Half-life of the 257 keV $1^+ \to 4^-$ transition in ^{90}Nb†

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The half-life of the 382 keV 1^+ state in ^{90}Nb has been determined by detecting the 257 keV conversion electron decay following the ^{90}Zr$(p, n)^{90}$Nb reaction induced by a chopped proton beam. The value obtained is 6.3 ± 0.2 ms, in good agreement with two earlier measurements but different from the value adopted in 1970 in Nuclear Data Tables.

[NUCLEAR REACTIONS ^{90}Zr(p, n), $E = 8.0$ MeV; ^{90}Nb detected ce, measured $T_{1/2}$.]

A new measurement of the half-life of the $1^+ \to 4^-$ transition in ^{90}Nb is presented. The value obtained does not agree with the adopted value found in Ref. 1, however, it does agree with two other published results.[2,3]

The $1^+ \to 4^-$ (257 keV) isomeric transition in ^{90}Nb was discovered by Mathur and Hyde.[4] A partial level scheme for ^{90}Nb is shown in Fig. 1. A half-life range of 10–20 ms was determined in their work from a delayed coincidence between the annihilation radiation following the positron decay of the ^{90}Mo ground state and the 257 keV γ decay of the 1^+ state.

Subsequent to the discovery of the ^{90}Nb isomeric transition, several measurements[2,3,5,6] of the half-life have been made. These previous results and the results of the present experiment are summarized in Table I. The value adopted by the compilers of the properties of the ^{90}Nb levels is 10 ms. The techniques used in making all of these measurements are very similar. The ^{90}Zr$(p, n)^{90}$Nb reaction is used to populate the isomeric level and the half-life is determined by multiscaling the 257 keV radiation as a function of time.

The measurement by Conlon[3] is deserving of special comment. The isomeric level in this case was observed in the proton bombardment of a natural Hf target. A naturally occurring contaminant in Hf is Zr. From his work, Conlon was not able to assign the 256 keV isomeric transition to any nuclide in the Hf mass region. The transition energy and measured half-life is suggestive of the isomeric level being in ^{90}Nb as a result of the Zr contaminant in Hf. A similarly mistaken attribution of the 18.8 s isomer in ^{90}Nb to ^{179}Ta has been reported by Geiger, Graham, and Johns.[7]

The present experiment was undertaken as a test of the efficacy of using a high-efficiency on-line conversion electron spectrometer to search for isomeric transitions with half-lives in the 10^{-3}–

TABLE I. Half-life measurements for the ^{90}Nb 257 keV $1^+ \to 4^-$ transition.

Reference	$T_{1/2}$ (ms)
Mathur and Hyde (Ref. 4)	10–20
Leipunski *et al.* (Ref. 5)	10
Morozov and Remaev (Ref. 6)	10
Ivanov (Ref. 2)	6.44
Conlon (Ref. 3)	6.1
Present work	6.3 ± 0.2

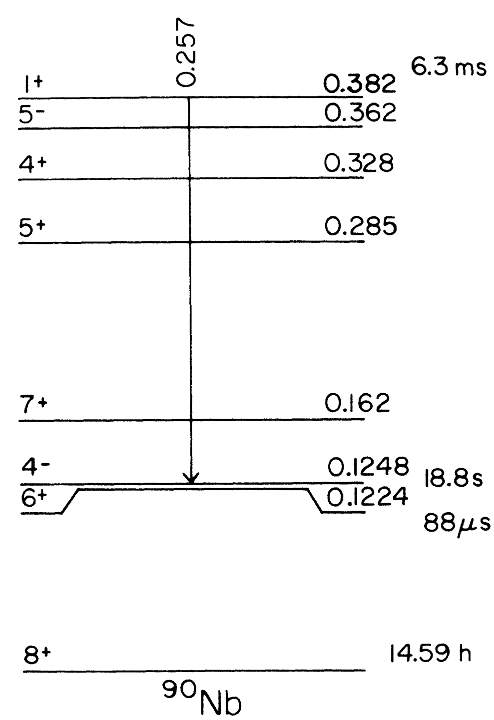

FIG. 1. Partial level diagram for ^{90}Nb (Ref. 1).

10^1 second region. The conversion electron spectrometer is of the Gerholm triangular field design[8] with a high-resolution Si(Li) detector at the focus. The design modifications to the original spectrometer are similar to those reported by Avignone, Pinkerton, and Trueblood.[9] This instrument is operated in a fixed current mode and is on line at the Florida State University tandem Van de Graaff accelerator.

The half-life measurements were performed using the leaky integrator system described in detail[10, 11] elsewhere. The spectrometer current was set to focus the 238 keV *K* conversion electrons from the 257 keV transition. A beam of 8 MeV protons was used to bombard a 1 mg/cm^2 Zr foil enriched in ^{90}Zr for approximately one mean life time (~10 ms). The beam was electrostatically deflected by a set of parallel plates at the low energy end of the accelerator. Successive 128 channel spectra of 2 ms each were accumulated under control of an on-line computer and external priority interrupts. A total of 64 spectra were taken following each beam bombardment and 40 000 bombardments were made.

The spectrum obtained by summing the individual spectra is shown in Fig. 2. Both the *K* and $L+M$ conversion electron groups are seen. The $K/(L+M)$ ratio of five determined from this sum spectrum is in good agreement with that measured by Cooper *et al.*[12] The low energy tailing evident in this spectrum arises from straggling of the elec-

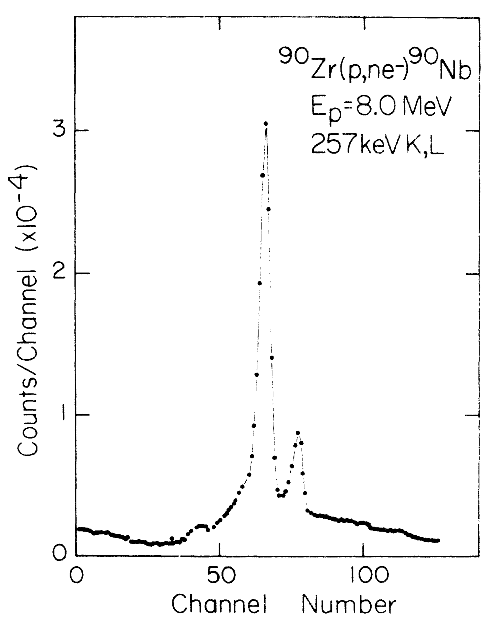

FIG. 2. Sum spectrum for *K* and *L* conversion electrons from the 257 keV transitions.

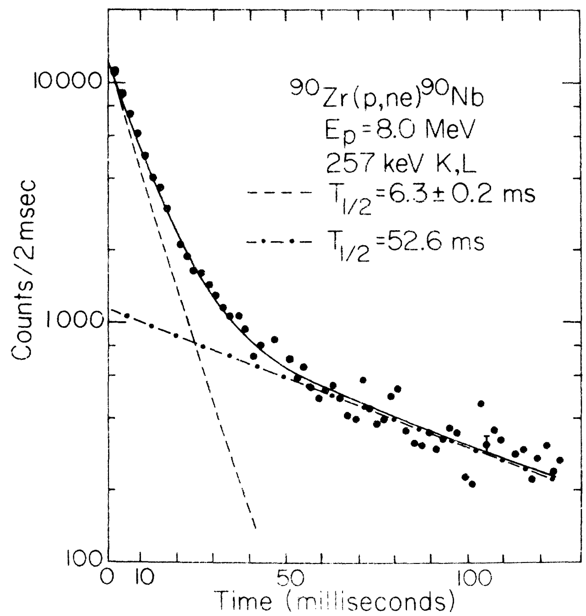

FIG. 3. Decay of the 382 keV 1^+ state in ^{90}Nb.

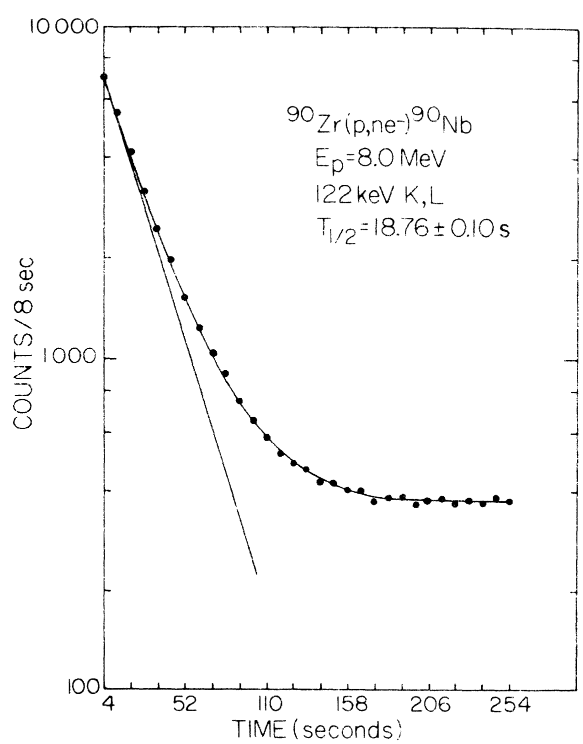

FIG. 4. Decay of the 124.8 keV, 4^- level observed via the 122.4 6^+ transition to the ground state.

trons in the ^{90}Zr foil. The resulting decay curve is shown in Fig. 3.

The decay curve was fit with a χ^2 minimization program to a sum of two decaying exponentials since the 6.3 ms activity apparently decays into a long-lived (approximately 50 ms) component. (The origin of the long-lived component is being studied further.) The half-life determined in this experiment is 6.3 ± 0.2 ms. The error estimate is based on reproducibility of fits over several runs.

In addition to the 6.3 ms half-life we measured the half-life of the 18.8 s isomeric level. These data are shown in Fig. 4. The value of the half-life obtained in the present experiment of 18.76 s is in excellent agreement with previous measurements[7,13] for the $4^- \rightarrow 6^+$ ^{90}Nb transition in a Zr foil.

The ease with which these data were accumulated (less than 8 h of accelerator time including time for setting up was used) demonstrates the efficacy of using the present system to measure half-lives in the 10^{-3}–10^{1} s range. The utility of this technique is found in a comparison of the product of conversion coefficient and spectrometer solid angle (a few percent of 4π) against that of the detection efficiency and solid angle available with Ge(Li) detectors. The additional information obtained from K/L conversion ratios should facilitate multipolarity assignments.

Note added in proof: Hashimuze, Kumagi, Tendow, and Katou [Nucl. Instrum. Methods 119, 209 (1974)] have recently reported a measurement of the half-life of the 257 keV transition. Their value of $T_{1/2} = 6.19 \pm 0.08$ ms is in good agreement with the present work.

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