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ON THE ^{221}Rn → ^{221}Fr DECAY SCHEME

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Experimental information on the structure of the ^{221}Fr levels can be gained from investigation of either the ^{225}Ac ($T_{1/2}$ =10 d) α-decay or the ^{221}Rn ($T_{1/2}$ =25 min.) β^--decay. In the latter case there arise difficulties with preparing ^{221}Rn sources: radon is a noble gas and the only way to produce sufficiently strong ^{221}Rn sources is via the reaction of spallation of thorium by protons yielding not only ^{221}Rn but also other radon isotopes. The most comprehensive investigation of ^{221}Rn sources was performed by Vylov et al. [1]. Data on the γ-spectrum, conversion electron spectrum, and α-spectrum were gained. A decay scheme was proposed. However, coincidence experiments could not be carried out at that time.

In [2] the α-decay ^{225}Ac $\rightarrow$^{221}Fr was investigated. Qualitative analysis was given to (α-γ)-coincidences to prove belonging of γ-transitions to the ^{225}Ac -decay. The ^{225}Ac -decay scheme was proposed. The results of the investigation also allow ^{221}Rn decay scheme proposed in [1] to be somewhat refined relying on, first, the proof [2] of existence of the relevant levels in ^{221}Fr and, secondly, the relative intensities of γ-rays at the de-excitation of these levels. The ^{221}Rn $\rightarrow$ ^{221}Fr decay scheme proposed by us on the basis of an analysis like that is displayed in Fig. 1. It shows all γ-transitions found in [2] at de-excitation of a level. Transitions observed in [1] are marked with an asterisk. A total intensity, including conversion, is given for each γ-transition. Intensities of γ-transitions that were not observed in [1] are calculated with relative intensities of γ-rays from each level given in [2].

Vylov et al. [1] assume that the ^{221}Rn decay may excite the 393.2-keV level in ^{221}Fr , which is then de-excited by the 119.9, 168.9, and 197.8-keV transitions. Seven transition from this level are found in the ^{225}Ac decay (see Fig. 1). Intensity ratios of the 168.9-keV and 197.8-keV γ-rays in [1] and [2] coincide within the error. Therefore, we believe that the 393.2-keV level in ^{221}Fr is excited at the ^{221}Rn decay. Intensities of the 114, 139.6, 243.2, 284.5, and 354.9-keV γ-rays are lower than the intensity of the 197.8-keV γ-transition, which explains their absence in [1]. Placing the 119.9-keV γ-transition between the 393.9 and 273.5-keV levels [1] is in conflict with the results [2]. The 273.5-keV level is introduced in [2] on the basis of coincidence of 236-keV γ-rays with E_α = 5563 keV α-particles. No 273.5-keV γ-rays were observed in [2, 3]. Therefore we believe that

273.5-keV γ-rays in [1] are due to presence of other isotopes in the ^{221}Rn source. Thus, we think that in [1] they did not have grounds for introducing the 273.5-keV level at the ^{221}Rn decay and thus for placing the 119.9-keV γ-transition between the 393.9 and 273.5-keV levels.

Intensity ratios of γ-rays from de-excitation of the 294.6, 279.2, 253.5, 234.5, 224.6, 195.8, and 150 keV in [1] and [2] coincide within the tolerable error. Therefore, we believe that excitation of the above levels at the ^{221}Rn decay is justified. The ^{221}Fr level at 288.1 keV excited at the ^{225}Ac α-decay is not found in [1] at the ^{221}Rn decay.

Gromov et al. [4] and Ardisson et al. [3] assumed excitation of the ^{221}Fr level at 145.9 keV at the ^{225}Ac decay. Investigation of the (α-γ)-coincidences [2] confirm existence of a ^{221}Fr level at this energy. The spectrum of α-particles coinciding with the 119.9-keV γ-rays is displayed in Fig. 2. Peaks with E_α = (5686±15), (5609±15), and (5443±15) keV are observed in this spectrum. Energies of these lines coincide with energies of α-particles populating levels at 145.9, 224.6, and 393.2 keV. Coincidences with E_α = (5609±15) keV are due to the fact that the 145.9-keV level is populated by 78.8-keV γ-rays at de-excitation of the 224.6-keV level more intensely than by the α-decay to the 145.9-keV level. The area of the E_α = (5443±15) keV peak is small, about 2.5% area of all peaks in Fig. 2. Coincidences of 119.9-keV γ-quanta with (5443±15)-keV α-particles is due to population of the 145.9-keV level by a cascade of the 78.8 and 169.2-keV γ-transitions from the 393.2-keV level through the 224.6-keV level. The intensity ratio of the 119.9 and 46.2-keV transitions is 17 in [2]; that is why 46.2-keV γ-rays were not observed in [1]. Thus, we consider introduction of the 145.9-keV level in the ^{221}Rn decay scheme to be justified.

Intensity ratios of γ-rays at de-excitation of levels at energies ranging from 25.9 to 108.3 keV in [1] agree with the data in [2] within the tolerable error, i.e., all these levels are excited at the ^{221}Rn decay and there is no contradiction in their properties.

Intensities of β^--transitions to ^{221}Fr level are found from the intensities of γ-transitions at the ^{221}Rn decay and reduced probabilities lgft of these β^--transitions are calculated [5]. The value Q_{β^-} (^{221}Rn) = 1130(100) keV [6] was used in this calculation. The values of I_{β^-} and lgft are shown in Fig. 1.

Levels at 108.3 keV $(7/2)^-$ and 294.6 keV $(9/2)^+$ are most intensely populated at the ^{221}Rn decay, the respective intensities being I_{β^-} = 10.3(34) and 25(2). To the 108.3-keV level there proceeds a once-forbidden

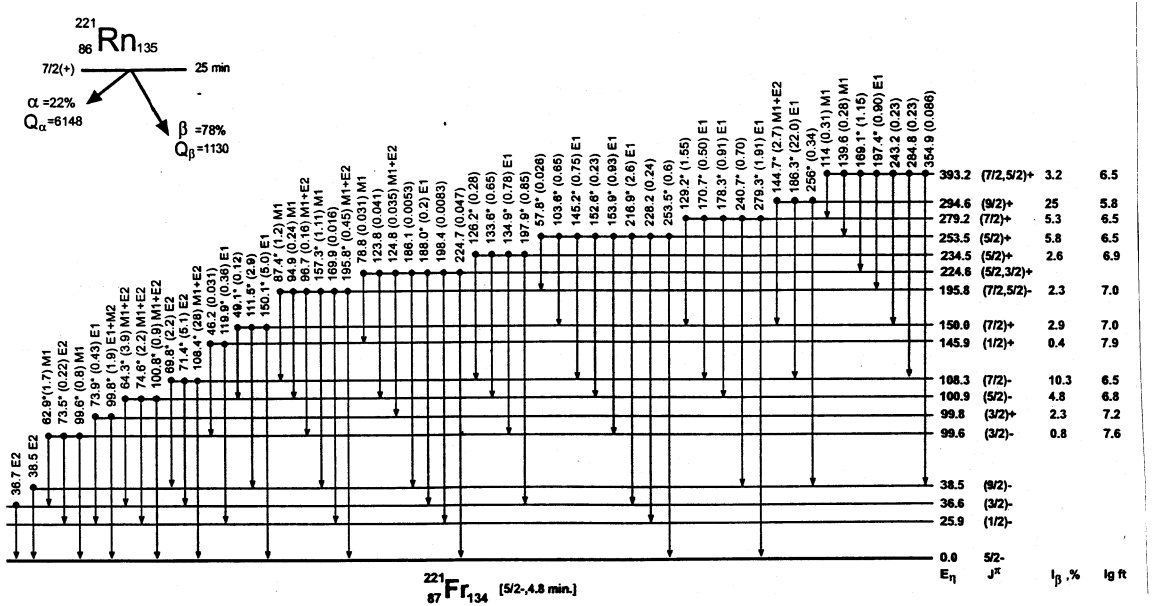

Fig. 1. ^{221}Rn decay scheme. Above γ-transitions there are their energies, total (including conversion) intensities (in parentheses), and experimental multipolarity data. An asterisk (*) marks γ-transitions observed in [1]. Next to the level energies are spins and parities [2], intensities and reduced β-decay probabilities.

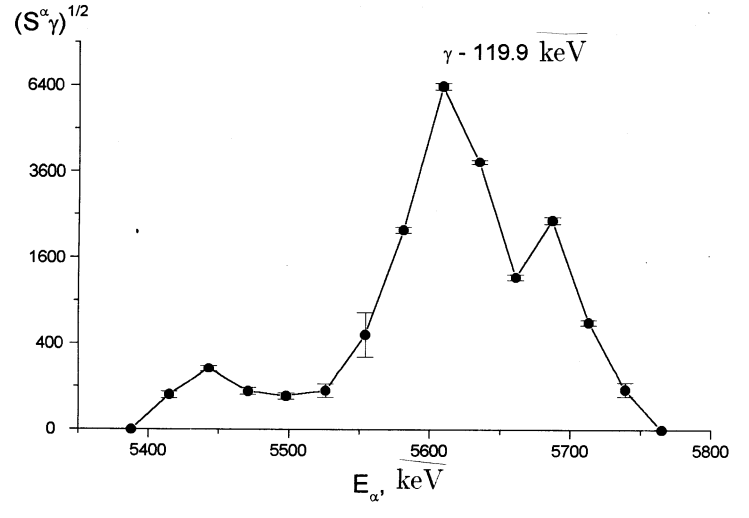

Fig. 2. Intensity of 119.9-keV γ-ray in (α-γ)-coincidence experiment as a function of the α-particle energy.

β^--transition. A β^--transition to the 294.6-keV level is allowed. The ^{221}Rn ground state spin is 7/2 [7]. Reduced probabilities for transitions to these levels allows a conclusion that the ^{221}Rn ground state parity is most probably positive. The reduced probabilities for transitions to other ^{221}Fr levels are not in contradiction with the assumption of the positive parity of the ^{221}Rn ground state.

Thus, in addition to those in [1], the 393.2-keV $(7/2, 5/2)^+$ and 145.9-keV $(1/2)^+$ levels are introduced in the ^{221}Fr level scheme. The assumption [1] of excitation of the 273.5-keV level at the ^{221}Rn decay is shown to contradict the results of investigation of $(\alpha\text{-}\gamma)$- coincidences at the ^{225}Ac decay [2]. The ^{221}Rn ground state parity appears to be positive.

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О схеме распада ^{221}Rn → ^{221}Fr

Сравниваются результаты исследований β^--распада ^{221}Rn и α-распада ^{225}Ac. Показано, что при распаде ^{221}Rn возбуждаются уровни ^{221}Fr с энергиями 145,9 и 393,2 кэВ. Определены интенсивности и приведенные вероятности β^--распада на уровни ^{221}Fr. Сделано заключение о положительной четности основного состояния ^{221}Rn.

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On the ^{221}Rn → ^{221}Fr Decay Scheme

The results of investigating the ^{221}Rn β^--decay and the ^{225}Ac α-decay are compared. It is shown that ^{221}Fr levels at 145.9 and 393.2 keV are excited at the ^{221}Rn decay. Intensities and reduced probabilities of the β^--decay to the ^{221}Fr levels are determined. A conclusion is drawn that the parity of the ^{221}Rn ground state is positive.

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

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