THE $Bi^{212} \to Po^{212}$ DECAY SCHEME

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Data obtained in the investigation of the conversion spectrum of an active precipitate of radiothorium are used in an attempt to refine the $Bi^{212} \to Po^{212}$ decay scheme. It is shown that in addition to the known 727.2, 1620.5, 1679.9 and 1800.4 kev levels, the Bi^{212} decay scheme contains a 1512.16-kev level. The 830, 2180, 2200 and 2230 kev levels suggested in the literature are confirmed experimentally. The possibility of the existence of vibrational levels in Po^{212} is discussed.

In spite of repeated studies of the α, β, and γ conversion spectra of active precipitates of radiothorium, the data available do not make it possible to construct a sufficiently complete scheme of levels of Po^{212}(ThC′). This is explained by the weak excitation of the Po^{212} levels, whereby the β decay Bi^{212} (ThC) → Po^{212}(ThC′) goes principally into the ground state Po^{212} (approximately 80%).

The most reliable data are those on the long-range particles.[1-3] Investigations devoted to a study of the conversion spectrum of an active precipitated RaTh[4-6] contained very little information on the Po^{212} spectrum. As regards the γ spectrum of Po^{212}, Refs. 7 – 11, devoted to its investigation, contain many contradictory data. The following γ lines, which belong to Po^{212}, were found in these investigations: 727 kev,[8,9,11] 1030 kev,[8,11] 1340 kev,[7,8,11] 1500 kev,[7,11] 1620 kev,[7,8,11] 1800 kev,[7,8,11] and 2200 kev,[7,8,11] Level schemes of Po^{212}, given in some of these works, differ noticeably from each other.

E_γ, Kev	Shell	I_e percent per decay
727.2	K	0.106
	L	0.024
	M	0.0045
785.4	K	0.051
	L	0.007
893.4	K	0.014
	L	0.004
952.7	K	0.010
1073.7	K	0.006
1078.5	K	0.014
1512.6	K	0.008
1620.4	K	0.013
1800.2	K	0.007

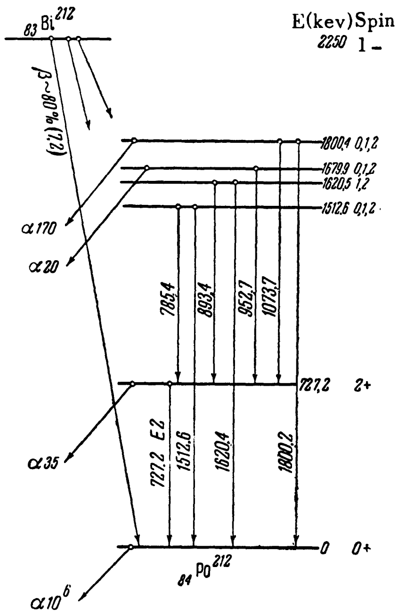
In the present work we attempt a refinement of the level scheme of Po^{212} on the basis of data[12,13] obtained by us in a study of a spectrum of internal-conversion electrons of an active precipitate of RaTh, made with a "ketron" type magnetic spectrometer. The relatively high sensitivity of the procedure had made it possible to detect lines of very low intensity. The line energies were determined with an accuracy of ~ 0.5 kev. The table lists the results of our investigations,[12,13] pertaining to the conversion spectrum of Po^{212}.

Data on long-range α-particles[3] indicate that there exists in Po^{212} three excited levels: 726, 1674, and 1979 kev (see diagram). These levels appear also in the conversion spectrum. The first excited level gives rise to the well-known 727.2 kev γ transition. The existence of a 1088.4 kev level is confirmed not only by the direct γ transition into the ground state, but also by the transition with E_γ = 1.073.7 kev to the first excited level, which we found.

These three excited levels of Po^{212} are not enough to interpret the remaining five γ lines listed in the table. In Refs. 7, 8, 10, and 14 the decay scheme of Bi^{212} includes a 1620 kev level. Our data confirm the existence of this level. It gives rise to the 1620.4 and 893.4 kev γ lines. The sum of the energies of the 727.2 and 893.4 kev cascade γ quanta coincided, within experimental accuracy, with the energy of the direct 620.4 kev transition.

Along with the above levels, we propose that there exists an excited state with energy 1512.6 kev. This level explains the origin of the 1512.6 and 785.4 kev γ lines. The 1500 kev line was found in the γ spectra,[7,12] and the 785.4 kev γ line, which was observed in the conversion spectra,[4,6] was not identified previously. The existence of a 1512.6 kev level in Po^{212} is confirmed by the good agreement between the sum of the energies of the 727.2 and 785.4 kev γ lines with the γ-transition energy of 1512.6 kev.

The proposed $Bi^{212} \to Po^{212}$ decay scheme does not include the 1078.5 kev γ transition. This indicates that Po^{212} contains at least one more excited state. There are not enough data at the present time to prove this statement. The decay achemes proposed in Refs. 7 and 8 contain 830 and 2200 kev levels, and Ref. 14 contains in addition the 2180 and 2230 kev levels. The 830 kev level introduced into the scheme appears to be in error. Its assumed presence was based, on one hand, on the existence of the corresponding group of long-range upper particles,[15] and on the other hand on the 860 kev γ line observed in the conversion spectrum.[4,6] However, in later works,[1,2] the existence of a group of α-particles that differ from the fundamental group by a decay energy of 830 kev has not been confirmed. In addition, it was shown that the 860 kev γ line belongs not to Po^{212} but to Pb^{208} (Refs. 16 and 17).



$Bi^{212} \rightarrow Po^{212}$ decay scheme

The 2180 and 2230 kev levels, proposed by Demichelis,[14] are also absent from Po^{212}. It was shown in that reference on the basis of experiments on $\gamma-\gamma$ coincidences that Po^{212} contains the 1.50 — 0.73 Mev and 1.35 — 0.83 Mev $\gamma-\gamma$ cascades. This gave rise to the assumption of the existence of 2230 and 2180 kev levels. However, the Demichelis conclusions may be in error, since in processing his experimental data he assumed that the 830 kev (more accurately 860 kev) γ transition belongs to Po^{212}. It was indicated above that the transition belongs to Pb^{208}. The Pb^{208} level scheme[16-18] discloses the existence of an intense 860 — 2620 kev cascade, which has probably also played an important role in the Demichelis experiments.

The existence of a 2200 kev level cannot be assumed at the present time to be sufficiently well proven. This level was proposed in Ref. 7 on the basis of a 2200 kev γ line found in the spectrum of the recoil electrons. However, no such γ line was observed in Ref. 10, and the upper limit proposed for this line is 10 times greater than the intensity given in Ref. 7. No lines in this energy region were observed when we plotted the conversion spectrum of an active precipitate of RaTh. The upper limit for the intensities of the possible conversion lines that are possible here amounts to approximately 10^{-5} electrons per Po^{212} decay act. Nor did we find the γ lines that could be explained by the transition from the 2200 kev to the first excited level.

As to the spins of the excited states, one can speak with certainty only concerning the spin of the 727.2 kev level. It follows from Ref. 9 that the spin of this level is 2^+, according to the general rules for even-even nuclei. This is confirmed also by our data; it follows from the K/R ratio for the 727.2 kev γ transition that this transition is of type E2. To determine the multipolarity of the γ transitions from higher levels one could use our data on the intensity of conversion lines and on the data of Refs. 7, 8, and 10 on the intensities of the γ rays. However, the data of these references are quite contradictory, and if one shows no preference to any one of these data, the following possibilities appear permissible for the level spins: for the 1620.5 kev level — 1 or 2, for the 1512.5, 1800.4 kev and apparently also for the 1670.9 kev levels — 0, 1, and 2. To determine the spins of these levels it is necessary to have more accurate and more reliable data on the intensities of the γ rays. It is impossible to determine the multipolarity of the 785.4 and 893.4 kev γ transitions from the K/L ratio, since the corresponding L-lines have intensities that are close to the sensitivity limit of our apparatus.

From theoretical considerations,[10] nuclei having four particles or more above the filled shells should exhibit a vibrational level structure. However, at the present time it is impossible to state with certainty that such a level structure takes place in Po^{212}. The following facts favor the existence of a vibrational structure in Po^{212}: (1) the equidistant nature of the first two excited levels 727.2 and 1512.6 kev; the ratio of their energies is 2.08; (2) according to the generalized nuclear model, one expects the transition from the second vibrational level to the first (single-phonon transition) to be easier than the transition into the ground state (two-phonon transition). This takes place in Po^{212}, if one assumes that the 1512.6 and 785.4 kev transitions are of type E2. In this case it follows from our data on the intensities of the conversion lines that the 785.4 kev transition is approximately twice as intense than the 1512.6 kev transition. Were these transitions to be single-particle ones, the 1512.6 kev γ transition would be approximately 40 times more intense than the 785.4 kev transition.

For further refinement of the level scheme of Po^{212} it is desirable to obtain sufficiently reliable data on the spectrum of Po^{212}.

Note added in proof (October 16, 1956). The 1679.9 kev level does not appear in the γ spectra.[7-11] Nor did we observe in the conversion spectrum the direct transition from this level into the ground state, although we did find a line with energy 952.7 kev, corresponding to the transition from this level into the first excited state.

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235

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THE DECAY SCHEME OF Pl^{208}

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The data obtained in an investigation of the conversion electron spectrum are used in an attempt to refine the decay scheme of Tl^{208}. It is shown that the spin of the ground state of Tl^{208} is 5^+, while the spin of the 3.961-Mev level of Pb^{208} is 6^-. It is assumed that there exists a 3.750 Mev level with spin 7^-. All the excited levels of Pb^{208} are explained by the excitation of one proton.

To study the decay schemes of nuclei belonging to the active precipitate of radiothorium, we investigaged the conversion spectrum of these nuclei.[1-3] The present work is an attempt to refine the decay scheme $Tl^{208} \rightarrow Pb^{208}$ on the basis of experimental data obtained.

The position of the Pb^{208} levels appearing in the decay of Tl^{208} was established in the works by Martin and Richardson.[4,5] An analysis of the intensities and the energies of the β and γ transitions was used