# LIFETIME OF THE 2007 keV LEVEL FOR THE $^{46}$Ti NUCLEUS

BY E. YE. BERLOVITCH, V. V. LUKASHEVITCH, A. V. POPOV AND V. M. ROMANOV

A. F. Ioffe Physical-Technical Institute of the USSR Academy of Sciences, Leningrad*,

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The lifetime of the 2007 keV excited state for the $^{46}$Ti nucleus was measured by the centroid method using a differential converter described earlier. The half-life was found to be: $(3.8\pm1.5 \times 10^{-12}$ sec $< T_{1/2} < (7.2\pm1.5)\times 10^{-12}$ sec.

*1.* Despite the fact that the resolution of time analyzers incorporating a time-amplitude converter presently equal to $(2-10)\cdot 10^{-10}$ sec cannot be improved because of limits imposed by time spread in scintillators and photomultipliers, an understanding of the statistical processes which occur in the crystal-photomultiplier combination [1] and improvements in the experimental procedure [2–4] enabled us to successfully use the method of delayed coincidences for nuclear level lifetime measurements in the pico-second range. In particular, it enabled us to make lifetime measurements of vibrational levels in even-even nuclei which were possible earlier by the Coulomb excitation and resonance scattering methods.

*2.* In this paper lifetime measurements of the $4^+$ excited state for the $^{46}$Ti nucleus with the energy of 2007 keV are reported. The lifetime of this level was measured earlier in [3, 5, 6] by the centroid method. In [3] the curves of $\beta$- $\gamma$-coincidences for the $\beta$ 357 keV — $\gamma$ 1120 keV transitions were compared with the curves of $\gamma$-$\gamma$ — coincidences for the $\gamma$ 1120 keV — $\gamma$ 888 keV cascade, with $T_{1/2} \leqslant 3.5\times 10^{-12}$ sec obtained for the half-life. In [5, 6], where a $^{60}$Co source was used as a reference, the upper limit values found for the half-life were $T_{1/2} < 21\times 10^{-12}$ and $T_{1/2} < 20\times 10^{-12}$ sec, respectively. The result obtained in [3] seems to be the most reliable.

In our experiment the lifetime of the second excited state of $^{46}$Ti was also measured by the centroid method using $\beta$- $\gamma$ — coincidences of the $^{60}$Co source as a reference. Use was made of PM-36 photomultipliers in combination with stilbene crystals of the following: for counting $\beta$ — particles $\sim$ 1 mm thick, 1 cm dia. and for counting $\gamma$ — quanta —1.5 cm thick, 3 cm dia. crystals, respectively.

Pulses shaped at the photomultiplier anodes using tunnel diode triggers were supplied to the time-amplitude differential converter described earlier by the authors [4]. A 256-chan-

* Address: USSR Academy of Sciences, A. F. Ioffe Physical Technical Institute, Leningrad, K-21, USSR.

nel analyzer counted fast coincidence pulses corresponding to the $\beta$ 357 keV — $\gamma$ 1120 keV cascade only. To eliminate the influence of the 888 keV level, the amplitude analyzer in the "slow" part of the device was tuned to the end of the Compton distribution for the 1120 keV $\gamma$ — transition.

In order for the statistical error in the measured results to remain within $\sigma \leqslant 1$ psec, the number of counts with each of the sources $S$ and the time width of channel $K$ estimated from the formula [7]

$$\sigma_{T_{1/2}} = (\ln 2) \sqrt{\frac{\tau_0^2}{4(\ln 2)^2 S} + \frac{\tau_0^2}{18}\left(\frac{K}{\tau_0}\right)^5} \tag{1}$$

should satisfy $S \geqslant 4 \times 10^4$ and $K \leqslant 80$ psec/channel, respectively. In formula (1) $\tau_0$ is time resolution defined as the width of the coincidence curve at half the height, and is equal in this experiment to $\tau_0 = 0.68$ nsec.

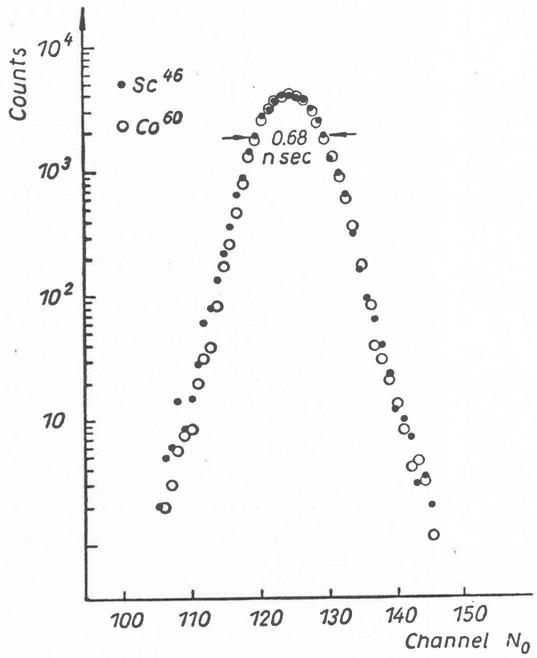


Fig. 1. The lifetime measurement of the 2007 keV level for $^{46}$Ti nucleus

Three sets of lifetime measurements were made for the 2007 keV level, the number of coincidence counts with each of the sources being $\sim 4 \times 10^4$. The time width of the channel in these measurements was $K = 68$ psec/channel. Each set was obtained with a 30-fold interchange of the $^{46}$Ti and $^{60}$Co sources. The results of one set of measurements are presented in Fig. 1.

The shifts of the centres of gravity for the coincidence curves with the $^{46}$Ti source relative to the centres of gravity for time distributions with the $^{60}$Co source for the three sets of measurements are

$$T_{1/2}(\mathrm{I}) = (+4.0 \pm 3.0) \times 10^{-12}\ \mathrm{sec}, \quad T_{1/2}(\mathrm{II}) = (+5.1 \pm 2.5) \times 10^{-12}\ \mathrm{sec}$$
$$\text{and } T_{1/2}(\mathrm{III}) = (+4.1 \pm 2.4) \times 10^{-12}\ \mathrm{sec}.$$

The weighted mean value for the three sets of measurements is $T_{1/2\ \mathrm{w.m.}} = 4.4 \pm 1.5 \times \times 10^{-12}$ sec. This value corrected by the difference of mean energy operating ranges for the sources under comparison [8], becomes

$$T_{1/2} = (3.4 \pm 1.5) \times 10^{-12}\ \mathrm{sec}. \tag{2}$$

For determination of the half-life of the 2007 keV level in the $^{46}$Ti nucleus, a correction for the lifetimes of the $2^+$, 1332 keV and $4^+$, 2505 keV levels in the $^{60}$Co nucleus should be introduced into the value (2). Under the experimental conditions described here, the scintillator counting $\gamma$ — quanta detected with equal probability $\gamma$ — rays of the $4^+ \rightarrow 2^+$ and $2^+ \rightarrow 0^+$ transitions with the energies of 1170 and 1330 keV, respectively. Hence these transitions took an equally probable part in the coincidence with $\beta$ — particles. Thus, the centre of gravity for the curve of $\beta$-$\gamma$ — coincidences obtained with the $^{60}$Co source is shifted relative to the true prompt time distribution by the value equal to

$$T^*_{1/2}(^{60}\mathrm{Ni}) = \frac{2\mathrm{T}_{1/2}(4^+) + T_{1/2}(2^+)}{2}, \tag{3}$$

where $T_{1/2}(4^+)$ and $T_{1/2}(2^+)$ are the half-lifes of the $4^+$ and $2^+$ levels for the $^{60}$Ni nucleus, respectively.

Using the values found in the published literature

$$T_{1/2}(4^+) < 3.5 \cdot 10^{-12}\ \mathrm{sec}\ [3], \quad T(_{1/2}2^+) = 0.74 \times 10^{-12}\ \mathrm{sec}\ [9]$$
$$\text{for } T^*_{1/2}(^{60}\mathrm{Ni}),$$

we obtain

$$0.35 \times 10^{-12} < T^*_{1/2}(^{60}\mathrm{Ni}) < 3.8 \times 10^{-12}\mathrm{sec}.$$

The left-hand part of this inequality is the case of a negligible lifetime for the $4^+$ level of $^{60}$Ni, and the right-hand part occurs in the case when the half-life for this level equals the upper limit value of $3.5 \times 10^{-12}$ sec obtained in [3].

Thus, it follows from the results of our experiment that the half-life of the second excited state of the $^{46}$Ti nucleus is

$$(3.8 \pm 1.5) \times 10^{-12}\ \mathrm{sec} < T_{1/2}(4^{+46}\mathrm{Ti}) < (7.2 \pm 1.5) \times 10^{-12}\ \mathrm{sec}.$$

In conclusion it should be noted that the upper extreme of the half-life found experimentally for the $4^+$ level of the $^{46}$Ti nucleus with respect to a combination of (3) half-life periods for both levels of $^{60}$Co may be slightly overstated due to a difference between the Compton-effect cross-sections in the scintillator material for the $\gamma$ — quanta of the 1120 keV transition for $^{46}$Ti and $\gamma$ — quanta of $^{60}$Ni transitions. The difference in cross-sections may in the final analysis result in different mean distances traversed by light in the crystal towards the photocathode and thus introduce a systematic error. The authors are presently calculating the corrections allowing for this effect.

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