L-subshell internal conversion ratios of the 99-keV transition in ^{195}Pt

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An individual particle-track counting technique, employing electron-microscope image plates, has been used to obtain accurate electron intensities with a high-resolution permanent-magnet spectrograph. The L-subshell ratios of the 99-keV transition in ^{195}Pt, have been remeasured as $L_I/L_{II} = 7.68 \pm 0.30$, $L_{II}/L_{III} = 3.67 \pm 0.20$, and $L_I/L_{III} = 28.3 \pm 1.4$. These ratios are consistent with an $E2/M1$ multipole mixing ratio of $0.114 \le |\delta| \le 0.133$ and a penetration parameter of $-2 \le \lambda \le 2.5$. Earlier double-focusing spectrometer results have been analyzed on the $|\delta|$ vs λ plane and were found to be consistent with $|\delta| = 0.160 \pm 0.003$ and $\lambda = -16.5 \pm 1.8$, which are in disagreement with both the present data and with more recent double-focusing spectrometer data.

I. INTRODUCTION

The ratios of the internal conversion intensities of electromagnetic transitions in nuclei are frequently used to accurately determine the multipolarities and mixing ratios of transitions. In some magnetic dipole transitions, however, the degree of overlap of the electron wave functions with the nuclear transition currents, can strongly effect the internal-conversion process. The result is that L-subshell ratios, as well as other internal-conversion data, depend on a nuclear penetration parameter λ as well as on the multipole mixing ratio $|\delta|$. Nuclear penetration effects have been reviewed in the literature[1] and the electron integrals needed to extract the penetration parameter λ from the conversion data, have been extensively calculated and tabulated.[2-4] The most dramatic penetration effect known is the classic case of the 482-keV transition in ^{181}Ta, for which λ has recently been reevaluated[5] as 175^{+7}_{-4}, where $\lambda = 1$ in normal conversion processes. However, only a hand full of clear-cut cases have been reported and the systematics of such effects are not yet known. As an example, experimental attempts to correlate the magnitude of λ with the retardation factor in four transitions of ^{133}Cs, resulted in the fact that no such simple connection was found[6,7] as had been previously speculated.[1] In light of the absence of systematic experimental information on penetration effects, it appears important to further investigate any cases in which inconsistencies between theoretical predictions and experimental internal conversion data, cannot be explained by multipole mixing alone.

The object of the investigation discussed in this note is twofold: first, to extend the earlier efforts by Sevier[8] to make accurate electron-intensity measurements using a permanent-magnet spectrograph, and second, to use this technique to remeasure the L-subshell conversion ratios of the 99-keV transition in ^{195}Pt, in order to clarify the question of penetration raised by reanalysis of the earlier data. Early attempts to measure these ratios used film-recording spectrographs and were rough at best; however, more recently Toburen and Albridge[9] have reported values of $L_I/L_{II} = 10.4 \pm 0.6$, $L_I/L_{III} = 34.3 \pm 0.8$, and $L_{II}/L_{III} = 3.28 \pm 0.10$, for this transition, which were measured at 0.13% momentum resolution using a double-focusing magnetic spectrometer. The authors of Ref. 9 report that this transition is $(99 \pm 1)\%$ $M1$ with a small possible $E2$ mixture; however, careful examination of their data shows that none of their ratios share a common range of the mixing amplitude $|\delta|$, even within several standard deviations. Such inconsistencies usually imply either systematic experimental error, penetration effects, or both; hence, we have reanalyzed their data by allowing both $|\delta|$ and λ to vary. We find their experimental L-subshell ratios are consistent with $|\delta| = 0.16 \pm 0.003$ and $\lambda = -16.5 \pm 1.8$.

These results are not in agreement with those of Hsu and Emery,[10,11] and Martin[12] who find $L_I/L_{II} = 7.55 \pm 0.23$, $L_I/L_{III} = 26.7 \pm 1.4$, and $L_{II}/L_{III} = 3.53 \pm 0.20$. These ratios are consistent with a multipolarity of $(98.29 \pm 0.12)\%$ $M1$ without large penetration effects.

The value of the penetration parameter λ, which is consistent with the data of Toburen and Albridge,[9] would constitute one of the larger values reported and is certainly worth reinvestigating.

II. EXPERIMENTAL PROCEDURE

The present measurements were made using the same 90-Gauss spectrograph described by Smith and Hollander.[13] The radioactive source of ^{195}Au was obtained from the Isotopes Products Laboratories where it was electroplated onto a 0.005-cm-diam drawn wire. Several films, emulsions, and counting techniques were tried; however, Kodak Electron Image Plates, developed in the recommended way and read by counting every mark on the plate with a microscope, was found to give superior results by far in this energy range. The plates were counted using magnifications of 10× and 97× for the microscope eyepiece and objective lens, respectively. A 20×20 grid with 0.1-mm spacings was inserted on the eyepiece. This choice of grid size resulted in 145 grid squares spanning the darkened electron lines which covered the entire 15-mm width of the cut image plate. The track counter then counts all of the tracks in each grid square across one of the 146 rows at a time. Figure 1 shows typical data obtained by counting one single row. A single exposure then contains 145 times the data shown in Fig. 1. Many different countings then can be averaged and statistical errors extracted from the fluctuations between the results of the various rows. The present results were found to have only the expected statistical fluctuations from one row to another. By counting every observable, darkened spot on the plate, regardless of grain density, one avoids the usual energy dependence and process dependence of the degree of exposure. The background was counted at widely varying energies and found to be extremely flat. The image plates are very stable under vacuum and far easier to store and process than other films and nuclear emulsions.

A word of caution is appropriate here. We have noticed that the track counter will have to change the focusing adjustment when shifting from the L_I to the L_{II} and L_{III} conversion lines, in order to clearly focus the majority of events. This has been found to be a depth effect which, if not accounted for, can lead to very large errors. In the present case the events of the L_I peak and the L_I tail are all simultaneously in focus, while the setting appropriate for the L_{II} peak will cause the track counter to miss the events in the tail which constitute a significant fraction. To avoid this error, several depth planes must be counted in order to construct the lower portion of the tails. We have found, however, that data read with the microscope adjusted to be properly focused on each individual peak gives the same results as those read in various depth planes, if only the area above 10% of the peak height is counted. This avoids involvement with the long tails while still accounting for the variation in line shape with electron energy.

This method certainly still contains most of the inconveniences well known to workers in the field in the 1950's; however, the high degree of development of electron-microscope technology coupled with individual particle-track counting does give an independent method of L-subshell intensity measurements and one in which data from all lines is collected simultaneously.

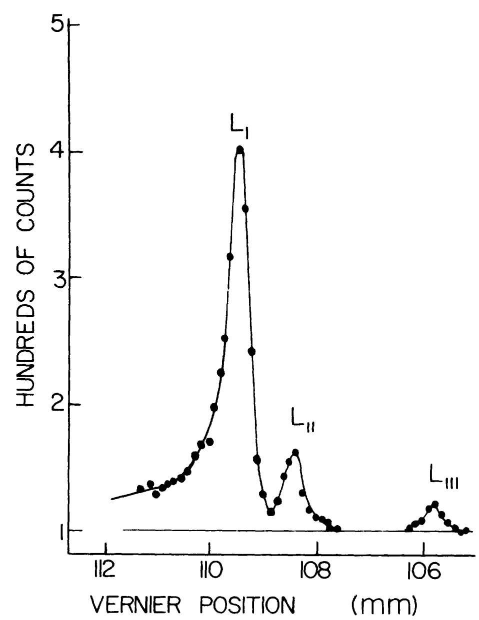

FIG. 1. Plot of typical L-subshell data in which the number of tracks per grid square is plotted against the position of the grid square.

III. ANALYSIS AND INTERPRETATION

The measurement of the width of the L_{III} line and the distance between lines, yields a momen-

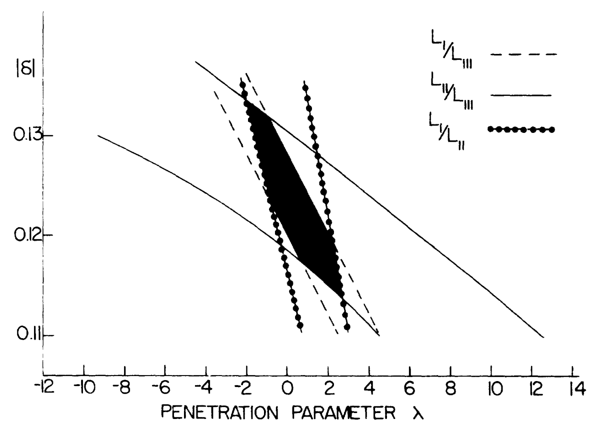

FIG. 2. Analysis of the L-subshell ratios on the $|\delta|$, λ plane. The curves represent the limiting ranges of $|\delta|$ and λ for each ratio and the darkened region includes all points on the plance which are in agreement with the experimental ratios.

tum resolution of 0.12%. The L-subshell ratios were found to be $L_{I}/L_{II} = 7.68 \pm 0.30$, $L_{II}/L_{III} = 3.67 \pm 0.20$, and $L_{I}/L_{III} = 28.3 \pm 1.4$. Each ratio was analyzed on the $|\delta|, \lambda$ plane as shown in Fig. 2. The solid, dotted, and dashed lines represent the limits of agreement between the present experimental results and the theoretical values calculated using the results of Hager and Seltzer.[4] The solid black region represents the overlap of the three ratios and corresponds to an $E2/M1$ mixing ratio of $0.114 \leq |\delta| \leq 0.133$ and a penetration parameter of $-2.0 \leq \lambda \leq 2.5$ which are significantly different than the values $|\delta| = 0.160 \pm 0.003$ and $\lambda = -16.5 \pm 1.8$ implied by the ratios reported in Ref. 9.

We conclude that the L-subshell ratios of the 99-keV transition are consistent with a predominantly $M1$ character without large penetration effects which is in disagreement with the conclusions drawn from the results of Toburen and Albridge[9] but in agreement with those of Hsu and Emery,[10, 11] and Martin.[12]

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