Precise Measurements of α_k for the 346.5 keV M4 Transition in $^{197}Pt^m$

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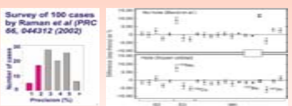
Introduction

•In Internal Conversion, nuclear de-excitation energy is transferred directly to an atomic electron in the K, L, M, or higher shell; this electron then leaves the atom. Subsequently, an electron from an outer shell moves to fill the hole left by the departed electron; this results in characteristic x-ray emission.

•This process competes with gamma-ray emission.

•The Internal Conversion Coefficient (ICC) is the ratio of the total number of decays for a particular transition that proceed by internal conversion to those that proceed by gamma-ray emission.

•A 2002 survey by Raman, et al. noted that many ICC measurements were not known to a high precision; it also highlighted the discrepancy between competing theoretical tables of ICC values and the lack of agreement between experimental and theoretical measurements.



•Two primary theoretical tables of ICC values differed over how they considered the atomic vacancy (or "hole") left by the electron after it departed its orbital; the calculations of Hager and Seltzer considered this hole to be filled immediately ("no hole" approximation), while the later calculations of Band and Trazhaskovskaya took the hole into account and considered the electron orbitals to remain in the state they were before the electron left ("frozen orbital" approximation).

•New precision measurements by the Hardy Research Group of the ICCs for ^{193}Ir, ^{134}Cs, and ^{137}Ba demonstrated agreement with the "frozen orbital" approximation.

•A 1987 paper by I.N. Vishnevsky, et al. gave the ICC of the 346.5 keV M4 Transition in $^{197}Pt^m$ as: $\alpha_k = 4.02 \pm 0.08$. This measurement differed from both theoretical ICC tables; because of this, the Hardy Research Group opted to precisely re-measure the ICC of this nuclide.

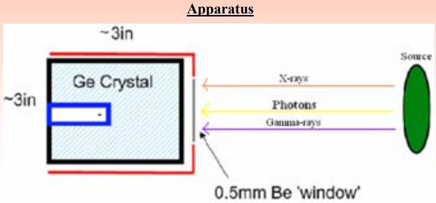
Experiment

Two sources of ^{196}Pt (97.43% +/- 0.02% pure) were used:

- S1: 0.7 mg of 10 mm diameter ^{196}Pt powder on thin Mylar backing; this was covered with 0.5 mil thick Mylar.
- S2: 1.53 mg of 10 mm diameter ^{196}Pt powder on thin Mylar backing; ths was covered with 0.5 mil thick Mylar.
- Both sources were activated by thermal neutrons; S1 was activated for a period of two hours, while S2 was activated for a period of thirty minutes.

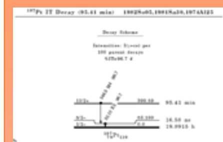
X-ray and gamma-ray emissions from both sources were recorded by a High Purity Germanium Detector, with an absolute efficiency of +/- 0.20%. 17 spectra were recorded for S1; 27 spectra were recorded for S2.

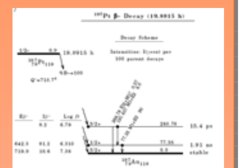
Apparatus



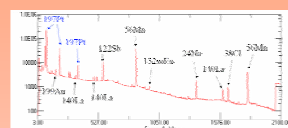
Impurity Analysis

The activation of ^{196}Pt created both $^{197}Pt^m$ and $^{197}Pt^{gs}$; $^{197}Pt^m$ IT decays to $^{197}Pt^{gs}$, which beta decays to ^{197}Au, which is stable. In addition, the source contained trace quantities of ^{190}Pt and ^{192}Pt and larger quantities of ^{194}Pt and ^{198}Pt, as well as other nuclides from the environment and handling.

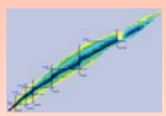




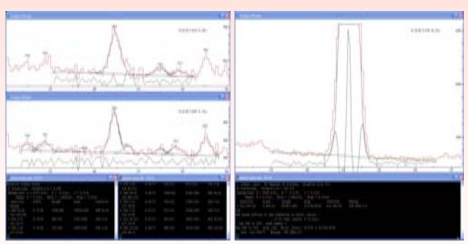
This led to a number of impurities in the activated source which contributed to the recorded x-ray and gamma-ray spectra. For a precision measurement, most of these impurity contributions cannot be ignored, and must be identified and subtracted from the spectra.



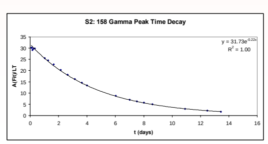
The NuDat and ENSDF tables contain valuable information on all known nuclides, including gamma-ray energies, intensities, and half-lives ($T_{1/2}$). These tables were used to understand the decay schemes of known impurities; they were also used to identify unknown impurities based upon gamma-ray energies and intensities.



A customized version of the RADWARE software suite, GF3_JCH, was used to examine the obtained spectra and obtain integrals of the area under gamma-ray peaks. These areas were then plotted sequentially in Microsoft Excel™; the data points were fitted to an exponential trend line of the form $y = Ae^{-\lambda x}$; the $T_{1/2}$ of the gamma-ray peak was then obtained using the formula $T_{1/2} = \ln(2)/\lambda$.



Comparison of gamma-ray energies, intensities, and $T_{1/2}$ with the values available in the ENSDF tables enabled the identification of the impurities from which unknown gamma-ray peaks originated.



Attenuation Coefficients

The presence of other media en route from the source to the detector, including the source itself, caused attenuation of the observed emissions. In order to correct for this attenuation, it was necessary to compute the attenuation correction factor for both sources. The attenuation is given by the formula $I_\gamma = I_{\gamma 0}e^{-\mu x}$, where μ is the attenuation coefficient.

In order to determine the correction factor, it was necessary to consider the x-rays and gamma-rays from each source; it was also necessary to consider the Mylar cover around the source. The source consisted of platinum powder that was not uniformly thick; also, the diameter of the source varied at different points along its surface. The average thickness of each source was calculated to take this fact into account:

•S1: average thickness of 4.5 µm.

•S2: average thickness of 2.1 µm.

These differences in the physical properties of each source meant that the corrrection factor for each source was different. The calculations to determine the attenuation correction factors are depicted below.

•S1: 0.6% attenuation

•S2: 1.4% attenuation

Results

Although the analysis of the impurities is not yet fully completed, enough of the work has been completed to obtain a preliminary result for the α_k value. The formula below gives this value.

• ω_k is the k-shell fluorescence yield, 0.959(4)*.

•N_k and N_γ are the total number of k x-rays or gamma-rays found by integration of spectra.

• ε_k and ε_γ are the known detector efficiencies at peak energies.

$$\alpha_K = \frac{1}{\omega_K}\frac{N_K}{N_\gamma}\frac{\varepsilon_\gamma}{\varepsilon_K}$$

•S1: **α_k = 4.24 (13)**

•S2: **α_k = Not yet calculated**

*E. Schönfel and, H. Jaben, NIM A 369 (1996) 527.

Conclusion

Theoretical calculations:

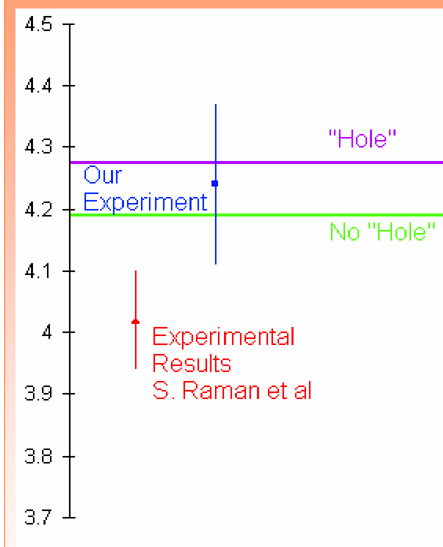
•"Frozen Orbital" approximation: **α_k = 4.275 +/- 0.001**

•"No hole" approximation: **α_k = 4.190 +/- 0.001**

Experimental calculations:

•S1: **α_k = 4.24 (13)**

•S2: **Not yet calculated**



These results are preliminary, but they already show a better agreement with the theoretical measurement obtained from the "frozen orbital" approximation. As with our three prior precision ICC measurements, this experiment continues to support the idea that the "frozen orbital" approximation is a better theory for calculating the ICC. The high number of impurities present in S1, combined with a weaker energy resolution in S2 will mitigate the precision obtainable in the final result; unlike our prior ICC measurements that were within 1% precision, this measurement will likely be within the range of 2-3% precision. However, this will still be sufficient to provide a precise value of α_k for the 346.5 keV M4 transition in $^{197}Pt^m$; should the final result demonstrate agreement with the value obtained from the "frozen orbital" approximation, it will bolster the position for favoring the "frozen orbital" approximation over the "no hole" approximation.

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