Precise measurement of α_K and α_T for the 109.3-keV *M*4 transition in ^{125}Te: test of internal-conversion theory

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Last year, we reported [1] on a measurement of the internal conversion coefficients (ICC), α_K and α_T, for the 109.3-keV *M*4 transition in ^{125}Te. At that time, analysis was incomplete and only preliminary results were presented. In the meantime, the analysis has been completed and the results submitted for publication [2].

In simple cases with a single transition that can convert in the K shell, the value of α_K is given by

$$\alpha_K = (N_K/N_\gamma)(\varepsilon_\gamma/\varepsilon_K)(1/\omega_K) , \qquad (1)$$

where ω_K is the fluorescence yield, N_K and N_γ are the total number of observed K x rays and γ rays, respectively; and ε_γ and ε_K are the corresponding photopeak detection efficiencies.

The decay of the 57.4-day isomer in ^{125}Te decay is not that simple, as illustrated by its decay scheme in Fig. 1. The presence of a second transition, having 35.5 keV, in cascade with the *M*4 transition adds a

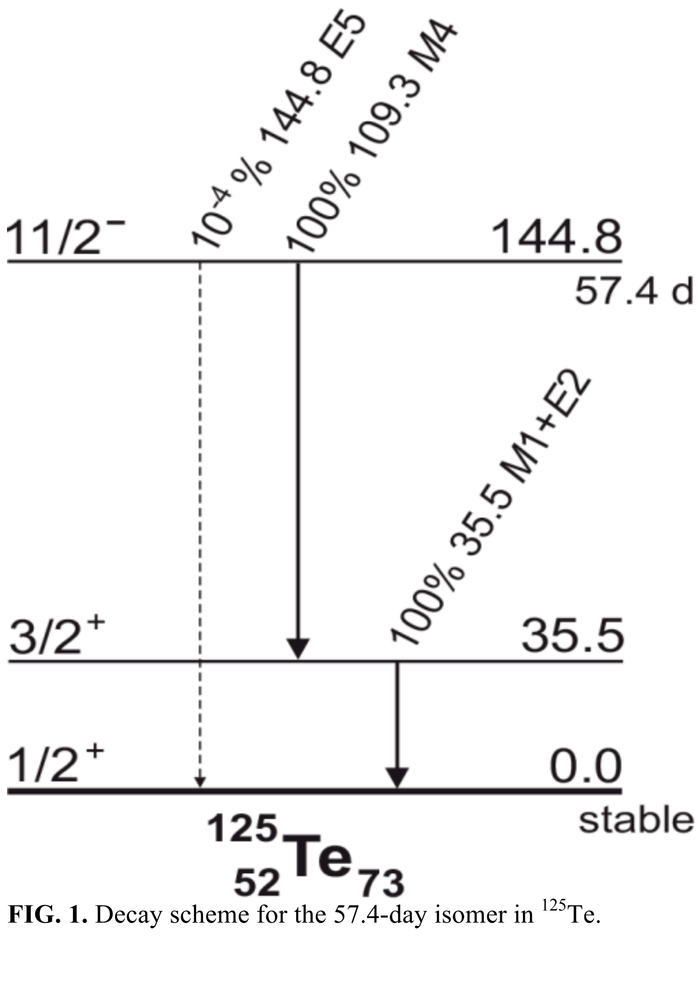

FIG. 1. Decay scheme for the 57.4-day isomer in ^{125}Te.

complication to our measurement. In this case, we must extract the α_K value for the 109.3-keV transition, with the help of a modified version of Eq. (1): *viz.*

$$\alpha_{K109} = (1/N_{\gamma 109})(\varepsilon_{\gamma 109}/\varepsilon_K)(1/\omega_K)\ \{N_K - \alpha_{K36}\, N_{\gamma 36}\, (\varepsilon_K/\varepsilon_{\gamma 36})\ \omega_K\}, \qquad (2)$$

where the subscripts 109 and 36 on a quantity denote the transition – either the 109.3-keV or 35.5-keV one – to which the quantity applies. Unfortunately, the 35.5-keV $M1+E2$ transition has a large value of α_{K36} = 11.64(4), so the K x rays from its conversion constitute about 60% of the total strength of the tellurium K x-ray peaks in the spectrum. This dilutes the precision with which we can determine the α_K value for the $M4$ transition. Nevertheless, it does offer an advantage: the opportunity to measure α_T as well as α_K for the 109.3-keV transition.

Although two transitions contribute to the K x ray peaks, there is no side feeding of the intermediate state so we can make use of the fact that the total transition intensities must be equal. Thus, we can determine α_{T109} via the equation

$$(1 + \alpha_{T109})\ (N_{\gamma 109}/\varepsilon_{\gamma 109}) = (1 + \alpha_{T36})\ (N_{\gamma 36}/\varepsilon_{\gamma 36})\ . \qquad (3)$$

To prepare our source, we first obtained tellurium metal powder enriched to 99.93(2)% in ^{124}Te from Isoflex USA. With it, we produced a thin neutron-activation target of ^{124}TeO on a pure aluminum backing by the molecular plating technique. The average thickness of ^{124}TeO was determined to be 308(9) μg/cm^2 as measured by mass. Then, this target was activated for a total of 24 hours in a neutron flux of ~7.5×10^{12}n/(cm^{2}s) at the TRIGA reactor in the Texas A&M Nuclear Science Center. Upon removal from the reactor, the active sample was stored for 3 weeks, after which time we acquired sequential gamma-ray spectra for 112 hours with our HPGe detector.

In analyzing our data, we took the N values from our spectra and the γ-ray efficiencies from our well-established HPGe detector calibration [3]. The K x-ray efficiency, ε_K, we took from a calibration we made more recently with a ^{109}Cd source [4]. All efficiencies took careful account of "self-attenuation" in the source material itself, an important effect both for the K x rays and for the 35.5-keV gamma rays. Our two ICC results appear in the top line of Table I, where each can be compared with three theoretical values, one that was calculated without accounting for the atomic vacancy and two that included the vacancy in different approximations, the "frozen orbital" (FO) or the "self-consistent field" (SCF).

Table I. Comparison of the measured α_K and α_T values for the 109.276(15)-keV $M4$ transition from ^{125m}Te with calculated values based on three different theoretical models. Shown also are the percentage deviations Δ from the experimental value, calculated as (experiment-theory)/theory.

Model	α_K	Δ(%)	α_T	Δ(%)
Experiment	185.0(40)		350.0(38)	
Theory				
No vacancy	179.5(1)	+3.0(22)	348.7(3)	+0.4(11)
Vacancy FO	185.2(1)	-0.1(22)	355.6(3)	-1.6(11)
Vacancy SCF	184.2(1)	+0.4(22)	354.2(3)	-1.2(11)

Clearly the result for α_K agrees well with the calculations that incorporate the vacancy. This is consistent with all our previous measurements of α_K.

The situation is more ambiguous for α_T: In that case our measured result agrees best with the no-vacancy calculation but it is consistent as well with the SCF version of the calculation, which includes the vacancy. Note also that the measured value of α_{T109} depends on a calculated value for α_{T36}, which in turn depends on the measured $E2/M1$ mixing ratio [5] for the 35.5-keV transition. If that mixing ratio were wrong, it could have an impact on our α_{T109} result.

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