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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THE DECAY SCHEME OF Pl^{208}

E. M. KRISIUK, A. G. SERGEEV, G. D. LATYSHEV, K. I. IL'IN and V. I. FADEEV

Leningrad Institute of Railroad Engineers

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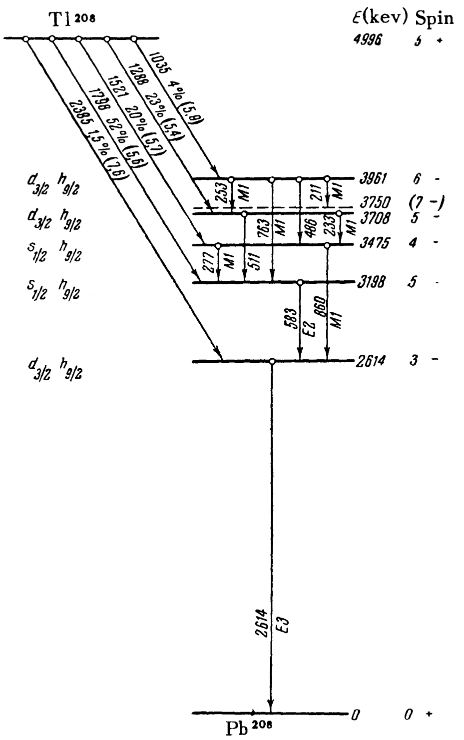
The data obtained in an investigation of the conversion electron spectrum are used in an attempt to refine the decay scheme of Tl^{208}. It is shown that the spin of the ground state of Tl^{208} is 5^+, while the spin of the 3.961-Mev level of Pb^{208} is 6^-. It is assumed that there exists a 3.750 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 by them to show the existence in lead of excited levels with energies 2.62, 3.20, 3.48, and 3.71 Mev. Elliot et al. have established the spins and parities of these levels. From the measurement of the coefficients of internal conversion, from the study of the $\gamma-\gamma$ angular correlations they established the following seɥuence of spins of the Pb^{208} levels: 0 Mev — 0^+, 2.615 Mev — 3^-, 3.198 Mev — 5^{-1}, 3.475 Mev — 4^{-1}, and 3.709 Mev — 5^{-1}.

It was noted in Ref. 7 that the 0.252 and 0.763 Mev γ rays coincide with the 2.6-5-Mev γ rays. It follows therefore that the 0.252 and 0.763-Mev γ rays belong to the $Tl^{208} \rightarrow Pb^{208}$ decay. To explain the origin of these rays, the authors have proposed the existence of a 3.961-Mev level.



E_γ, Kev	Shell	I_e, %	Multi-polarity	I_{trans}, %
211.4	K L	0.15 0.02	$M1$	0.32
233.4	K L	0.13 0.03	$M1$	0.34
252.54	K L	0.37 0.085	$M1$	1.1
277.35	K L M N	2.4 0.44 0.10 0.03	$M1$	8.4
485.9	K	0.01		0.5
510.84	K L M N	1.7 0.073 0.03.		22.6
583.2	K $L_I + L_{II}$ L_{III} M N	0.77 0.09 0.097 0.03	$E2$	83.2
763.2	K L	0.058 0.01	$M1$	2
860.5	K L M	0.27 0.048 0.01	$M1$	12.3
2614.3	K L M	0.17 0.031 0.0093	$E3$	100

Our own measurements of the spectrum of the internal-conversion electrons confirm such a level scheme for Pb^{208} (see figure). Furthermore:

(1) All the known γ transitions fit energywise into this decay scheme with an accuracy of ~ 0.1 kev, which is within the experimental error of our measurements.

(2) The multipolarities of all the lines agree with the ascribed spins and parity (see table). The multipolarities of the lines were determined from the conversion ratios on the K and L shells, and for the 2.614-Mev lines also from the absolute value of the conversion coefficient on the K shell.[8]

(3) The existence of a 3.961-Mev level was confirmed not only by the 0.253 and 0.763-Mev transitions, which were identified by Elliot,[7] but also by the 0.486-Mev transition; the conversion line corresponding to this transition was not identified previously. There are no data in the literature concerning the spin and parity of the 3.961 Mev level. According to our measurements, the 0.253 Mev transition is magnetic dipole. Therefore the 3.961 Mev level can have three spin values, 4^-, 5^-, and 6^-. However, the first two values are of little likelihood, since the 0.486-Mev transition for these values should also be of the magnetic-dipole type and should show an intensity considerably greater than experimentally observed. We therefore assigned a spin 6^- to the 3.961 Mev level.

As to the spin of the ground state of the Tl^{208}, the data available in the literature are contradictory. On the basis of the changes in the $\alpha-\gamma$ angular correlation in the $Bi^{212} \rightarrow Tl^{208}$ decay, Horton[9] assigns a spin 5^+ to the ground state of Tl^{208}, although he cannot exclude completely a spin value 4^+. Demichelis[10] assigns a spin 4^+ to the ground state of Tl^{208}, on the basis of measurement of the $\beta-\gamma$ angular correlation in the $Tl^{208} \rightarrow Pb^{208}$ decay. To resolve this question we estimated $\log(\tau f)$ for β transitions at all excited levels of Pb^{208}. The calculations were made from the measured absolute intensities of the conversion lines and from the theoretical conversion coefficients.[11] The intensity of the β transition at the 2.614-Mev level was taken according to Demichelis;[12] its value was obtained by direct measurement. Our value in this case is not exact, since it is obtained as the difference of two nearly equal numbers. The values of $\log(\tau f)$ obtained by us can be explained only if the spin of Tl^{208} is taken to be 5^+.

It should be noted that all β transitions in this decay scheme are first-order forbidden and the dispersion in the values of $\log(\tau f)$ for the transitions with $\Delta J = 0$ is very small; the same applies to transitions with $\Delta J = 1$. The values of $\log(\tau f)$ themselves are in very good agreement with their classification for nuclei near the twice-filled shells of Pb^{208} (see, for example, Ref. 13), which confirms the correctness of the decay scheme for Tl^{208}.

We undertook an attempt to include the 0.211 Mev γ line in the decay scheme of Tl^{208}. Its presence in this scheme is due to the energy difference of the K and L conversion lines. This transition is of the magnetic-dipole type with respect to the probabilities of conversion on the K and L shells. The diagram shows the possible position of this transition. If the spin of the thus-obtained 3.750-Mev level is 7^-, it should be weakly excited in the β decay of Tl^{208}, and all transitions from this level should be too weak to be detected by their conversion electrons. Attempts to assign another spin to this level or to place the 0.211-Mev transition somewhere else in the decay scheme in such a manner that the initial or final level is a known level lead to the necessity of observing strong γ transitions. Careful searches of the conversion lines corresponding to such transitions did not give positive results. In the work by Tauber[14] an attempt is made to assign definite configurations to the excited levels of Pb^{208}. The 2.614, 3.708, and 3.961 Mev levels are attributed by the author to the excitation of the proton from the $d_{3/2}$ state to the $h_{9/2}$ state, i.e., to the $d_{3/2}h_{9/2}$ proton configuration. The 3.198 and 3.475-Mev levels are assigned either a proton configuration $s_{1/2}h_{9/2}$ or a neutron configuration $p_{1/2}g_{9/2}$. If the scheme for Pb^{208} has any proton and neutron levels, the transitions between them should be noticeably forbidden compared with the single-particle transitions.

We calculated the probability ratios for the competing transitions, using the Moszkowski formula for the single-particle γ transitions.[15] These ratios were compared with the intensity ratios of the γ transitions, given in the table. The comparison shows that the transitions between the levels with various configurations are not strongly forbidden. It follows therefore that both configurations should be of the proton type.

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