Tests of internal-conversion theory and efficiency calibration with precise γ- and x-ray spectroscopy: the $^{197}Pt^{m}$ case

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As the next case in a series of precision internal-conversion-coefficient (ICC) measurements [1, 2] designed to test internal-conversion theory, we have studied the 346.5-keV, *M4* transition from the decay of $^{197}Pt^{m}$. The previously measured α_K for this transition, 4.02(8) [3], which is shown as the grey points in Fig. 1 at the marked $^{197}Pt^{m}$ location, disagrees with modern Dirac-Fock calculations whether or not the atomic vacancy caused by the electron-capture process is incorporated in the theory.

The technique we use is to measure the intensity ratio of the K x-ray peaks relative to the γ-ray peak for the transition of interest. Our precision depends on there being no other significant contributors to the x-ray peaks (or to the γ-ray peak). One can easily see that a measurement on the 346.5-keV γ transition presents a number of challenges. We produce $^{197}Pt^{m}$ by neutron activation of enriched ^{196}Pt, and one of the main difficulties is that the cross section for producing the ^{197}Pt ground state (σ_{th} = 0.72 b) is 16-times larger than that for producing the isomer of interest (σ_{th} = 0.044 b). The ^{197}Pt ground state β^- decays with a 19.9-hr half-life to states in ^{197}Au, whose subsequent γ-decays involve internal conversion and give rise to gold K x rays. These x rays are very close in energy to the platinum x rays, whose intensity we need to determine. However, since the half-life of $^{197}Pt^{m}$ is 95.4 min we are able to use a time analysis of the decay spectra to help with the separation.

Another difficulty comes from the strong 77.4-keV γ ray which is produced by the ^{197}Pt ground state β^- decay and effectively obliterates the platinum K_β peaks (75-78 keV). Moreover, this γ ray creates a scattering "shelf" to lower energies in the γ-ray spectrum, which complicates the background in the region of the platinum K_α x rays. Once again, we must make use of the different half-lives to separate the peaks of interest from the background. These complications have served to limit our precision compared with our previous results.

We prepared two samples, S1 and S2, at the Cyclotron Institute from 97.4%-enriched ^{196}Pt as a thin powder held between thin mylar foils. These ensembles were separately activated in the Triga reactor at the Nuclear Science Center of Texas A&M University. Source S1 contained 0.7 mg of the powder and was activated for 4 h; while S2 contained 1.5 mg and was activated for 1 h.

We measured γ-ray spectra from each activated source for about two weeks using our very precisely efficiency-calibrated HPGe detector [4]. Next we carefully scanned the spectra from both sources and identified all γ-ray peaks, using intensity ratios and decay curves. Based on this γ-ray-intensity information, we then calculated the contribution, if any, to the platinum K x-ray region from each impurity activity detected.

Because of the long activation time for sample S1, the initial counting rate in our detector was very high, leading to dead-times of up to 40%. This restricted the accuracy of our half-life analysis.

Furthermore, this source also included a much higher contribution from impurities. As a result, we did no further analysis of the S1 spectra and concentrated on source S2.

With this source we successfully separated the K x-rays associated with the $^{197}Pt^{m}$ *M4* transition from the 77.4-keV γ ray and gold K x-rays caused by the decay of the ^{197}Pt ground state. The resulting decay curve for the platinum K x-rays and the measured decay curve for the 346.4-keV γ ray were then fitted with a common half-life and their ratio obtained. Our result, $\alpha(K)_{exp}=4.25(5)$, can be compared with the theoretical calculations of 4.275 (with the vacancy included in the "frozen orbital" approximation) and 4.19 (no vacancy). Our result is statistically consistent with both calculations (see Fig. 1) and removes the discrepancy that the previous measurement had indicated.

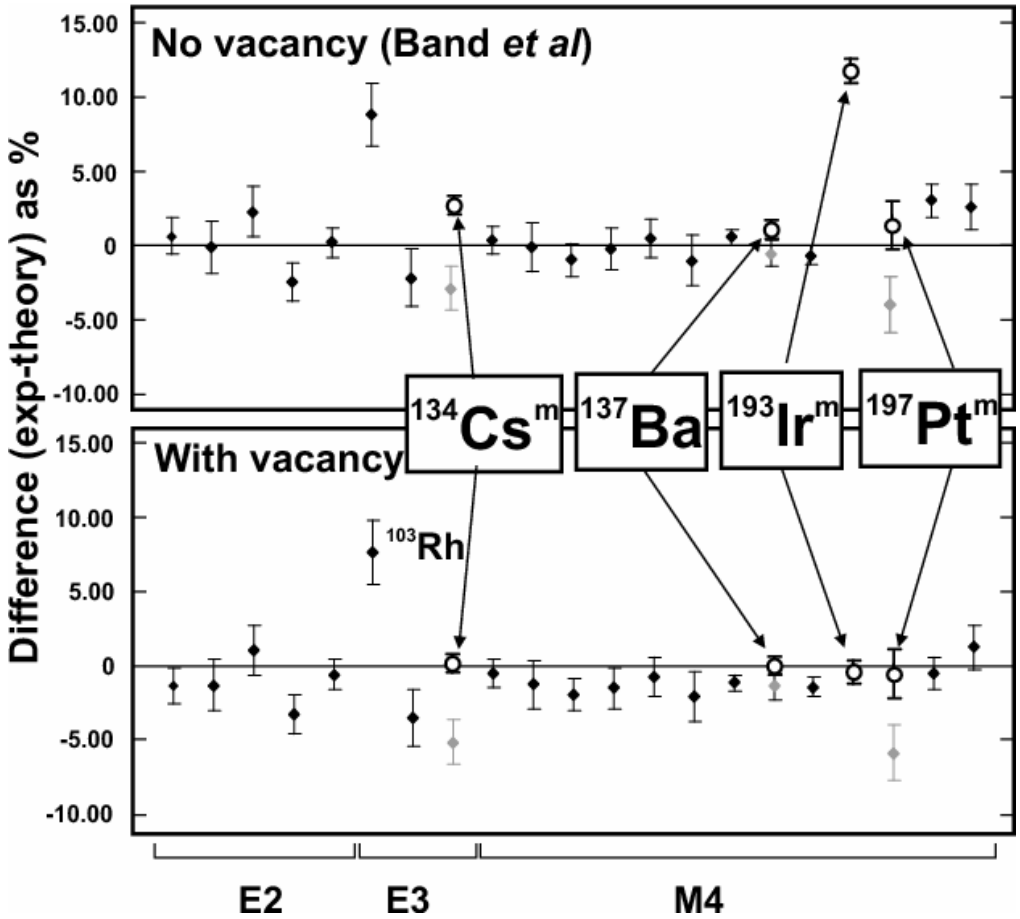

FIG. 1. Percentage differences between the measured and calculated ICCs for two Dirac-Fock calculations: one (top) is without the atomic vacancy and the other is with it included in the "frozen orbital" approximation. The points shown as solid diamonds in both plots correspond to the twenty cases that have better that 2% precision [5]; as indicated at the bottom, five are for E2 tranditions, three for E3, and the remainder are for M4 transitions. The points shown as open circles correspond to our recently measured α_K values. The grey points with error bars at the same horizontal positions are the previous α_K results, which our measurements replace.

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