Possible observation of an MO transition

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(Submitted 18 June 1988)
Pis'ma Zh. Eksp. Teor. Fiz. **48**, No. 9, 177–178 (25 August 1988)

The decay of the 2819.8-keV level of the 0^- daughter nucleus ^{170}Yb goes to low-lying levels. Partial decay half-lives of the competing transitions have been found through a normalization to the one-particle probability for the 1101.5-keV $E2$ transition. The 2819.9 ± 0.9-keV conversion transition is directed to the 0^+ ground state. Its partial decay half-life is 1×10^{-6} s. It has been assigned a multipolarity MO.

There has been no previous report of an experimental observation of an MO transition. Such transitions may occur between levels with identical spins and different parities. Monochromatic γ-ray emission is forbidden here, but monoenergetic internal-conversion electrons may be emitted. A mechanism for the appearance of such electrons through a nuclear-electron bridge was examined by Krutov.[1]

The most likely place to find an MO transition is in an even-even nucleus, in the decay of 0^- excited levels to 0^+ ground states. A suitable nucleus for searching for MO transitions is ^{170}Yb. The 0^- levels in this nucleus are excited in the β decay of ^{170}Lu (0^+, $T_{1/2} = 48.2$ h).[2] The first searches for 0^- levels in ^{170}Yb were carried out in 1967; they were reliably established in 1972 (Ref. 9). Among these levels is a level at 2819.6 keV with 0^-. In its decay to low-lying levels, one observes an $M2$ transition at 2735.6 keV ($0^- - 2^+$), an $E1$ $0^- - 1^+$ transition, and two $E2$ and 12 $M1$ transitions. The review by Dzhelepov[2] contains data on the spectra of the γ rays of the internal-conversion electrons and on the conversion coefficients, which have been determined in several studies.

The spectrum of internal-conversion electrons contains a transition at 2819.9 ± 0.9 keV, which has not seen in the γ-ray spectrum. We believe that this is a direct transition from the 2819.6-keV, 0^- level to the 0 ground state of ^{170}Yb. The possibility that this transition is of multipolarity MO is not ruled out. Taking 0.02% as an upper limit on the intensity of a γ-ray transition (this is roughly the same as the intensities of the weak nearby transitions in the spectrum), we estimate the conversion coefficient to be $\alpha_c > 5 \times 10^{-4}$. This figure rules out an $E1$ multipolarity, but not $M1$, $M2$, or higher. Furthermore, it does not rule out MO.

In principle, there are two groups of possibilities for the position of the 2819.9-keV transition: 1) Beside the level at 2819.6 keV, within ± 0.5 keV, there is another level, with $J^\pi = 1^+$ or 0^+, which decays to the ground state through a 2819.9-keV transition. 2) There is a level at $2819.9 + 84.3 = 2904.2$ keV with 1^+; from it, there is a 2819.9-keV transition to the 84.3-keV first excited 2^+ level. Spins of 2^+ and higher are ruled out for either of these proposed levels by the values of $\log ft$ for the β transitions, since the β decay of ^{170}Lu comes from a 0^+ level. Neither of the two

possible levels has been confirmed; transitions of the required energy and multipolarity are not observed. Such transitions may go from the proposed levels to other known levels in ^{170}Yb. These possibilities cannot be ruled out entirely, although they do seem unlikely.

An estimate of the partial decay half-life of the 2819.9-keV transition yields 1×10^{-6}s. This estimate was found by comparing the intensities of various transitions which come from the 2819.6-keV level. It is necessary to know the partial decay half-life for at least one transition. Let us assume that the partial decay half-life with respect to the $E2$ transition at 1101.5 keV (0^-–2^-) is equal to the one-particle value, T (one-particle, $E2$) $=1\times10^{-11}$ s. For any competing ith transition, the partial half-life is given by $T_i = T(E2)I(E2)/I_i$. The validity of the normalization is supported by the hindrance factors $F_h = T_i/T_i$ (one-particle). As it turns out, these factors do not go beyond the systematics. For the 530.4-keV $E1$ transition, the factor is $F_h(E1) = 7\times10^4$; that for the 2135.6-keV $M2$ transition is $F_h(M2) = 200$; and the 834.4-keV $E2$ transition is accelerated by a factor of four. The $M1$ transitions are hindered by factors ranging from 5 to 6000.

We know that both γ-ray emission and ordinary internal conversion of electrons are forbidden in a 0^-–0^+ transition. In 1962, however, Krutov studied and carried out calculations on the emission of electrons in an MO conversion through a mechanism of a nuclear-electron bridge.[1] The transition results from a cascade of pairs of virtual $E1$ and $M1$ transitions through levels close to the original state, lying both above and below it. More than 20 1^- levels and more than 10 1^+ levels have been observed in ^{170}Yb in the interval of excitation energies 2300–3300 keV. There is a need for calculations based on this model and a comparison of the results with the value found here, T(MO) $=10^{-6}$ s.

Competing mechanisms for the de-excitation of the 2819.6-keV level might be the simultaneous emission of two continuum γ rays or two internal-conversion electrons.

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[2]B. S. Dzhelepov, V. E. Ter-Nersesyants, and S. A. Shestopalova, *Decay Schemes of Radioactive Nuclei. A* = 169, 170, Nauka, Leningrad, 1988.
[3]N. A. Bonch-Osmolovskaya, Ya. Vrzal, E. P. Grigor'ev *et al.*, Preprint R6-3452, Joint Institute for Nuclear Research, Dubna, 1967.
[9]D. C. Camp and F. M. Berntal, Phys. Rev. **C6**, 1040 (1972).

Translated by Dave Parsons