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LIFETIME OF THE 114-keV *LEVEL IN THE* Pr^{139} *NUCLEUS*

A. A. SOROKIN

Institute of Nuclear Physics, Moscow State University

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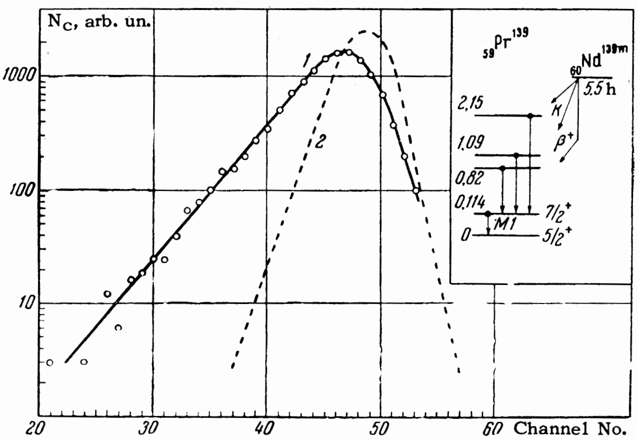
The half-life of the 114-keV first-excited state in the Pr^{139} nucleus is measured by the delayed coincidence method with aid of a time-to-pulse height converter. The value obtained is $T_{1/2} = 2.5 \pm 0.2 \times 10^{-9}$ sec. This corresponds to hindrance of M1 transitions to the ground state by a factor f = 310 as compared with the Weisskopf single-particle estimate. Forbidden M1 transitions to the ground states of the neighboring isotopes Pr^{141} and Pr^{143} are characterized by approximately the same hindrance factor.

AN investigation of the decay scheme of the isomer Nd^{139m} ($T_{1/2}$ = 5.5 hours) has established[1,2] that the first-excited state of the daughter nucleus Pr^{139} has an energy 114 keV, and is deexcited to the ground state in a practically pure M1-transition. As is well known, the ground and first-excited states of odd-even nuclei with $51 \leq Z \leq 63$ are described by proton configurations $g_{7/2}$ and $d_{5/2}$, and the M1 transitions between them are l-forbidden and are characterized by a hindrance factor on the order of several hundred compared with an estimate based on the single-particle model. We can thus expect the 114-keV state in Pr^{139} to have a lifetime on the order of several nanoseconds.

In the present investigation, the lifetime of this state was measured by the delayed coincidence method using a time-amplitude to pulse-height converter. The preparation of the sources was described by us earlier (see [1,2]). Coincidences were registered between the conversion electrons of the 114-keV transition and the hard γ quanta ($E_\gamma > 510$ keV) which excited this level. The electrons were detected with an anthracene crystal and the γ quanta with a 50×50 mm plastic scintillator. FÉU-13 photomultipliers operating at 2—25 kV were employed. The time to pulse height converter, which was similar to that described by Jones[3], operated on the principle of overlap of pulses shaped beforehand in time and in amplitude with a cut-off germanium diode. The time spectrum was registered with an AI-100 100-channel pulse-height analyzer; the input of the analyzer was gated by a coincidence circuit ($\tau = 10^{-7}$ sec), to which pulses were fed from single-channel amplitude discriminators in the side channels. The time analyzer was calibrated against the shift of the instantaneous-coincidence curve when additional segments of the calibration cable were connected to one of the converter inputs. In our measurements, each channel corresponded to $(1.08 \pm 0.05) \times 10^{-9}$ sec.



Measurement of the lifetime of the 114-keV level in the Pr^{139} nucleus. Curve 1 was measured with an Nd^{139} source, $T_{1/2} = (2.5 \pm 2) \times 10^{-9}$ sec; curve 2 — "apparatus" curve, measured with a Co^{60} source. Upper right — part of the level scheme with the most intense transitions participating in the coincidences.

The figure shows the results of one of five measurements performed in succession for several days. The total coincidence counting rate decreased with time with a half-life $T_{1/2}$ = 5.5 hr. The same figure shows for comparison the "instantaneous" $\beta\gamma$-coincidence curve obtained for Co^{60} under the same experimental conditions. As can be seen from the figure, the decrease in the coincidence curve for Nd^{139m} is steeper on the side corresponding to the delay of the 114-keV transition and is characterized by a value $T'_{1/2} = 2.7 \times 10^{-9}$ sec. However, inasmuch as the instantaneous curve was characterized by a half-life $T''_{1/2} = 1.08 \times 10^{-9}$ sec, which could not be regarded as infinitely steep, the true value half-life of the 114 keV level was determined from the relation

$$T_{1/2} = (T'^2_{1/2} - T''^2_{1/2})^{1/2} = (2.5 \pm 0.2) \cdot 10^{-9} \text{ sec}.$$

The error in this quantity is made up of the statistical errors and inaccuracy in calibration.

To check our result, we measured with the same apparatus the half-life of the 86-keV level of Dy^{160}, which is excited in the decay of Tb^{160}. As a result of an analogous data reduction we obtained

$$T_{1/2} = (1.7 \pm 0.2) \cdot 10^{-9} \text{ sec}$$

which agreed with the data of Sunyar[4] and Nathan[5]

$$T_{1/2} = (1.8 \pm 0.1) \cdot 10^{-9} \text{ sec}.$$

Using the tabulated value[6] $\alpha = 0.88$ of the total conversion coefficient for the pure 114-keV M1-transition, we obtain for the lifetime of the first excited state of Pr^{139} relative to the radiative transition a value

$$\tau_\gamma = 1.44 T^{1/2}(1 + \alpha) = (6.8 \pm 0.5) \cdot 10^{-9} \text{ sec},$$

corresponding to a hindrance factor ~ 310 compared with the estimate given by the single-particle model, and coinciding with the hindrance factor for most l-forbidden M1 transitions between the levels $d_{5/2}$ and $g_{7/2}$ in odd-even nuclei[7].

This result can be regarded as an indirect confirmation of the correctness of the assignment of $7/2^+$ to the 114-keV level[2], since the characteristic of the ground state of Pr^{139} is apparently $5/2^+$[8].

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