Precise measurement of α_K and α_T for the 150.8-keV $E3$ transition in ^{111}Cd: 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 150.8-keV $E3$ transition in ^{111}Cd. At that time, analysis was incomplete and only preliminary results were presented. In the meantime, the analysis has been completed and the results published [2]. Since the experimental details were described last year [1], we focus here on the analysis.

The decay scheme of the 48.5-min isomer in ^{111}Cd is shown in Fig. 1. The presence of a second transition in cascade with the $E3$ transition of interest might be expected to present a problem for our measurement but, in fact, because the conversion coefficients for the higher energy $E2$ transition are much smaller, it does not seriously degrade the uncertainty on α_K and it actually offers a further advantage: the opportunity to measure α_T as well as α_K for the $E3$ transition.

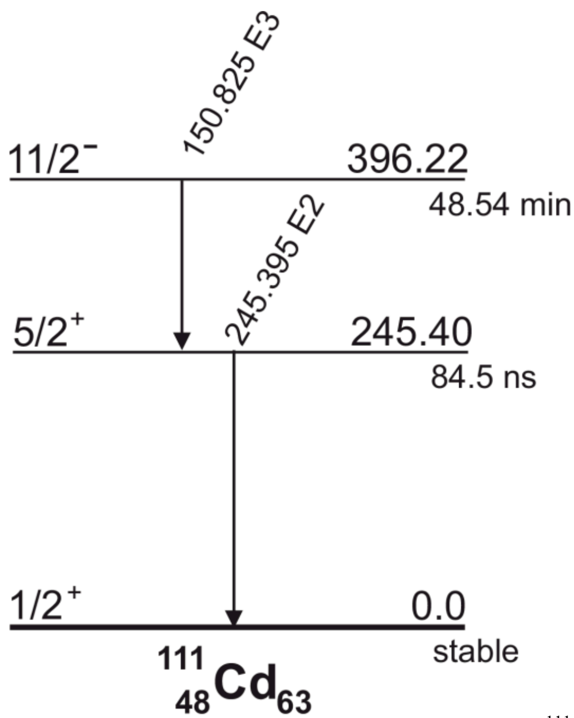

FIG. 1. Decay scheme for the 48.5-min isomer in ^{111}Cd.

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

$$\alpha_K = (N_K/N_\gamma)(\varepsilon_\gamma/\varepsilon_K)(1/\omega_K) , \tag{1}$$

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.

In the case of ^{111m}Cd decay there are two transitions involved that both can contribute to the *K* x ray peaks. However, 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 extract the α_K value for the 150.8-keV transition, by using a modified version of Eq. (1): *viz.*

$$\alpha_{K150} = (N_K/N_{\gamma150})(\varepsilon_{\gamma150}/\varepsilon_K)(1/\omega_K) - \alpha_{K245}\,(N_{\gamma245}/N_{\gamma150})(\varepsilon_{\gamma150}/\varepsilon_{\gamma245})\ , \qquad (2)$$

where the subscripts 150 and 245 on a quantity denote the transition – either the 150.8-keV or 245.4-keV one – to which the quantity applies. Furthermore, we can determine α_{T150} via the equation

$$(1 + \alpha_{T150})\,(N_{\gamma150}/\varepsilon_{\gamma150}) = (1 + \alpha_{T245})\,(N_{\gamma245}/\varepsilon_{\gamma245})\ . \qquad (3)$$

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]. Our two ICC results appear in the top line of Table I, where each can be compared with two theoretical values, one that was calculated without accounting for the atomic vacancy and one that included the vacancy in the "frozen orbital" (FO) approximation.. Clearly the result for α_K agrees well with the calculation that incorporates the vacancy. This is consistent with all our previous measurements of α_K.

Table I. Comparison of the measured α_K and α_T values for the 150.853(15)-keV *E*3 transition from ^{111m}Cd with calculated values based on two 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	1.449(18)		2.217(26)	
Theory				
No vacancy	1.425(1)	+1.7(12)	2.257(1)	-1.8(12)
Vacancy FO	1.451(1)	-0.1(12)	2.284(1)	-2.9(12)

Our α_T result does not lead to such a simple conclusion: It is lower than both calculations, with the worst disagreement (~2.5σ) being with the FO calculation. One possible explanation [2] arises from the fact that the 150.8-keV transition is hindered by a factor of 10^4 relative to the single-particle Weisskopf estimate. Under such conditions, one could expect to encounter "penetration", which is a dynamic effect associated with the change from transition electromagnetic potentials used for a point nucleus to transition potentials required for a realistic finite-sized nucleus. For unhindered electric transitions, the penetration effect is not significant, but it may reach several percent for magnetic transitions. The effect is included in our ICC calculations by an approximation based on the surface-current model but it is done uniformly with all nuclei and all transitions. For strongly hindered transitions, the penetration effect can become more important, giving rise to non-negligible nuclear matrix elements in the expressions for the ICCs. In this way these particular ICCs become dependent on nuclear structure details and nuclear transition dynamics. It is plausible that this can explain our results; certainly a no more definitive explanation is possible.

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