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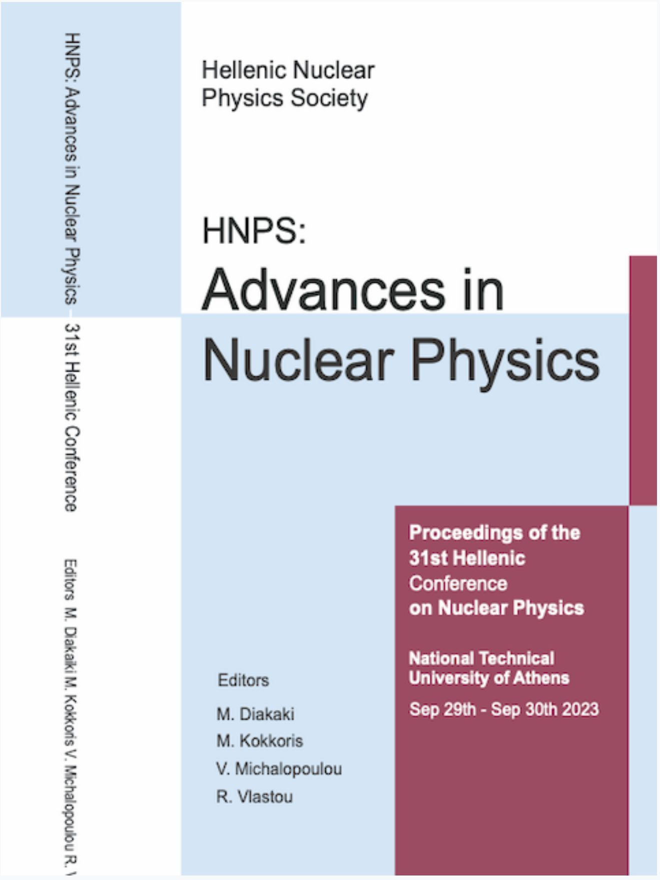

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Nuclear lifetime measurements around Z=50

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Abstract In the present work, a dedicated experimental study of the lifetimes of Te and Sb isotopes was undertaken at the 9 MV Tandem accelerator at the IFIN-HH. Beams of ^{11}B at 35 MeV impinged on a ^{nat}Ag target to populate the nuclei of interest and study their decay using the activation method. The emitted gamma rays and charged particles were detected by the ROSPHERE and SORCERER arrays. Lifetimes of the decaying isomeric and ground states in ^{117}Te and ^{115,117}Sb were measured. The present results update existing literature data from half a century ago employing a new reaction mechanism to populate the states of interest along with a more advanced array of detectors.

Keywords Decay chain Te-Sb-Sn, Activation method, Half-life

INTRODUCTION

The tellurium isotopes (Z=52) are located above the Z=50 proton shell, which makes them suitable candidates to examine the interplay between collective and single-particle degrees of freedom and relevant phenomena, such as shape coexistence and shape evolution. The fact that many of the available lifetime data in literature predate 1960 [1-3] has provided a strong motivation for experimental work with modern instrumentation and reaction mechanisms. In the present work, activation measurements were carried out to measure the ground-state lifetimes of the populated nuclei of the examined decay chains in Te and Sb isotopes.

EXPERIMENTAL DETAILS

Lifetime measurements in ^{117}Te and ^{115,117}Sb were carried out in the 9 MV Tandem accelerator laboratory at IFIN-HH, Romania [4]. A natural Ag target (51.8% ^{107}Ag, 48.2% ^{109}Ag) with thickness of 5.2365 mg/cm^2 was bombarded with ^{11}B ions accelerated at 35 MeV. From the reaction, the unstable ^{115}Te and ^{117}Te isotopes were created and subsequently decayed. The gamma rays and the charged particles were detected by the ROSPHERE (15 HPGe + 10 $LaBr_3$) [5] and SORCERER (6 Si detectors) [6] array, respectively (see Figs. 1 and 2). Reference is made to SORCERER for the completeness of the description of the experimental setup used, without playing a role in the present stydy. The activation method was used to monitor the activity of the daughter products and reconstruct the decay curves, from which the lifetimes could be deduced.

The total irradiation time was about 8.5 days and the monitoring of activation lasted approximately 26 hours. The first six activation runs lasted 15 min to account for a few lifetimes of the decay of the ground state of ^{115}Sb ($t_{1/2}$=32.1 min) [7], while the remaining 33 runs lasted about 45 min each. The gamma-ray spectra (Figs. 3 and 4) were calibrated using a standard ^{152}Eu source and the GASPware software [8] was used for the analysis of the spectra.

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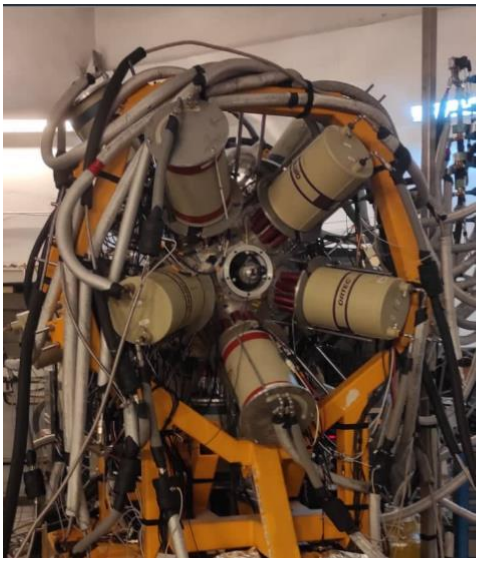

Figure 1. *The ROSPHERE detector array*

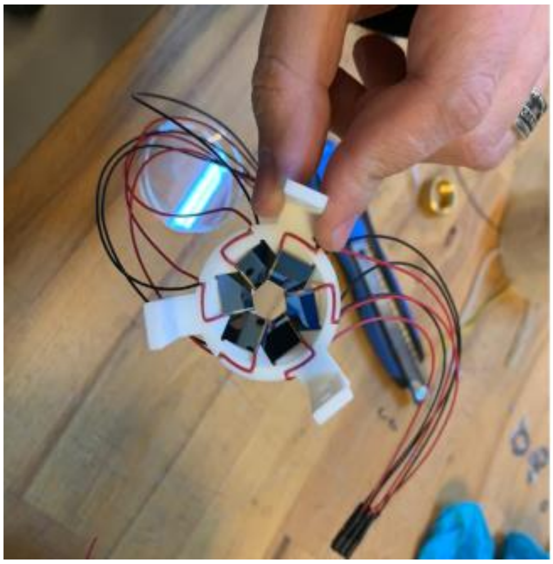

Figure 2. *The SORCERER detector array*

ANALYSIS AND RESULTS

Three lifetime measurements (relevant isotopes marked in bold below) were performed with the activation method in two different decay chains:

$$\mathbf{^{117}Te} \rightarrow \mathbf{^{117}Sb} \rightarrow {}^{117}\mathrm{Sn}$$

$${}^{115}\mathrm{Te} \rightarrow \mathbf{^{115}Sb} \rightarrow {}^{115}\mathrm{Sn}$$

After identifying the transitions of interest (shown in Table 1) in the collected singles spectra, every transition was monitored in each run until it vanishes due to decay (see Figs. 3 and 4). Then, the recorded decay rate for each transition was plotted against time and the data were fitted with a function of the form:

$$y = A \cdot exp\left(-\frac{x}{a}\right) + y_0\,, \tag{1}$$

where A, α, and y_0 are the parameters of the fit. Then, the equation below was used to extract the half-life value from the measurement:

$$t_{1/2} = a \cdot ln(2) \tag{2}$$

A typical case of this procedure is the decay curve of the ^{117}Te → ^{117}Sb branch shown with the experimental data and with the fitting curve in Fig. 5. The same procedure was followed in all other experimental cases. The results of the half-life measurements for all the cases studied in the present work are shown in Table 1, together with the literature values from the evaluated NuDat database [7].

Table 1. *Half-lives and characteristic transitions of the isotopes of interest in this work*

Parent nucleus	Daughter nucleus	Eγ (keV)	$t_{1/2}$ (h) this work	$t_{1/2}$ (h) NuDat [7]
^{115}Sb	^{115}Sn	497.3	0.52(1)	0.54(1)
^{117}Te	^{117}Sb	719.7	1.08(5)	1.03(5)
^{117}Sb	^{117}Sn	158.6	2.38(1)	2.80(1)

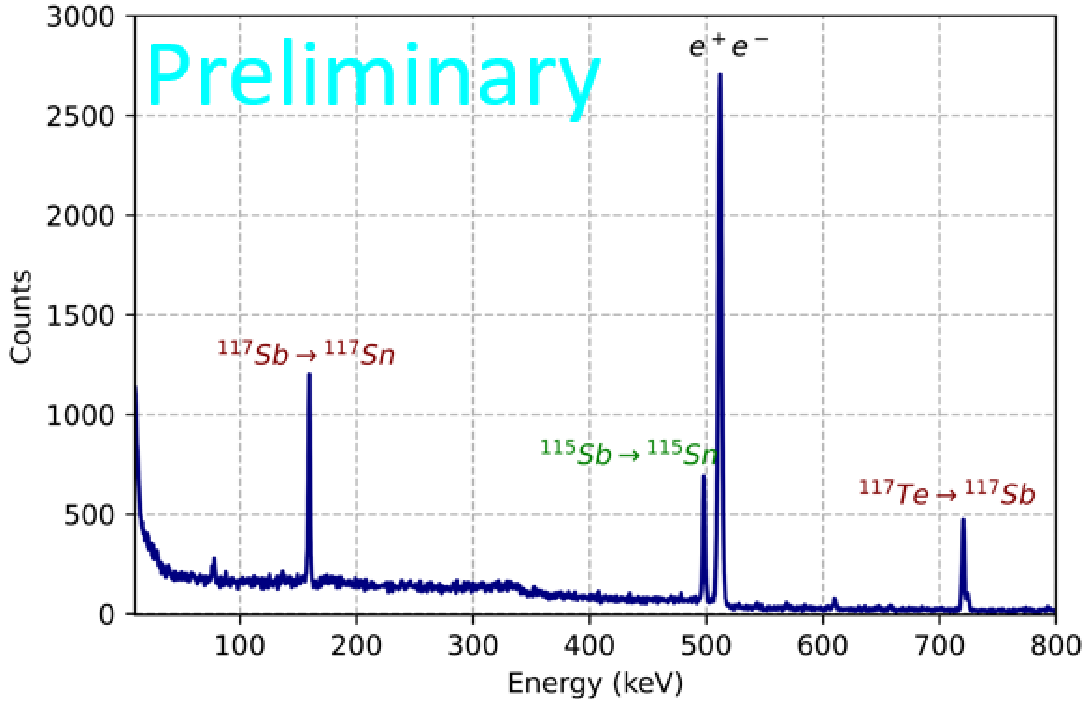

Figure 3. *Activation spectrum for all 15 HPGe detectors after the first 15 minutes*

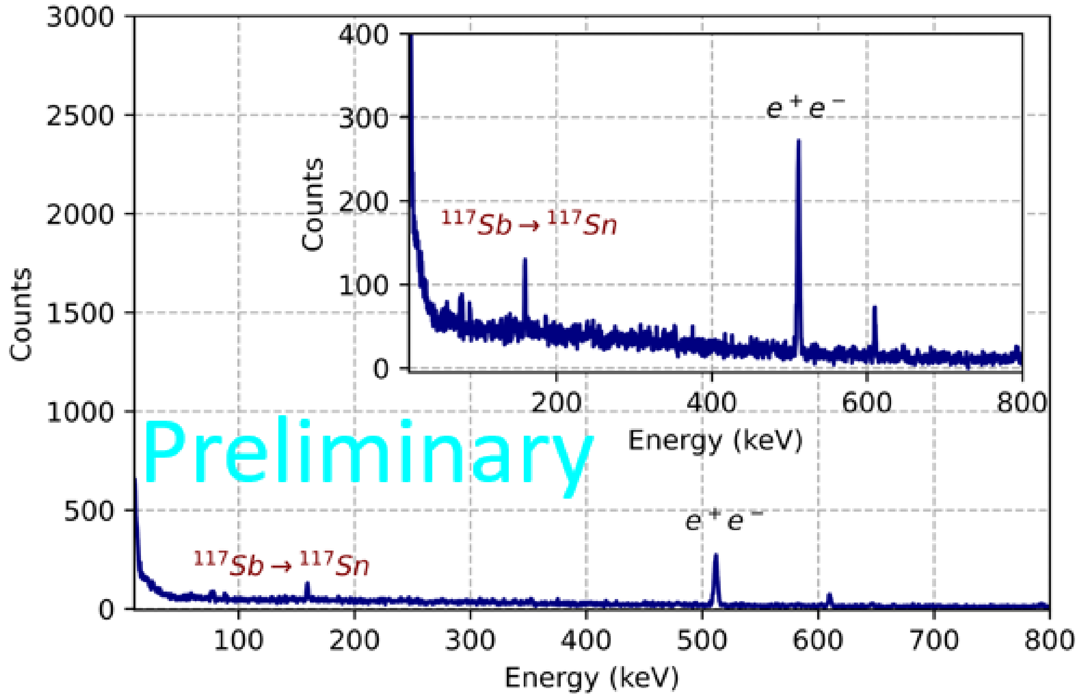

Figure 4. *Activation spectrum for all 15 HPGe detectors after the first 736 minutes*

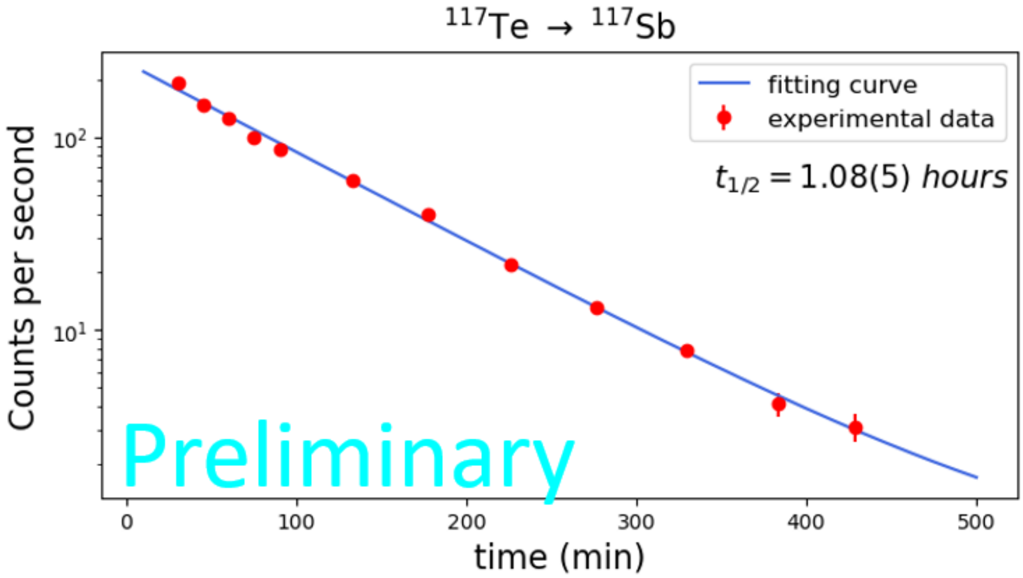

Figure 5. *Decay curve of the $^{117}Te \rightarrow {}^{117}Sb$ branch with the y-axis shown in log scale. The zero on the x-axis means the start of the measurements after the activation period ended. Error bars are generally smaller than the symbol size.*

DISCUSSION AND CONCLUSIONS

The results shown in Table 1 agree fairly well with the literature values, especially in the cases of $^{117}Te \rightarrow {}^{117}Sb$ and $^{115}Sb \rightarrow {}^{115}Sn$. The measured lifetime of the decay $^{117}Sb \rightarrow {}^{117}Sn$ shows some deviation with respect to the published value, approximately 15%. However, it is worth mentioning that the existing value was deduced in the 1960s via a radiochemical technique [7]. As this work reports on preliminary data, further work is required to have a firm conclusion on this comparison. In any case, the activation technique studied with a high-resolution gamma array seems to be promising for the update of this value in ^{117}Sb.

In summary, the applied activation method works well for the studied isotopes and can be used to carry out more measurements in the future. Also, more data from this experiment are under analysis for the nuclear isomers in the vicinity of the unstable, neutron-deficient tellurium isotopes.

Acknowledgments

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