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α decay of ^{105}Te

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The α decay of the neutron-deficient nuclide ^{105}Te was observed. The ^{50}Cr(^{58}Ni,3n) reaction was used to produce ^{105}Te nuclei. The ^{105}Te residues were selected with the Argonne Fragment Mass Analyzer and implanted into a double-sided Si strip detector where their subsequent α decay was detected. An α-decay Q value of $Q_\alpha = 4900(50)$ keV and a half life of $T_{1/2} = 0.70(-0.17 + 0.25)\mu$s were measured for ^{105}Te and a reduced α-decay width of $W_\alpha = 3.3(-1.7 + 2.1)$ was deduced. The decay properties of ^{105}Te are compared with those of heavier Te isotopes and theoretical predictions.

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The doubly magic, self-conjugate ^{100}Sn nucleus and its neighbors have been a subject of intense research. It culminated in the production of a handful of ^{100}Sn nuclei via fragmentation reactions [1,2]. Neutron-deficient nuclei near the $N = Z$ line, just above the $N = 50$ shell closure, exhibit large α-decay branches [3]. In addition, the proximity of the proton drip line manifests itself by the presence of proton emitters [4]. The α- and proton-decay Q values constrain mass models and the decay widths provide information about the structure of low-lying states. It has also been speculated that the occupation of the same orbitals by the valence nucleons might enhance the α-particle preformation probability, leading to faster α decays. The $N = Z+2$ ($T_z = 1$) α emitters along the ^{114}Ba-^{110}Xe-^{106}Te decay chain have been recently studied in Refs. [5,6]. The observation of α-decay fine structure in ^{107}Te yielded the energy separation between the $d_{5/2}$ and $g_{7/2}$ neutron single-particle states in ^{103}Sn [7]. The same measurement could also be done for ^{105}Te. This Rapid Communication reports the results of a search for the main α-decay branch in ^{105}Te.

A ^{58}Ni beam from the Argonne Tandem Linac Accelerator System impinged on a ^{50}Cr target to produce ^{105}Te nuclei following the evaporation of three neutrons. Three beam energies, namely 224, 214, and 204 MeV, were used during the experiment to optimize the ^{105}Te yield. Reaction products recoiling from the target were separated from the beam and dispersed according to their mass over charge state ratio in the Argonne Fragment Mass Analyzer (FMA) [8]. The calculated time of flight through the FMA for ^{105}Te residues was about 650 ns. Mass slits were used to select only $A = 105$ residues with charge states $Q = 25^+$ and $Q = 26^+$ ($A = 106/Q = 25^+$ and $A = 106/Q = 26^+$ residues were partially allowed as well). After passing through a position-sensitive parallel-grid avalanche counter at the focal plane of the FMA, the recoils were implanted into a double-sided Si strip detector (DSSD). The 32×32 mm^2, 60-μm-thick DSSD was divided into 80 horizontal front strips and 80 vertical back strips, forming 6400 pixels. Subsequent α decays took place in the same pixel as the implantation. In the analysis, the implants were correlated with their subsequent α decays using spatial and temporal relations.

Because of the expected short half-life of ^{105}Te, special care was taken to optimize the detection of fast α-decay events. First, delay-line amplifiers, which recovered within 0.6 μs after the implantation signal, were used to detect α decays. Second, only implant events followed by decay events within 8 μs triggered the data acquisition system. This reduced the dead time drastically and allowed running with high rates in the DSSD.

Figure 1 shows the α spectra collected during the experiment. The top panel contains decays correlated with $A = 105$ recoils, whereas the bottom panel corresponds to $A = 106$ residues. Because of the trigger used, only decays faster than 8 μs were collected. A line containing 7 counts around 4 MeV is visible in the $A = 106$ spectrum. The properties of these 7 events are consistent with the known ^{106}Te α decay [5,6,9]. The $A = 105$ spectrum contains a group of 13 counts just above 4.5 MeV. The wide energy distribution of these events is associated with the significant radiation damage caused by a large number of ions implanted in the DSSD. These events were interpreted as the α decay from ^{105}Te; all other known $A = 105$ nuclei produced in this reaction do not exhibit such a decay. Their time distribution is given in the inset. The observed yield for the ^{105}Te events corresponds to a cross section $\approx$10 nb (for beam energies of 214 and 204 MeV; no events were observed at 224 MeV), if an FMA efficiency of 5% is assumed together with a factor of 4 loss because of the short half-life (see below).

Individual DSSD strips were gain matched using ^{244}Cm and ^{240}Pu long-lived α emitters. To avoid systematic errors associated with implant-decay pileup, the ^{105}Te energy was determined relative to the ^{106}Te events. A value of 4128(9) keV from Ref. [9] was adopted for E_α(^{106}Te). The ^{105}Te half-life was obtained from the decay times of the

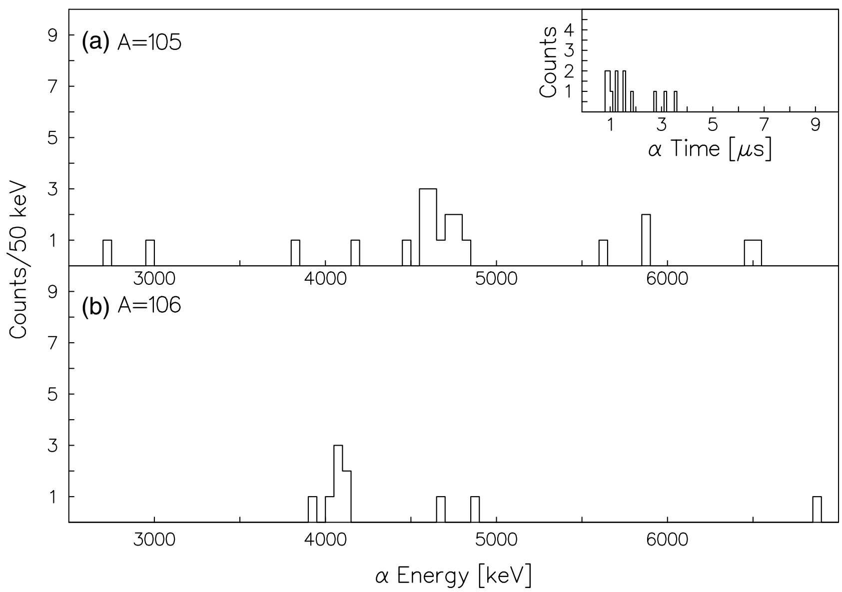

FIG. 1. Alpha spectrum for (a) $A = 105$ and (b) $A = 106$ residues. The inset in the top panel contains the decay time spectrum for the 13 events corresponding to the full energy ^{105}Te α decay. Only decays with decay times longer than 0.6 μs and shorter than 8 μs were detected.

^{105}Te events using the maximum likelihood method. As a result, an energy of $E_\alpha = 4720(50)$ keV, corresponding to $Q_\alpha = 4900(50)$ keV, and a half-life of $T_{1/2} = 0.7(-0.17 + 0.25)\mu$s were extracted. This is the shortest half-life ever observed using the implantation-decay correlation technique. Only statistical fluctuations were considered in error determination.

The α-decay constant can be factored into the reduced width, δ^2, and the barrier penetration factor, P, according to the formula $\lambda b_\alpha = \delta^2 P/h$ [10], where b_α is the α-decay branching and h is Planck's constant. Assuming a 100% α branch and calculating the penetration factor using the WKB approximation (a screening correction of 17 keV was added to the Q_α value), a reduced width of $\delta^2 = 230(-140 + 100)$ keV was obtained for ^{105}Te, after taking into account the errors associated with the energy and half-life. The reduced width, relative to the 70-keV reduced width in ^{212}Po, was calculated to be $W_\alpha = 3.3(-1.7 + 2.1)$. This should be compared to $W_\alpha = 4.6(-1.3 + 0.7)$ [6], $W_\alpha = 1.46(0.64)$, and $W_\alpha = 2.57(0.24)$ for ^{106}Te, ^{107}Te, and ^{108}Te, respectively. The ^{105}Te and ^{106}Te widths appear to increase modestly compared to these of ^{107}Te and ^{108}Te, supporting the idea of an increasing α-particle formation probability toward the $N = Z$ line, although the errors are rather large.

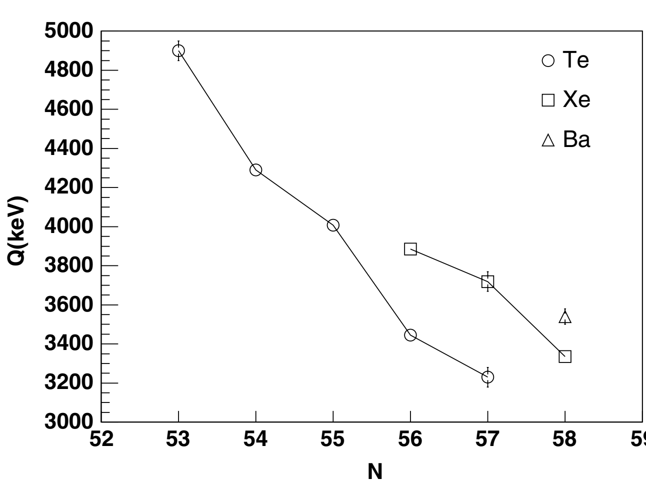

FIG. 2. Alpha-decay Q values for nuclei in the island of α activity above ^{100}Sn. The line connects the experimental points to guide the eye.

Figure 2 contains Q_α values for the neutron-deficient α emitters above ^{100}Sn. The Q_α value for ^{105}Te obtained in this work is larger by about 600 keV than the corresponding value for ^{106}Te. It compares very well with a prediction of $Q_\alpha(^{105}\text{Te}) = 4.69$ MeV from the Liran-Zeldes semiempirical formula [11], which is known to give good results far from the line of stability. A much larger value, $Q_\alpha(^{105}\text{Te}) = 6.31$ MeV, was calculated using the FRDM model [12]. The Q_α values increase by about 300 keV between ^{109}Te and ^{108}Te and between ^{107}Te and ^{106}Te. Thus, the extrapolation from ^{105}Te to ^{104}Te suggests a Q_α value of about 5.2 MeV for the latter nucleus. If the same reduced width as in ^{106}Te is assumed, a half-life of about 20 ns can be calculated for ^{104}Te. Unfortunately, this implies that the direct observation of ^{104}Te, produced in a fusion-evaporation reaction or via fragmentation, using a recoil separator is very difficult if not impossible, because of inherently long flight times. However, the observed ^{105}Te yield makes the search for a 1% α decay branch to the neutron $g_{7/2}$ excited state in ^{101}Sn possible.

In conclusion, the ^{105}Te α decay was observed. It is the fastest α emitter observed directly using the implantation-decay correlation technique. The Q_α value measured for ^{105}Te is reproduced well by the semiempirical formula of Liran and Zeldes [11]. The ^{105}Te α-decay reduced width supports a modest enhancement of α-decay rates toward the $N = Z$ line.

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