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

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As the next step in a series of precision internal-conversion-coefficient (ICC) measurements [1, 2] designed to test internal-conversion theory, we have proceeded with another interesting case, the 346.5-keV, M4 transition in $^{197}Pt^{m}$. As shown in Figure 1, the previously measured α_K for this transition, 4.02(8) [3], disagrees with modern Dirac-Fock calculations whether or not the atomic vacancy caused by the electron-capture process is incorporated in the theory.

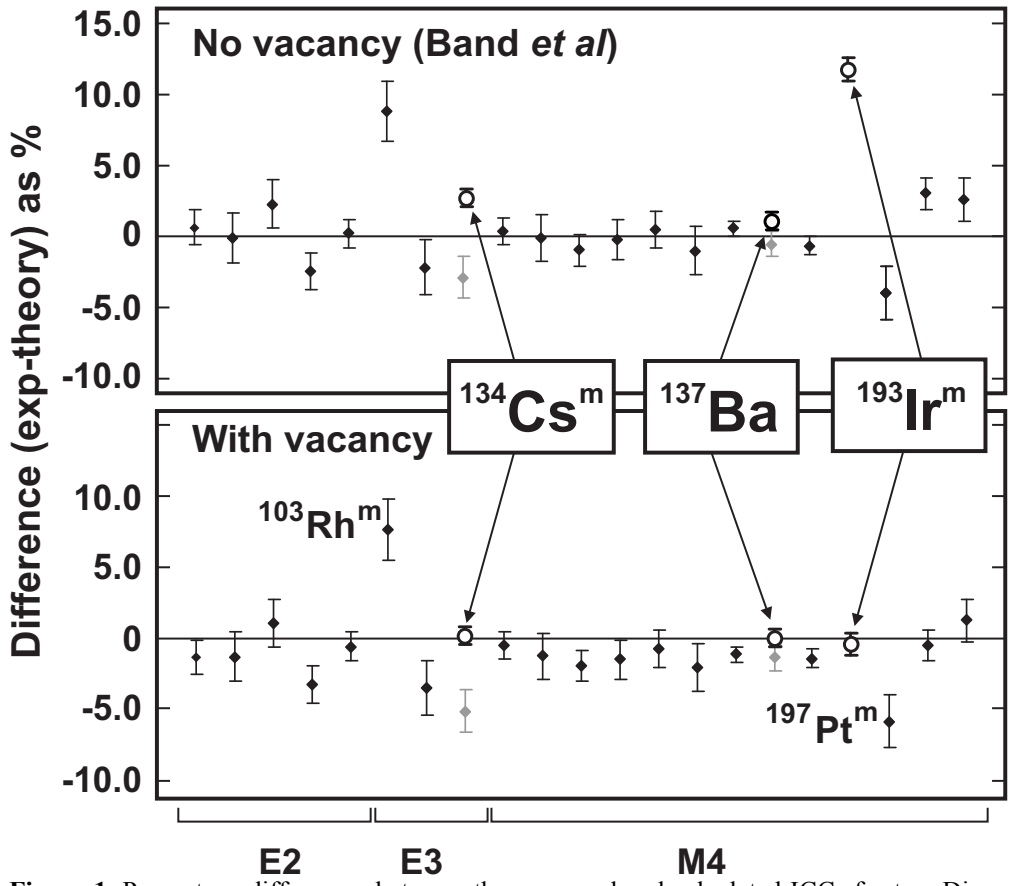

Figure 1. Percentage differences between the measured and calculated ICCs for two Dirac-Fock calculations: one (top) is without the atomic vacancy and the other is with it included in the "frozen orbital" approximation. The points shown as solid diamonds in both plots correspond to the twenty cases that have better that 2% precision; 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 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 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 can 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. We will again have to make use of the different half-lives to determine the exact shape of this background. These complications will undoubtedly limit our precision.

We prepared our samples at the Cyclotron Institute from 97.4%-enriched ^{196}Pt as a thin powder held between thin mylar foils. This ensemble was then activated in the Triga reactor at the Nuclear Science Center of Texas A&M University. Because of the low cross section for production of $^{197}Pt^{m}$ by thermal neuron activation (as noted above), both the mass of Pt and the activation time were relatively high. These factors too will affect our ultimate precision.

We measured spectra from the activated source using our very precisely efficiency-calibrated HPGe detector [4]. The full decay of the source was recorded in 17 spectra over about two weeks in order to have sufficient information for multiple decay-curve analysis. A detailed impurity analysis has already been completed, which identified sources of Ir and Hg K x rays; these are relatively weak and can be precisely accounted for by an analysis of their observed γ-rays. A complete analysis is currently in progress.

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[4] R. G. Helmer *et al.*, Nucl. Instrum. Methods Phys. Res. **A511**, 360 (2003).