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Search for a 70-ms transition of very low energy in ^{90}Nb

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The decay rate of 1^+ ^{90}Nb^m is observed via $E3$ conversion electrons to investigate if this 1^+ isomer is populated by another isomeric transition of extremely low energy. Such a transition could be of interest for perturbation studies, but has not been found.

[NUCLEAR REACTIONS ^{90}Zr(p,n), $E=7.8$ MeV; ^{90}Nb detected conversion electrons; measured $T_{1/2}$.]

There is a growing awareness of the importance of nuclear low-energy transitions when the nuclear decay rates can be influenced by chemical environment and when these rates can be related to phenomena studied with, e.g., Mössbauer and electron spectroscopy for chemical analysis (ESCA) techniques. In view of this our attention was drawn by an interesting ^{90}Nb^m half-life determination reported by Courtney *et al.*[1,2] They measured the $E3$(257 keV, 1^+-4^-) decay and found for the 1^+ state at 382 keV a half-life of 6.3 ± 0.2 ms, in good agreement with the value 6.19 ± 0.08 ms according to Hashizume *et al.*[3] However, the feature of possible interest is that the observations by Courtney *et al.* may suggest that the known 1^+ state is populated by a new and unknown longer-lived isomeric transition. Their first measurements[1] with protons of 8.0 MeV showed indications of a feeding component with a half-life of about 53 ms, while later observations[2] with protons of 7.6 MeV suggested a somewhat longer half-life of 85 ± 14 ms. When such a longer-lived transition with $T_{1/2}\simeq70$ ms exists, indeed, then it must be in essence totally converted and of very low energy, because no γ rays or x rays with corresponding half-life have been reported. Considering the level structure of odd-odd ^{90}Nb, it is hardly conceivable that an additional isomeric state will have spin $J\geq1$. An off-hand possibility may be a 0^+ state lying very closely above the known 1^+ state. The production of this hypothetical 0^+ state must be relatively enhanced when the ^{90}Zr(p,n) activations are done with proton energies not far above the threshold of 7.35 MeV.

It is fortuitous that a perturbed decay has been observed[4] for another isomer of the same ^{90}Nb nucleus: variations of up to 5% have been observed for the half-life of $\sim$ 19 s of the 4^- level at 125 keV, which level decays by an $M2$ transition of 2.38 keV. The perturbation could become dramatic for an eventual transition of even lower energy; the thresholds for L, M, and N_1 conversion being 2368, 202, and 55 eV, respectively.

We made a search for the 70-ms feeding of the 1^+ state by following its decay rate after ^{90}Zr(p,n) activations during 100 ms with protons of 7.8 MeV. Four runs were made with Zr targets of 1 to 1.5 mg/cm^2, both natural (51.4% ^{90}Zr) and enriched in ^{90}Zr(97.6%). Cyclic activation and subsequent multispectrum scaling was controlled by a PDP15 computer with a repetition time of 1.0 s. After activation the cyclotron beam was removed by internal deflection with a suppression of better than one part in 10^4. Before spectrum accumulation a typical waiting or cooling period of 10 to 30 ms has been inserted. The spectra were then taken during subsequent periods of 6, 12, 48, 48, 48, 96, and 192 ms. Figure 1 shows that the K- and L-conversion electrons from the $E3$ transition were observed and well separated from each other with a

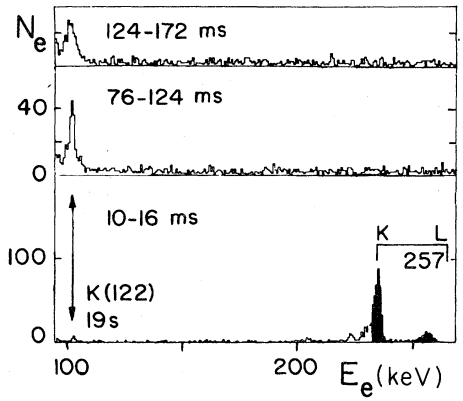

FIG. 1. Spectra of conversion electrons. Accumulation started 10, 76, and 124 ms, respectively, after the end of 100-ms activations. $K(257)$ is present in the first spectrum, but no more in the following ones. $K(122)$ illustrates the 4^- isomer in ^{90}Nb with $T_{1/2}=19$ s. Target : 1.1 mg/cm^2 of enriched ^{90}Zr metal. Accumulation time for this example: 3 h.

Mini-Orange spectrometer.[5] The first spectrum shows the 6.2-ms component of the $E3$ transition. In the following spectra, however, the K and L lines disappear without showing a trace of a longer decay mode. The strength of the searched long-lived isomer (53 to 85 ms) is anyhow minor. Since its decay is supposed to proceed via the short-lived state, the ratio of cross sections σ_l/σ_s ($l=$ long-, $s=$ short-lived state) will be reflected in the ratio of strengths of the two half-life components for the $E3(257)$ transition. The latter ratio is calculated in a straightforward way by taking into account the timing of the activation and counting cycle. We estimate: $\sigma_l/\sigma_s < 2\times 10^{-3}$. The background underneath the $K(257)$ line (Fig. 1) is remarkably minor so that the 6.2-ms decay could be followed for more than 10 half-lives. At 80 to 100 ms after the various activations the peak could no more be distinguished within statistical accuracy. This is in contrast with Fig. 3 of Ref. 1, where the supposed signs of the long-lived component started already after a few tens of ms.

Unfortunately, since otherwise there would have been a decay with interesting applications, the conclusion has to be that there is no 70-ms decay. We presume that the origin of the tail in Fig. 3 of Ref. 1 is of some instrumental origin, e.g., due to a not yet perfect beam suppression after activation periods.

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