Anomalous $M4$ conversion coefficient in $^{125}_{52}Te^{m}$

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The absolute $M4$ K-conversion coefficient of the 109.3 keV transition in $^{125}_{52}Te^{m}$ decay is measured using K-x-ray gamma ray summing in a Ge(Li) x-ray detector. The measured K conversion coefficient is 10% lower than the theoretical value.

[RADIOACTIVITY $^{125}Te^{m}$, chemical separation, Ge(Li) x-ray detector, measured α_K and α_T of 35.5 and 109.3 keV transitions.]

$M4$ transitions in odd N nuclei are known[1] to exhibit certain regularities quite unlike the general trends for the other gamma decay transitions. It is also known that the internal conversion coefficients for the $M4$ transitions are free from the nuclear structure effects,[2] further supporting the uninhibited nature of the $M4$ gamma decays involving pure shell model states. It is for these reasons that the consistent overestimation by about 2–3% of the theoretical $M4$ conversion coefficients, as noted by Raman *et al.*,[3] is indicative of a new and interesting feature of the $M4$ conversion process and calls for further experimental studies. Over the past few years we have developed[4] a simple and straightforward method to measure the absolute K-conversion coefficients, utilizing the x-ray gamma ray summing technique in a high resolution Ge(Li) x-ray detector. In the present work we used our system to measure the absolute K-conversion coefficients of the 109.3 keV $M4$ transition as well as the 35.5 keV $M1$ transition in the decay of 58 d $^{125}_{52}Te$. While the measured 35.5 keV $M1$ conversion coefficient agrees well with the theoretical estimates, we find a large discrepancy between the measured and theoretical conversion coefficients for the 109.3 keV $M4$ transition.

The ^{125}Te activity was chemically separated from the 2.77 yr parent activity ^{125}Sb, following the procedure quoted by Ledicotte.[5] Sources of $^{125}Te^{m}$ of different strengths were prepared to investigate the random summing effect, as well as the self-absorption of the low energy gamma rays. The gamma ray spectra were recorded with a high resolution ORTEC Ge(Li) x-ray detector at two different geometries: 2 and 50 mm from the detector window. The 2 mm geometry was standardized previously for our summing work.[6] For both the 2 and 50 mm geometry the efficiency of the detector was measured during the present work with several standard sources. The decay of the K x-rays and the two gamma rays, 35.5 and 109.3 keV, were followed for several weeks and the data yielded a half-life of $T_{1/2}=58\pm3$ d. The complete absence of the 427.9 keV gamma ray of ^{125}Sb was an indication of the effectiveness of our chemical separation. In the long-run data no other impurity lines were observed.

All together eight sets of spectra were recorded for about 5×10^{5} sec. A typical spectrum is shown in Fig. 1. From the decay scheme shown in the figure the α_K of the 109.3 and 35.5 keV transitions are given by the following two equations:

$$N^{\text{sum}}_{35.5+K_\beta}=\alpha_K^{109.3}\omega_K\frac{I(K_\beta)}{I(K_\alpha)+I(K_\beta)}\frac{\epsilon_{K_\beta}}{\epsilon_{109.3}}N^{\text{sum}}_{35.5+109.3}\,, \tag{1}$$

$$N^{\text{sum}}_{109.3+K_\alpha}=\alpha_K^{35.5}\omega_K\frac{I(K_\alpha)}{I(K_\alpha)+I(K_\beta)}\frac{\epsilon_{K_\alpha}}{\epsilon_{35.5}}N^{\text{sum}}_{35.5+109.3}\,, \tag{2}$$

where N^{sum} denotes the area of the sum peaks, ϵ is the efficiency of the detectors, ω_K is the K-flourescence yield in Te, and $I(K_\alpha)$, $I(K_\beta)$ are the

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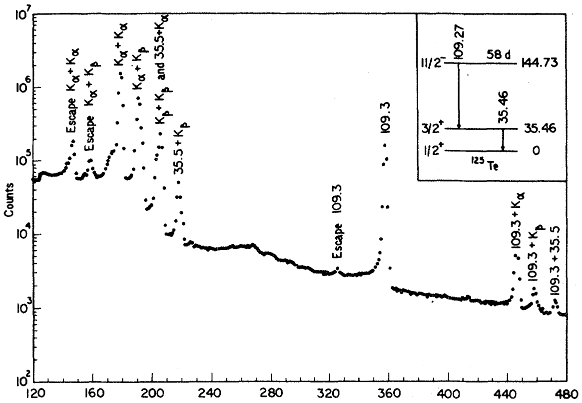

FIG. 1 K x-ray gamma ray sum spectra in the decay of $^{125}Te^m$. Insert shows the decay scheme of $^{125}Te^m$.

intensities of the K_α and K_β x-rays.

Extreme care was taken to measure the efficiency of the detector. Standard sources of ^{241}Am, ^{207}Bi, ^{152}Eu, and ^{133}Ba were used for calibration. The efficiency curve was fitted with a polynomial for interpolation. ω_K for Te was taken as 0.875 ± 0.028 from the work of Bambynek *et al.*,[11] and $I(K_\beta)/I(K_\alpha)$ for Te was taken as 0.226 from the same work.

From the measured spectra typical values of $N^{\rm sum}$ are the following:

$$N^{\rm sum}_{35.5+K_\beta}=64\,403\pm531\ ,$$

$$N^{\rm sum}_{109.3+K_\alpha}=6988\pm175\ ,$$

$$N^{\rm sum}_{35.5+109.3}=888\pm75\ .$$

Equations (1) and (2) give

$$\alpha_K^{109.3}=167\pm11\ ,\quad \alpha_K^{35.5}=12.1\pm0.7\ .$$

These values are the averages of four sets of data. The measured value of $\alpha_K^{35.5}$ agrees very well with the theoretical estimate $\alpha_K^{35.5}(M1)=12.0$. Combining Eqs. (1) and (2) and using this theoretical value of $\alpha_K^{35.5}$ one can avoid using the estimated ω_K and also the weaker sum peak $N^{\rm sum}_{35.5+109.3}$ to get a better estimate of $\alpha_K^{109.3}$. This is found to be $\alpha_K^{109.3}=171\pm10$.

In the above estimates we have neglected the effect of gamma-ray angular correlation on summing. The effect of angular correlation was found to be negligible in the summing of gamma rays from standard sources of ^{60}Co and ^{108}Ag in a 32.2 cm^2 Ge(Li) detector, as indicated by the precise determination of source strengths from summing data.

An independent determination of α_K and α_T for the 109.3 keV transition was made from the 50 mm

TABLE I. Gamma ray energies and intensities in $^{125}Te^m$.

Energy	Relative Intensity I
27.4 (K_α)	$1454\ \pm 73$
31.0 (K_β)	$325\ \pm 16$
35.5	100
109.3	4.95 ± 0.22

geometry spectra, where the summing was completely absent. From the intensity balance we get

$$I_\gamma\alpha_K^{109.3}=\frac{I_{KX}}{\omega_K}-I_\gamma^{35.5}\alpha_K^{35.5} \tag{3}$$

and

$$I_\gamma^{109.3}(1+\alpha_T^{109.3})=I_\gamma^{35.5}(1+\alpha_T^{35.5})\ . \tag{4}$$

Since the experimental $\alpha_K^{35.5}$ and $\alpha_T^{35.5}$ agree with the theoretical estimates[7] we have utilized the theoretical values of $\alpha_K^{35.5}$ and $\alpha_T^{35.5}$ to minimize the error in the estimates of $\alpha_K^{109.3}$ and $\alpha_T^{109.3}$ from Eqs. (3) and (4).

From our intensity data (Table I) we get

$$\alpha_K^{109.3}=168\pm22 \text{ and } \alpha_T^{109.3}=304\pm17\ .$$

Table II summarizes our conversion coefficient measurement and compares them with the theoretical estimates.

Table II indicates that both the measured $\alpha_K^{109.3}$ and $\alpha_T^{109.3}$ deviate considerably from the theoretical estimates.[7] It should be noted that our $\alpha_K^{109.3}$ and $\alpha_T^{109.3}$ values are consistent within the error with the reported[8] $K/L/M\ldots$ intensity ratios, whereas the only other accurate measurement[9] of $\alpha_T^{109.3}$, although being nearer to the theoretical estimate, gives rather smaller $K/L/M\ldots$ ratios. We feel that the disagreement between the experimental and

TABLE II. Conversion coefficients of the gamma rays in $^{125}Te^m$.

E_γ (keV)	α_K (Expt.)	α_K (Th)	α_T (Expt.)	α_T (Th)
35.5	12.1 ± 0.7	12.0		
109.3	167 ± 11[a]	189	304 ± 17[c]	366
	171 ± 10[b]			
	168 ± 22[c]			

[a]From sum spectra [Eq. (1)].
[b]From sum spectra [Eqs. (1) and (2) with $\alpha_K^{35.5}=12.0$].
[c]From intensity balance with $\alpha_T^{35.5}=14.0$.

theoretical values of $\alpha_T^{109.3}$ in our work is essentially due to the appreciable deviation of the measured α_K values from the theoretical estimates. In the available literature there is only one more measurement[10] of α_K by Bowe and Axel, who gave $\alpha_K^{109.3}=160\pm20$. This measurement is in agreement with our data, as listed in Table II. The simplicity of our method and the consistent α_K values measured by us for other well known cases,[4] together with the measured α_K value for the 35.5 keV transition in the present work, make us believe that the 109.3 keV $M4$ K-conversion coefficient does not agree with the theoretical estimates. The difference between the experimental and theoretical α_K values demands further studies of such cases.

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