nuclei from the ^{225}Ac chain.

The fine structure lines in the ^{221}Fr α-decay were identified by Liang [1] as he investigated the ^{225}Ac α-recoil nuclei α-spectrum with the magnetic spectrograph. Ardisson et al. [2,3] developed and used fast radiochemical methods for separation of ^{213}Bi, ^{209}Tl and ^{221}Fr nuclei and investigation of their γ-spectra. Sheline et al. [4] and Gromov et al. [5-8] confirmed the belonging of γ-transitions to the ^{225}Ac, ^{221}Fr and ^{217}At decay in $(\alpha-\gamma)$-coincidence experiments.

But some problems still require careful studies of the weak components of the ^{221}Fr, ^{217}At and ^{213}Bi α-spectra. For example,

- Liang [1], when studying the α-spectrum of recoil nuclei from the ^{225}Ac source, observed a weak line with E_α = 6037 keV, J_α = 0.003 % per decay. An excited ^{217}At level with energy 310 keV and $I^\pi = (13/2^+)$ is introduced on this basis [1,4,6]. Unlike the case with other levels introduced on the basis of the ^{221}Fr fine structure α-lines [1], no γ-transitions from the 310 keV level are observed. It is not impossible that the 6037 keV line is not associated with the ^{221}Fr α-decay, but with the α-decay of the daughter ^{217}At nucleus to the 1050 keV level of ^{213}Bi and, therefore, this line can be found in the α-spectrum of ^{217}At.

- Ardisson et al. [2] assumed that the 868 keV ^{209}Tl level is excited in the ^{213}Bi α-decay. The sum intensity of the 868 and 545 keV γ- rays from this level was determined to be 0.03 % per decay. Accordingly, the fine structure α-line, with E_α=5018 keV and J_α=0.03 %, should be observed in the α-spectrum of ^{213}Bi.

- Chumin et al. [7], studying $(\alpha-\gamma)$-coincidence in the decay of ^{225}Ac

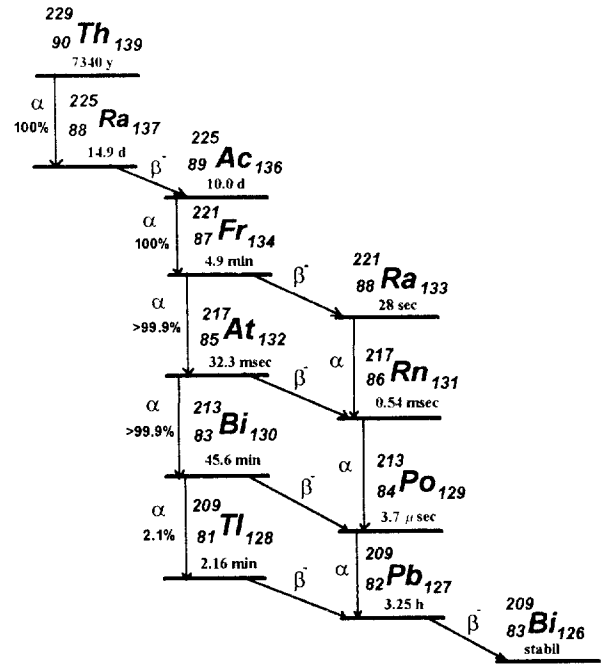

Fig. 1. Decay chain of ^{229}Th to ^{209}Bi

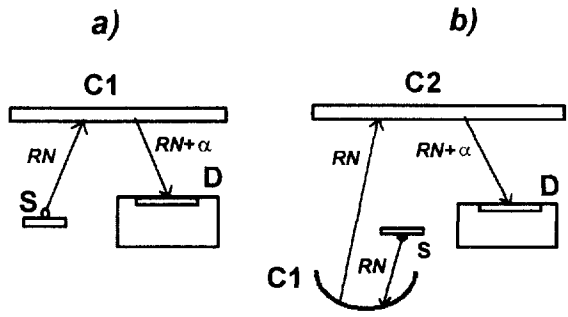

Fig. 2. Block diagram of the experiments for α-spectra investigation using an α-recoil: once (a) and twice (b).

S - ^{225}Ac source, C1 and C2 - collectors of recoil nuclei, D - α-particle detector, RN - recoil nuclei

and its daughters, observed the coincidences of 150 keV γ-rays with $E_{\alpha 150}$=6612 keV α-particles of ^{221}Ra, resulting from the β-decay of ^{221}Fr [1]. Thus, the observation of the ^{221}Fr β-decay [1] was confirmed. Its intensity was redetermined as $(11\pm5)\cdot10^{-5}$ decays. It is of interest to confirm this result in direct α-spectrum measurements.

- Chunnin et al. [8] found the ^{217}At α-decay to the ^{213}Bi 759 keV level. The α-line $E_{\alpha 759}$ (^{217}At)=6322 keV, $J_{\alpha 759} = 5\cdot10^{-3}$ % is close to the ^{221}Fr α_0-line ($E_{\alpha 0} = 6341$ keV, $J_{\alpha 0} = 85$ %) and was observed only in $(\alpha - \gamma)$-coincidences. It is worthwhile to confirm these data in direct α-spectrum measurements.

In the present paper the weak components of the ^{221}Fr, ^{217}At, and ^{213}Bi α-spectra are studied. The phenomenon of recoil in α-decay is used to eliminate the contribution to these spectra from the α-radiation of mother nuclei.

2. Experimental set-up

The main source of α-radiation was ^{225}Ac separated from ^{229}Th by the technique "The isotope generator of ^{225}Ac" [9]. The ^{225}Ac source activity was about 20 mCi. The ^{225}Ac activity was electrolytically deposited on a tantalum foil and then vacuum evaporated on an aluminum foil. Small thickness of the resulting sources provided a considerable (up to 30 %) yield of recoil nuclei. To study α-spectra of the recoil nuclei, the ^{225}Ac source was placed in a vacuum chamber so that the detector, situated in the chamber, could not detect α-particles from the source (Fig. 2). The recoil nuclei from the α-decay of ^{225}Ac and daughter nuclei were gathered on a collector (C1 in Fig. 2). The detector recorded α-particles from the decay of the recoil nuclei gathered on the collector. Thus the α-spectrum of the ^{221}Fr and daughter nuclei free of the contribution from α-particles of ^{225}Ac was provided (from here on it is called the ^{221}Fr α-spectrum).

To have the ^{217}At α-spectrum the α-recoil phenomenon was used twice. The detector was placed in the chamber in a position where it could not "see" both the ^{225}Ac source and the first collector. The recoil nuclei from the α-decay on the first collector were gathered on the second collector. The detector recorded α-particles from the decay of nuclei on the second collector (Fig. 2(b)).

A Canberra Si(Au) detector (diameter 10 mm, FWHM 15 keV) was used to measure α-spectra. The ^{221}Fr and ^{217}At decay spectra shown in Figs.

3(b,c), are compared with the α-spectrum of the ^{225}Ac and daughter nuclei (Fig. 3(a)). Note that the widths and forms of the α-lines from the decay of different nuclides are different. This is because part of the nuclei resulting from the α-decay penetrate into the collector material, which broadens the α-lines of these nuclei. That is why the narrowest in spectrum Fig. 3(a) lines belong to the ^{225}Ac decay, in Fig. 3(b) to the ^{221}Fr decay, and in Fig. 3(c) to the ^{217}At decay. Note also that since the recoil nuclei leave the ^{225}Ac source or the collectors with a relatively high yield, the number of decays recorded per time unit will be not constant for different members of the ^{225}Ac decay chain. It decreases with increasing number of α-decays leading to formation of the nucleus in question from ^{225}Ac. Therefore, the relative intensities of α-lines from the decay of nuclei with the same mass numbers were used in the analysis of the result given in Tables 1 and 2. The relative intensities of α-lines were taken to be proportional to their areas, i.e. the efficiency of the detector was taken to be constant in the energy interval $E_\alpha = 5.0 \div 8.5$ MeV.

3. Experimental Results

The comparison of the ^{221}Fr and ^{217}At spectra (Figs. 3(b,c)) with the spectrum of the ^{225}Ac and daughter nuclei (Fig. 3(a)) allows one to estimate the degree of their purity from α-radiation of mother nuclei. In the ^{217}At α-spectrum the $E_{\alpha 0}$=6341 keV ^{221}Fr line is observed. Its intensity is $5{\cdot}10^{-4}$ $J_{\alpha,\ ^{217}\mathrm{At}}$. Thus the investigations, whose results are displaed in Fig. 3(c), are equivalent to the investigations with the mass-separated source of ^{217}At (32 ms) with the ^{221}Fr impurity of the order of $5{\cdot}10^{-4}$. To evaluate the ^{225}Ac impurity is more difficult because the α-lines ($E_{\alpha 0}(^{225}\mathrm{Ac})$=5830 keV and $E_{\alpha 0}(^{213}\mathrm{Bi})$ =5870 keV) are too close in energy. But it can be said with confidence that the intensity of the $E_{\alpha 0}(^{225}\mathrm{Ac})$ line in these spectra is below $5{\cdot}10^{-3}$.

Table 1 gives the results of the analysis of the spectra from Figs. 3(b) and (c).

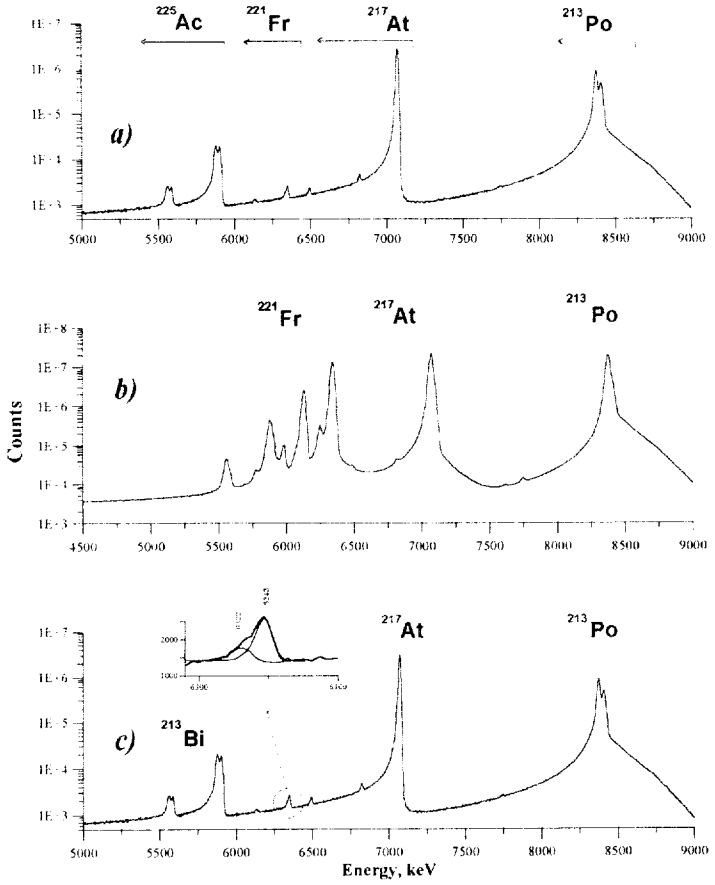

Fig. 3. Alpha spectra of:

a) ^{225}Ac and daughter nuclei (exposition 108 h);

b) ^{221}Fr and daughter nuclei (once recoil nuclei, exposition 270 h);

c) ^{217}At and daughter nuclei (twice recoil nuclei,exposition 182 h).

Complex line: $E_0(^{221}\mathrm{Fr}) = 6341$ keV and $E_{\alpha 759}(^{217}\mathrm{At}) = 6322$ keV is shown in the insert

Table 1. Intensities of the α-lines of the ^{217}At, ^{213}Bi, and ^{213}Po decay

Energy, keV		Intensity per cent	
Levels	α-particles	Present paper	Other publications
^{217}At → ^{213}Bi			
0	7067	>99.9	>99.9
258	6814	0.038(4)	0.036(3) [8]
(465)	6609	-	0.010(5) [10]
593	6485	0.022(2)	0.021(2) [8]
759	6322	0.012(6)	0.005(1) [8]
(1050)	6037	<0.002	(0.003) [1,10]
^{213}Bi → ^{209}Tl			
0	5869	2.05(3)	1.94(11) [10]
324	5549	0.153(3)	0.16(3) [10]
(868)	(5018)	$<10^{-4}$	(0.03) [2,10]
^{213}Po → ^{209}Pb			
0	8376	97.76(3)	97.91(3) [10]
779	7614	0.0030(2)	0.0047(5) [10]

Note: Energies of alpha-particles and levels are from references [1,2,8,10].

- **The ^{217}At α-spectrum:** Intensities of the $E_{\alpha 258}$ = 6814 keV and $E_{\alpha 593}$=6485 keV lines are in good agreement with the results of the $(\alpha-\gamma)$-coincidence experiments [8]. The E_α = 6341 keV line (Fig. 3(c)), whose main part we attribute to the ^{221}Fr decay (see above), is a complex one. Its decomposition, shown in the insert in Fig. 3(c), allowed us to determine the intensity of the new $E_{\alpha 759}$ = 6322 keV line (α-decay of ^{217}At in the 759 keV level of ^{213}Bi). It is $J_{\alpha 759} = (12\pm6)\cdot10^{-3}$ % and agrees with [8]. The intensity evaluation of the E_α=6037 keV line does not exclude the possibility of assigning this α-line to the ^{217}At decay.

- **The ^{213}Bi α-spectrum:** The measured intensities of the $E_{\alpha 0}$ (^{213}Bi)= 5870 keV and $E_{\alpha 324}$ (^{213}Bi)=5549 keV lines agree with the known ones [10]. The measured upper limit for the intensity of the $E_{\alpha 868}$=5018 keV line appeared to be 100 times smaller than expected from [2]. Thus, the assumption that the ^{209}Tl 868 keV level is excited in the ^{213}Bi α-decay is not confirmed. Note that in their later paper [3] the authors of [2] attributed the 868 keV γ-transition to the ^{213}Bi →^{209}Po β-decay, but did not abandon the earlier assumption that the 868 keV

level is excited in ^{209}Tl. Accordingly, in the 1996 Table of Isotopes [10] the 868 keV level in ^{209}Tl is preserved.

- **The ^{213}Po α-spectrum:** The measured intensity of the $E_{\alpha 778}(^{213}\mathrm{Po})$ line agrees with the known data [10].

Table 2 gives the results concerning the β^--decay of ^{221}Fr, ^{217}At and ^{213}Bi.

Table 2. Intensities of the ^{221}Fr, ^{217}At, and ^{213}Bi β^--decay

Nuclei	β-decay	
	Present paper	Other publications
^{221}Fr	$(4.8\pm1.5)\cdot10^{-5}$	$(11\pm5)\cdot10^{-5}$ [7]
^{217}At	$(6.7\pm2.4)\cdot10^{-5}$	$(12\pm6)\cdot10^{-5}$ [1]
		$<5\cdot10^{-5}$ [7]
^{213}Bi	0.9776(3)	0.9791(3)[10]

- **^{221}Fr:** In the ^{221}Fr α-spectrum very weak lines of ^{221}Ra are observed. The $E_{\alpha 150}$= 6612 keV line is the most distinct. This line was earlier attributed in the ^{225}Ac decay chain to the ^{217}At decay [10]. Its belonging to the ^{221}Ra decay was proved in [7] by observation of coincidences of this line with the 150 keV γ-ray, and is confirmed in the present study by the fact that ^{221}Ra α-lines are displayed in the ^{221}Fr spectrum and are not observed in the ^{217}At spectrum. In the ^{225}Ac decay chain ^{221}Ra results from the β-decay of ^{221}Fr. There is not another explanation of the ^{221}Ra presence in the ^{225}Ac decay chain. Using the 6612 keV α-line intensity we determined the intensity of the ^{221}Fr β-decay branch to be $(4.8\pm 1.5)\cdot10^{-3}$ % in agreement with the result of [7]: $(11\pm5)\cdot10^{-3}$ %. Now that the 6612 keV α-line is ascribed to the ^{221}Ra α-decay, there are not experimental data for introduction of the ^{213}Bi 450 keV level in the decay of ^{217}At [10].

- **^{217}At:** In the ^{217}At α-spectrum, (Fig. 3(c)) the $E_{\alpha 0}$=7741 keV, $J_{\alpha 0}$=100 % α_0-line of ^{217}Rn ($T_{1/2}$=0.54 ms) is observed. This ^{217}Ra is formed both in the ^{221}Ra α-decay and in the β-decay of ^{217}At. The intensity of the ^{217}At β-decay branch was calculated as a difference between the $E_{\alpha 0}$=7741 keV line intensity in the spectrum of Fig. 3(c) and the ^{221}Fr β-decay branch intensity found above. The

value $(6.7\pm2.4)\cdot10^{-5}$ per decay does not contradict the upper limit determined in [7] and earlier investigations.

- **^{213}Bi:** The intensity of the ^{213}Bi α-decay determined from the ratio of the α-line areas in the spectrum of Fig. 3(c):

$$\frac{S_{\alpha0}(^{213}Po)}{S_{\alpha0}(^{213}Po)+S_{\alpha0}(^{213}Bi)+S_{\alpha324}(^{213}Bi)}=0.9776(10).$$

is in agreement with the known value [10].

4. Conclusion

The use of the α-recoil phenomenon to study α-spectra in the ^{225}Ac equilibrium decay chain has allowed us to free spectra investigated from the α-radiation of mother nuclei and to gain new or more reliable experimental data on the intensity of weak components of these spectra.

The research of the ^{217}At α-spectrum confirms the results [8] about the excitation of the 759 keV level in ^{213}Bi and yields more correct data on the intensity of the ^{217}At α-decay to the 258 and 593 keV levels in ^{213}Bi. It is established that the 6612 keV α-line, previously attributed to the ^{217}At α-decay, arises from the ^{221}Ra α-decay and thus there is no experimental basis for the introduction of the 450 keV level in ^{213}Bi.

It is shown that the assumed [2] excitation of the ^{209}Tl 868 keV level in the ^{213}Bi α-decay contradicts the results of the present ^{213}Bi α-spectrum investigation.

Identification of the ^{221}Ra and ^{217}Rn α-lines in α- spectra of the nuclei from the ^{225}Ac decay chain and measurement of their intensity has allowed us to repeat determination of the β-decay intensity for ^{221}Fr, ^{217}At, and ^{213}Bi.

The authors are grateful to Dr. V.B. Brudanin for his interest in this investigation. The investigation was supported by the Russian Foundation for Basic Research (Project No. 94-02-04828).

References

1. Liang C.F. Theses LT University de Paris, Orsay (1969).
2. Konassi M.C., Hachem A., Ardisson C. and Ardisson G. NIM, A280 (1989) 424.
3. Ardisson G., Barci V., El-Samad O. NIM, A339 (1994) 168.

4. Sheline R.K., Liang C.F., Paris P. Phys. Rev. C51 (1995) 1192.

5. Gromov K.Ya., Kuznetsova M.Ya., Norseev Yu.V. et al. Izv. RAN, ser. fiz., 58, No. 1 (1994) 35.

6. Butabaev Yu., Adam I., Gromov K.Ya. et al. Izv. RAN, ser. fiz., 59, No. 11 (1995) 35.

7. Chumin V.G., Elissev S.S., Gromov K.Ya. et al. Izv. RAN, ser. fiz., 59, No. 11 (1995) 58.

8. Chumin V.G., Fominikh V.I., Gromov K.Ya. et al. JINR Preprint E6-96-160, Dubna, 1996. Accepted by Z.Phys. A.

9. Tsupko-Sitnikov V.V., Norseev Yu.V., Khalkin V.A. Journal of Radioanalytical Nucl. Chem., 202 (1996) 75.

10. Firestone P.B., Shirley V.S. Table of Isotopes, eighth edition (1996).

Received by Publishing Department
on June 9, 1997.

Чумин В.Г. и др.
E6-97-189

Исследование α-спектров при распаде ^{221}Fr, ^{217}At, ^{213}Bi и ^{213}Po

Для получения информации об интенсивности слабых компонентов α-спектров нуклидов из цепочки распадов ^{225}Ac использовано явление отдачи при α-распаде. Показано, что нет экспериментальных оснований для введения уровней 450 кэВ ^{213}Bi при распаде ^{217}At и 868 кэВ ^{209}Tl при распаде ^{213}Bi. Подтверждается возбуждение уровня 759 кэВ ^{213}Bi при распаде ^{217}At. Измерены интенсивности β^--распада ^{221}Fr, ^{217}At и ^{213}Bi.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 1997

Chumin V.G. et al.
E6-97-189

Studies of α-Spectra in ^{221}Fr, ^{217}At, ^{213}Bi and ^{213}Po Decays

The alpha-recoil phenomenon is used to gain data on the weak components of the α-spectra of the nuclides from the ^{225}Ac equilibrium chain. It is established that there is no experimental basis for introducing the 450 keV level of ^{213}Bi in the ^{217}At decay and the 868 keV level of ^{209}Tl in the ^{213}Bi decay. Excitation of the 759 keV level in the ^{217}At decay is confirmed. The intensities of the ^{221}Fr, ^{217}At and ^{213}Bi β^--decay are measured.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 1997

Редактор Е.И.Кравченко. Макет Т.Е.Попеко

Подписано в печать 02.07.97
Формат 60 × 90/16. Офсетная печать. Уч.-изд.листов 1,14
Тираж 335. Заказ 50034. Цена 1368 р.

Издательский отдел Объединенного института ядерных исследований
Дубна Московской области