Search for an $M0$ transition in ^{170}Yb

A. Kuhnert, E. A. Henry, T. F. Wang, M. J. Brinkman, M. A. Stoyer, J. A. Becker, and D. R. Manatt
Lawrence Livermore National Laboratory, Livermore, California 94550

S. W. Yates
University of Kentucky, Lexington, Kentucky 40506

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We have examined the suggestion that an $M0$ transition occurs between the 2819.6-keV 0^- level of ^{170}Yb and the 0^+ ground state by internal-conversion electron emission. Gamma rays, internal-conversion electrons, and internal e^+e^- pairs were detected from the β^+ and electron capture decay of two-day ^{170}Lu (0^+). At an upper limit of 2×10^{-8} electron per ^{170}Lu decay, no evidence was obtained for $M0$ decay of the 2819.6-keV level of ^{170}Yb by single-electron emission.

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Magnetic monopole transitions between nuclear levels with identical spins but different parities have not been observed experimentally and are not expected. Gamma-ray emission is rigorously forbidden in this case, but other decay modes may be possible. According to the electron-nucleus bridge mechanism suggested by Krutov and Knyazkov [1], monoenergetic electron emission may also be a viable decay mode for an $M0$ transition. In this proposed mechanism, the transition occurs by a cascade of pairs of virtual $E1$ and $M1$ transitions through levels close to the original state, and the probability for single-electron emission can become remarkably large.

Grigor'ev [2] has pointed out that the most likely situation for an $M0$ transition is in the decay between an excited 0^- level and the 0^+ ground state of an even-even nucleus. The levels of ^{170}Yb populated in the electron-capture (EC) decay of ^{170}Lu ($J^\pi=0^+$, $t_{1/2}=2.02$ day) are particularly interesting, since it is anticipated that 0^- states at energies above 2 MeV will be populated in this decay. Indeed, several excited 0^- states have been

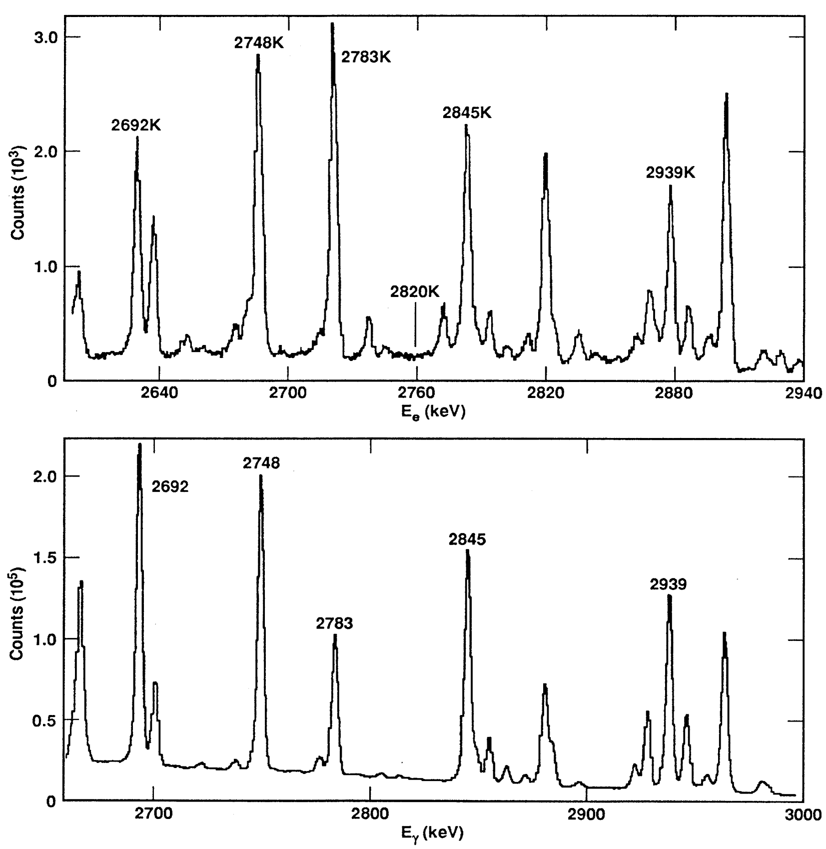

FIG. 1. Spectra of (top) internal conversion electrons detected with the superconducting solenoidal spectrometer with a fixed momentum window centered at 2800 keV and (bottom) γ rays observed with a high-purity germanium detector (80% relative efficiency) following the decay of ^{170}Lu. The energies of intense γ rays are labeled in the lower spectrum and their corresponding K-conversion lines are indicated in the upper spectrum. The expected position of a 2820 keV internal conversion line is also indicated in the upper spectrum.

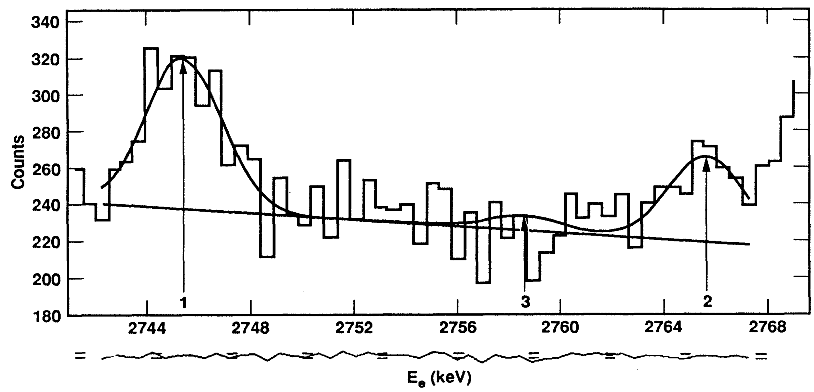

FIG. 2. Portion of the internal conversion electron spectrum (Fig. 1) in the region of the expected 2820 keV transition. Data are shown by the histogram while the smooth curves indicate the fits to the peaks and the background. The residuum between the fitted curves and the data is shown channel-by-channel below the figure. Arrows labeled 1 and 2 mark the 2748 keV M line and the 2775 keV L line, respectively. The position of a 2820 keV K-conversion electron line is indicated by the arrow labeled 3. Note that the peak labeled 2 has 350 counts, approximately the same number expected for peak 3 based on the electron intensities determined by Dzhelepov, Ter-Nersesyants, and Shestopalova [5].

identified [3,4] in ^{170}Yb, and the 2819.6 keV 0^- state is populated directly in 6% of the decays [3].

Grigor'ev [2] has recently reported the possible observation of an $M0$ transition following the decay of ^{170}Lu. This assertion is based on the interpretation and placement of a weak internal-conversion electron line at 2819.9±0.9 keV, with no corresponding γ ray, listed in the compilation by Dzhelepov, Ter-Nersesyants, and Shestopalova [5]. Unfortunately, except for its intensity [0.025±0.015 relative to 100 for the 1450 keV K-conversion transition from the 1534 keV (2^+) state of ^{170}Yb to the first excited state at 84 keV] no additional information is available about this transition. Grigor'ev [2] has associated this transition with the decay of the aforementioned 2819.6 keV 0^- state of ^{170}Yb to the ground state and has suggested that this is the first example of an $M0$ transition in nuclei. Clearly, such an astounding claim demands greater scrutiny.

We have reinvestigated the β^+/EC decay of ^{170}Lu to levels in ^{170}Yb and have searched for the possibility of the aforementioned $M0$ decay. The decay of ^{170}Lu is quite complicated, and no attempt was made to extend or clarify the detailed level schemes constructed by Camp and Bernthal [3] and Dzhelepov, Ter-Nersesyants, and Shestopalova [5]. Our focus was on the high-energy portion of the internal-conversion electron spectrum from this decay and the reported 2820 keV transition, in particular. In this study, the Lawrence Livermore National Laboratory (LLNL) superconducting solenoidal electron spectrometer [6] proved to be an exemplary instrument to document the possibility of a high-energy $M0$ transition. This spectrometer has high transmission and, with recent detector improvements, unusually good efficiency for high-energy electrons.

The ^{170}Lu activity was produced with the ^{171}Yb(p,2n) reaction. Four thin (approximately 500 μg/cm^2), self-supporting enriched ^{171}Yb foils were bombarded with a 200 nA beam of 16 MeV protons from the LLNL Tandem Van de Graaff accelerator for 24 h. These foils were then counted simultaneously without further processing, and the ^{170}Lu activity was followed for several days. Electrons were detected with the aforementioned superconducting solenoidal spectrometer [6]. In addition, γ-ray spectra were also accumulated with a large-volume

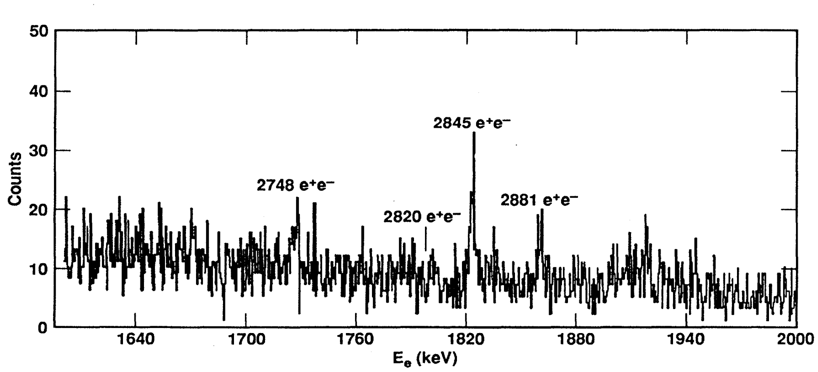

FIG. 3. Internal pair spectrum in the region of the expected 2820 keV transition. Known peaks are labeled with their energies. The position of a peak from a 2820 keV transition is also indicated.

(80% relative efficiency) Ge detector and a 20% Compton-suppressed Ge detector.

Internal conversion and γ-ray spectra from our measurements in the energy range from about 2.6 to 3.0 MeV are shown in Fig. 1. In Fig. 2, the internal-conversion electron spectrum in the region of the expected 2820 keV transition is illustrated in greater detail. Conclusively, no evidence exists for this transition. A direct comparison of the electron intensities determined by Dzhelepov, Ter-Nersesyants, and Shestopalova [5] with our spectrum suggests that, if present, a peak at a transition energy of 2820 keV should contain 370±220 counts in our spectrum. An upper limit (2σ) of 56 counts for such a peak could be established from our data. This limit indicates that the suggested 2820 keV $M0$ single-electron transition occurs in less than $2\times10^{-6}\%$ of all ^{170}Lu decays.

In a separate measurement, the spectrometer was set to detect internal e^+e^- pairs (a possible alternate decay mode [2]) with transition energies in the 2.6–3.0 MeV region. In this detection mode, a positron-electron pair strike the detector simultaneously and provide a sum energy, so the statistical quality of these data is considerably poorer than for single-electron detection. Nonetheless, the spectrum in Fig. 3, which unquestionably exhibits a peak corresponding to the e^+e^- pair produced by the nearby 2845 keV $E1$ transition, provides no evidence for a possible transition at 2820 keV.

Dzhelepov, Ter-Nersesyants, and Shestopalova [5] present their data in tabular form only, so direct spectral comparisons are not possible; however, our measurements appear to be of greater sensitivity. In neither the internal-conversion electron nor the internal pair spectra was the sought 2819.9 keV transition observed. We, therefore, find no evidence for an $M0$ transition in ^{170}Yb.

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