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L SHELL FLUORESCENCE YIELDS AND COSTER-KRONIG TRANSITION PROBAB--ETC(U)
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Accurate knowledge of x-ray fluorescence yields is an important ingredient in the solution of many practical problems and in the understanding of the decay mechanisms of atomic states characterized by inner-shell vacancies. In the present work, coincidence and singles techniques, employing high resolution semiconductor x-ray detectors and radioactive isotopes, are applied to obtain information on the decay of inner-shell → next page

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vacancy atomic states. Precision measurements of K-shell fluorescence yields at Z = 78, 82 and 92 are performed. X ray and Coster-Kronig yields at Z > 60 are measured. It is clearly established that a discrepancy exists in the interpretation of experimentally observed L_2 subshell Coster-Kronig transition probability around Z = 80. A careful and detailed study of the decay of (LL)-, (LX)-vacancy atomic states at Z = 82 (in the decay of ^{207}Bi) is made by (x-ray)-(x-ray) and (x-ray) Auger electron coincidence techniques.

L SHELL FLUORESCENCE YIELDS

AND

COSTER-KRONIG TRANSITION PROBABILITIES

USING RADIOACTIVE ISOTOPES

Final Report

P. Venugopala Rao, J. M. Palms, R. E. Wood

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Emory University
Atlanta, Georgia

I. STATEMENT OF THE PROBLEM

Accurate knowledge of x-ray fluorescence yields is an important ingredient in the solution of many practical problems and in the understanding of the decay mechanisms of atomic states characterized by inner-shell vacancies. Before the advent of high resolution semiconductor detectors reliable information existed only on the x-ray yields of single K-shell vacancy atomic states. Late in the 'sixties, application of coincidence techniques using semiconductor x-ray detectors to measure the fluorescence yields of L_2 and L_3 subshells at high Z, where L shell characteristic x rays' energies are in the range of 10 to 15 keV, was successfully demonstrated at Emory. The problem was to extend these measurements over a wide range of Z values in order to obtain sufficiently *accurate values for* L subshell yields. During the four-year period of this grant, this objective was not only completely realized, but also ground work was done for the studies of the decay of complex atomic states. These studies, besides providing a reliable experimental technique, have provided sufficient incentive and encouragement to theoreticians in atomic physics to provide careful theoretical estimates of x-ray emission rates and non-radiative transition rates as evidenced in the work of Crasemann, Bhalla, McGuire and Scofield. This final report is to summarize and put in proper perspective the work performed at Emory.

II. RESULTS

a) Measurement of L_2 and L_3 subshell yields

By measuring coincidences between Kα x rays and L x rays, L_2 subshell Coster-Kronig yields f_{23} were measured. The Coster-Kronig yields at 7 atomic

numbers in the region $63 \leq Z \leq 82$ were carefully measured. (Ref. 1,6,2). These were compared with the theoretical estimates. The general trend of the theoretical estimates of f_{23} is substantiated by these experiments but there exists a substantial discrepancy between theory and experiment in the region around Z = 80. The experimental values are 25% higher than theoretical estimates in this region. In an experiment in which M x rays (3 keV to 4 keV) were observed in coincidence with K_α and K_β x rays it was established that the f_{23} Coster-Kronig transition probability does not have a substantial radiative component. In addition ω_2 and ω_3 were measured at Z = 73[1] and L x ray emission rates from L_2 and L_3 subshells were measured in the region of $65 \leq Z \leq 94$.[2]

b) Measurement of L_1 subshell yields

Compared to L_2 and L_3 subshells, very little information was available on L_1 subshell decay. An important contribution of this work was the development of methods to obtain information on the x ray emission from L_1 subshells. Three basic techniques were employed: The first technique involved studying a well resolved L x ray spectrum and analyzing it to determine the number of L_1 subshell characteristic rays emitted by the samples and calculating the L_1 subshell characteristic fluorescence yield ω_1 by using the knowledge of L_1 subshell vacancy states produced in the sample. This method was employed at two Z-values 82 and 83 (Ref: 2,17). This method can be successfully employed at high Z using suitable radioactive isotopes (in which L shell ionization takes place substantially) and high resolution x-ray detectors.

The second technique was to employ L conversion electrons as signals of L vacancy states and observe L x rays in coincidence with them as in the

case of Z = 82. This method is also potentially capable of being extended to other isotopes by properly choosing the isotope in which L-conversion is taking place predominantly in L_1 subshell.

The third method was to select nuclear transitions in which L_1 conversion is predominant. By observing L x ray emission, by singles and coincidence methods, average L_1 subshell fluorescence yields ν_1 were measured at Z = 63, 73, 77 and 83. (Ref. 1,17,18).

c) Si(Li) spectrometer for low energy photons and electrons

These measurements just discussed, required a high resolution Si(Li) spectrometer the efficiency of which had to be known. Hence a considerable part of research involved developing methods to measure the efficiency of the detector using routinely available laboratory-standard radioactive isotopes. High resolution windowless Si(Li) spectrometers, which can also simultaneously detect electrons emitted by radioactive isotopes in Auger process and internal conversion process (and with a facility to rapidly change the electron sources mounted inside the vacuum) was constructed. (Ref. 4).

d) Measurement of high-Z K-shell fluorescence yields

By comparing the relative intensities of K Auger electrons and K x rays emitted in the radioactive decay of carrier free ^{195}Au, ^{207}Bi, and ^{235}Np, the K-fluorescence yield ω_K was determined with high accuracy at Z = 78, 82, and 92. There were no precision measurements available in this region prior to this work. (Ref. 5).

In addition relative intensities of (K-LL), (K-LX) and (K-XY) Auger electrons at Z = 82 and 92 were measured. (Ref. 5,15,17).

e) Theoretical studies

As part of this investigation, it was necessary to have clear and definite information on the L-vacancy production in various radioactive isotopes used in this work. Hence a comprehensive and systematic study of the L and M shell vacancy production following the decay of a K vacancy or L vacancy state was made. All available experimental values of Auger transition rates in literature were compiled, initially reviewed and tabulated for use by research workers in this area. Theoretical estimates based on j-j coupling model were computed and compared with experiment data. (Ref. 7).

f) Decay scheme studies

In addition, it was also necessary to obtain more precise information on decay schemes of radioactive isotopes used in this work. Particularly careful study of the decay schemes of ^{151}Gd, ^{159}Dy, and ^{194}Os was completed. (Ref. 10,18).

g) Study of double vacancy states

The most significant contribution of this work, however, was to extend the above discussed experimental techniques to study the double inner-shell vacancy states. (Ref. 9,13,15,17). The basic principles and details of the experimental technique using the Si(Li) detector and x ray detector were given in Ref. 15. In this work the radioactive decay of LL, LX and MX vacancy states in Pb created during the decay of ^{207}Bi was studied by observing coincidences between K Auger electrons and LX rays, LX rays and LX rays, and KX rays and MX rays. The angular correlation between the two cascade LX rays emitted during the decay of double L-vacancy states was studied. This study was the first of its kind and can be extended to yield

information on double vacancy states over a large range of high-Z values above Z = 70.

III. CONCLUSIONS

The advantage of coincidence techniques in the study of the decay of inner shell vacancy atomic states (popular in nuclear spectroscopy) was clearly demonstrated. This was facilitated by the judicious use of high resolution semiconductor detectors.

A wealth of information was accumulated on the decay of L_1, L_2 and L_3 subshell vacancy states at high Z (>60). It was clearly established that a discrepancy exists in the interpretation of experimentally observed L_2 subshell Coster-Kronig transition probability around Z = 80.

Precision measurements of K-shell fluorescence yields at high Z were performed, thus extending the use of the semi empirical equation $[\omega_K/(1-\omega_K)]^{1/4} = B_o + B_1 Z + B_3 Z^3$ to predict fluorescence yields.

For the first time careful measurements were performed to study the decay of double inner shell vacancy states and ground work was laid to extend these techniques over a wide range of Z.

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V. PARTICIPATING PERSONNEL

J. M. Palms	Professor of Physics
P. Venugopala Rao	Associate Professor of Physics
R. E. Wood	Associate Professor of Physics