LIFETIME OF THE 0.570 MeV LEVEL IN THE Te^{122} NUCLEUS

Yu. K. SHUBNYĬ

Institute of Nuclear Physics, Academy of Sciences, Kazakh S.S.R.

Submitted to JETP editor March 23, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) **45**, 460-463 (September, 1963)

The lifetime of the first excited state of the Te^{122} nucleus with an energy 0.570 MeV is measured by the nuclear resonance scattering method using gaseous Sb^{122} in the SbH_3 compound. The value $\tau_\gamma = (1.20 \pm 0.30) \times 10^{-11}$ sec is obtained for the lifetime of the level. Vibrational parameters are computed for even-even Te nuclei.

We studied the lifetime of the 0.570-MeV first excited state of Te^{122} by the nuclear resonance scattering method. The source was the Sb^{122} isotope with half-life 2.75 days. The energy lost by the γ quantum to recoil (~ 2.8 eV) was recovered by using the recoil of the nucleus from the preceding 1.4-MeV β transition. Taking into account the order of magnitude of the lifetime of the level (10^{-11} sec), it was necessary to use a gaseous source in which the time between the collisions of the recoil nuclei with the surrounding atoms is considerably larger than the lifetime of the investigated level. In this case the lifetime can be measured from the intensity of the resonant scattering; the "self-absorption" method is ineffective because of the small level width ($\sim 10^{-5}$ eV) and the small content of Te^{122} in the natural mixture (2.46%).

For an unambiguous interpretation of the experimental results it is necessary to employ in this case a source in the form of a monatomic vapor, for which the energy distribution of the emitted quanta (the microspectrum) can be calculated. The use of molecular compounds leads to a change in the microspectrum as a result of the chemical binding effect.

A gaseous source was obtained by evaporating metallic antimony, the vapor of which can contain, however, the molecules Sb_2 and Sb_4 along with the Sb atoms. Control measurements were made with antimonous hydride (stibine) SbH_3, which is gaseous under normal conditions and which comes closest to a monatomic source.

The source Sb^{122} was obtained from a target enriched to 95.5% Sb^{121}, bombarded in a reactor for several days. The specific activity at the end of activation was 6 mCi/mg. The metallic antimony was evaporated by heating a 4 cc quartz ampoule containing 5 mg of Sb^{122} to a temperature of 1260° at which part of the antimony turned into vapor. The stibine was obtained by first heating a mixture of Mg and Sb in a hydrogen stream to form Mg_2Sb_3, which then was treated with dilute hydrochloric acid to form SbH_3. The activity was ~ 7 mCi.

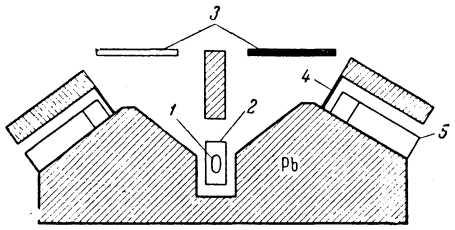

FIG. 1. Diagram of experimental setup: 1 – source; 2 – electric oven; 3 – Te and Cd scatterers; 4 – Pb absorber; 5 – scintillation spectrometer.

The experimental setup is shown in Fig. 1. The scattered γ quanta were detected with a NaI(Tl) crystal, 4 cm in both diameter and height, connected to an FÉU-12b photomultiplier. A lead screen 25 cm thick shielded the detector against the direct beam. The scatterers used were metallic plates of Te, measuring $26 \times 26 \times 1.5$ cm and $14 \times 14 \times 1$ cm ($\rho = 5$ g/cm^3). Cadmium scatterers of equal dimensions were used for comparison. The average scattering angle was 105°. A lead absorber 3 mm thick was placed between the scatterer and the crystal to protect the detector against the quanta scattered via the Compton effect. The thickness of the filter was chosen by trial.

In the measurements, the "window" of the analyzer was set for the 0.570-MeV photopeak, and the "window" width was 5 V. The scatterers were changed every two minutes during the

experiment. Altogether, 16 runs were made with solid sources and 20 runs with gaseous sources. Each run included 30 pairs and was measured for 4 hours. Measurements with solid and gaseous sources were carried out alternately. The average resonant scattering counting rate was 20.8 ± 1.2 pulses per minute, amounting to 5—6% of the total counting rate. In the case of SbH_3, the scattered radiation was registered with a 100-channel pulse analyzer. For purposes of analysis, the spectrum of the radiation scattered from the Te and Cd plates was compared in the region of the 0.570-MeV photopeak. The magnitude of the effect was 2%. To determine the average resonance scattering, we measured the following in the experiment: a) the intensity of the direct beam from a source located several meters from the detectors; b) the linear coefficient of absorption of the quanta in the tellurium scatterer, and c) the efficiency of γ-quantum registration and the scatterer–detector solid angle. The measurements were carried out for several points of the scatterer.

The angular distribution of the scattered γ quanta for the spin sequence 0–2–0 was taken into account in the calculation of $\bar{\sigma}$, for which the values obtained were $(2.06 \pm 0.16) \times 10^{-25}$ and $(2.58 \pm 0.51) \times 10^{-25}$ cm^2 for the Sb and SbH_3 sources.

The energy distribution of the emitted γ quanta (microspectrum) was calculated starting from the $Sb^{122} \rightarrow Te^{122}$ decay scheme for different variants of β-decay theory (Fig. 2). A value (0.080 ± 0.005) eV^{-1} was obtained for P(E) —the fractions of the quanta in an interval of 1 eV—near the resonance energy. Using the well known relations between P(E), τ, and $\bar{\sigma}$, we obtain for the lifetime of the 0.570-MeV level values of $(1.50 \pm 0.23) \times 10^{-11}$ and $(1.20 \pm 0.30) \times 10^{-11}$ sec for Sb and SbH_3, respectively. Although the first value slightly exceeds the second, both are within the limits of experimental error. This can be explained by recognizing that the Sb atoms can predominate in the vapor of metallic antimony at high temperatures, owing to dissociation of the Sb_2 and Sb_4 molecules. The microspectrum, however, will obviously not differ much in this case from that calculated for the monatomic source.

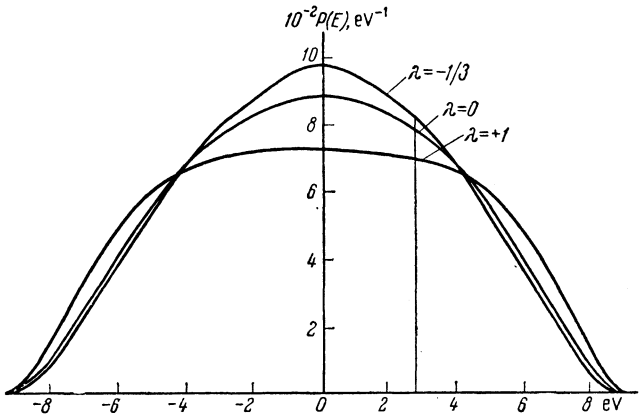

FIG. 2. Microspectrum calculated under the assumption that there are no $\beta\gamma$ correlations, the β transition is allowed, and the $\beta\nu$ correlation has the form $(1 + \lambda(v/c)\cos\theta_{\beta\nu})$. It was assumed that the first-order forbiddenness ($\Delta I = 0$, yes) of the $Sb^{122} \rightarrow Te^{122}$ β transition, changes the calculated distribution of the γ quanta insignificantly. $\lambda = +1$ – vector interaction, $\lambda = -1/3$ – axial-vector interaction.

The value of τ_γ obtained here agrees well with the data of Temmer and Heydenburg[1] and Stelson and McGowan[2], who used the Coulomb excitation method and obtained $\tau = 1.4 \times 10^{-11}$ sec[1] and $\tau = 1.1 \times 10^{-11}$ sec[2]

To explain the properties of the excited states of the nuclei in the region $40 \leq A \leq 150$, the vibrational model was used[3] along with the non-axial rotator model developed by Davydov and his co-workers[4]. In the vibrational model the first-excited states of the even-even nuclei are regarded as the result of quadrupole oscillations of the nuclear surface. For the case of a quadrupole harmonic oscillator, the excitation energy E and the reduced transition probability B(E2) are connected with the parameters of the theory—the effective surface tension C_2, the mass parameter B_2, and the mean square of the oscillation amplitude $\langle\beta^2\rangle$. The parameter $\langle\beta^2\rangle$ can be regarded as a characteristic of the effective deformation of the nucleus. The table lists the values of the vibra-

Vibrational parameters for Te isotopes

Nucleus	E, MeV	$B(E2,2\rightarrow0)$ *, $e^2\cdot b^2$	F	C_2, MeV	B_2/B_2 hydr	$\langle\beta^2\rangle^{1/2}$
Te^{120}	0.560	0.110	31	49	12.4	0.174
Te^{122}	0.570	0.102	28	55	13.2	0.163
Te^{124}	0.608	0.108	29	57	11.8	0.165
Te^{126}	0.670	0.082	22	82	13.3	0.144
Te^{128}	0.750	0.066	17	120	15.2	0.127
Te^{130}	0.850	0.058	15	153	14.7	0.117

*The values of B(E2,2→0) are from [1,2,8,9]

tional parameters from data on B(E2) for the even-even Te nuclei.

The mass parameter B_2 is expressed in B_{2hydr} units, i.e., the values of B_2 which follow from the hydrodynamic model. The radius of the nucleus is assumed equal to $1.2 \times 10^{-13} A^{1/3}$ cm. As can be seen from the table, the parameter C_2 has the expected dependence on the neutron number, increasing as N = 82 is approached. The parameter B_2 exceeds the hydrodynamic estimate in the mean by 12—13 times and is practically constant in this nuclear region.

The Coulomb excitation of the excited levels of even-even nuclei was investigated in [2,5]. The values obtained for the probabilities of the transitions $B(E2, 2' \rightarrow 0)$ and $B(E2, 2' \rightarrow 2)$ make it possible to compare the experimental relations

$$B(E2,2' \rightarrow 2)/B(E2,2 \rightarrow 0) \text{ and}$$

$$B(E2.2' \rightarrow 0)/B(E\,2,2 \rightarrow 0)$$

with those considered by means of the vibrational model and the model of Davydov and Filippov. Analysis has shown[5,6] that the model of nonaxial rotator is in somewhat better agreement with experiment than the vibrational model, which yields, for example, too low a value for $B(E2, 2' \rightarrow 0)/B(E2, 2 \rightarrow 0)$. However, the introduction of anharmonic corrections has recently been shown[7] to give better agreement with experiment.

In conclusion the author thanks D. K. Kaipov for interest in the work, R. B. Begzhanov for affording the possibility of carrying out the experiment, and A. A. Islamov and A. V. Kuz'min for help with the measurements.

[1] G. M. Temmer and N. P. Heydenburg, Phys. Rev. **104**, 967 (1956).

[2] P. H. Stelson and F. K. McGowan, Phys. Rev. **121**, 209 (1961).

[3] G. Scharff-Goldhaber and J. Weneser, Phys. Rev. **96**, 212 (1955).

[4] A. S. Davydov and G. F. Filippov, JETP **35**, 440 (1958), Soviet Phys. JETP **8**, 303 (1959).

[5] Yu. P. Gangrskiĭ and I. Kh. Lemberg, Izv. AN SSSR ser. fiz. **26**, 1001 (1962), Columbia Tech. Transl. p. 1009.

[6] D. P. Grechukhin, Nucl. Phys. **24**, 576 (1961).

[7] S. T. Belyaev and V. G. Zelevinskiĭ, JETP **42**, 1590 (1962), Soviet Phys. JETP **15**, 1104 (1962).

[8] P. Stelson and F. McGowan, Phys. Rev. **110**, 489 (1958).

[9] Akkerman, Kaipov, and Shubnyĭ, JETP **40**, 1031 (1961), Soviet Phys. JETP **13**, 725 (1961).

Translated by J. G. Adashko
85