STUDIES ON TOTAL AND K-SHELL PHOTOELECTRIC CROSS SECTIONS

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DECLARATION

The author declares that this work is original and carried out in the Department of Physics, University of Mysore, Manasagangotri, Mysore 570 006, India. This work, or any part of It, has not been submitted for a higher degree either in this University or in any other University.

August 3, 1974.

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CERTIFICATE

I certify that this is a bonafide research work done by Mr. Ramakrishna Gowda independently under my supervision.

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CONTENTS

PREFACE

The photoelectric effect is one of the most predominant processes among the different types of gamma ray interactions at low energies (< 1 MeV). Studies on the photoelectric absorption of gamma rays in matter have been receiving great attention both in theoretical and experimental aspects. Renewed interest in the photoelectric process began in the late 1950's. With the rapid development of nuclear physics, knowledge of photoelectric cross sections was needed in order to establish various nuclear properties (e.g., experimental internal conversion coefficients) and perform calculations related to radiation shielding and astrophysical problems (e.g., opacity).

Although a good deal of work has been done on the photoelectric absorption of gamma rays in matter, the direct experimental determination of total and K-shell photoelectric cross sections are very few. A careful survey of the results of the earlier experimental studies reveal definite diacripencies at low gamma ray energies. The direct measurements of K-shell photoelectric cross sections are made using beta ray spectrometers. It is very difficult to get absolute cross sections, since it is known, from the study of the angular distribution of emitted photoelectrons, that the photoelectron number has to be integrated over all angles, and also owing to the poor transmission in the magnetic spectrometer, counting statistics suffer. In order to increase the production of photoelectrons stronger gamma ray sources are required. However, it is very difficult to get such strong sources at low gamma ray energies. The available measured total and K-shell photoelectric cross sections are not in good agreement, in many cases, with the predicted values of Schmickley and Pratt, and Scofield. And also the measurements are available only for high Z materials like gold, lead and uranium.

In the present investigation the total and K-shell photoelectric cross sections are determined in aluminum, copper, zirconium, silver, tin, tantalum, gold and lead for 145.4, 279.1, 411.8 and 661.6 keV gamma rays. For this purpose a well type plastic (Ne-102) scintillation spectrometer is assembled. She spectra of electrons resulting from the interaction of gamma rays of different energies with the converter foils have been obtained. This method of measurement involves the detection in a very nearly 4 geometry of the photoelectrons released from the converter foil. Aluminum is assumed as a pure Compton scatterer to correct for the scattering events, since the photoelectric cross sections in it are very small. However, at 145.4 keV gamma ray energy interpolation has been made for the Compton continuum in aluminum converter, and the photoelectric contribution is subtracted. The smooth Compton continuum is used for subtraction purpose in all other converter materials. The resolved photoeleotron spectra are plotted and the area under these peaks gives the number of total photoeleotrons. This number is corrected for self absorption in the converter foil and used to estimate the total photoelectric cross sections. Since the K-shell photoelectric contribution is predominant the observed main peak in the photoeleotron spectrum is attributed to the K-shell photoeleetrons. The number of K-shell photoelectrons in each case is estimated by fitting a Gaussian to the respective peak in the photoelectron spectrum and this number is also corrected for self absorption. Thus the total and K-shell photoelectric cross sections are calculated by estimating the incident number of photons and the number of atoms exposed to the gamma ray beam in the converter foil.

The measured values of total and K-shell photoelectric cross sections are compared with the predicted values of Schmickley and Pratt (1967) and recent values of Scofield (1973). There is good agreement between the experimental and calculated values. The errors are found to be within 4 to 7 percent. These errors come mainly from statistical uncertainties and the subtraction procedure. Z dependence and energy dependence of cross sections and the variation of total to K-shell photoelectric cross section ratios with atonic number and incident gamma ray energy ere also discussed.

The thesis embodies the above work and contains six chapters. The contents of each chapter is outlined briefly is the following paragraphs.

A brief historical account of. theoretical studies on photoelectric cross sections, a survey of experimental investigations and the motivation for the present work are given in Chapter 1.

In Chapter 2 a summary of the types of gamma ray interactions with matter is given. Elements of theory of coherent, incoherent and photoelectric cross sections have been discussed in detail.

The tabulations of cross sections made by different workers are discussed. The theoretically predicted total and K-shell photoelectric cross sections are tabulated for all the converter materials and gamma ray energies used in the investigation is given in Chapter 3.

The experimental setup used in the present study is described in Chapter 4 and a brief account of detecting system, gamma ray sources and converter materials used in the present investigation is given.

Experimental procedure adopted in the estimation of the number of total and K-shell photoelectrons, the number of atoms interposed to the gamma ray beam and the incident gamma ray flux is discussed in Chapter 5.

In Chapter 6 the experimentally measured total and K-ahell photoelectric cross sections are tabulated. These cross sections are compared with the theoretically predicted values of Schmickley and Pratt (1967) and recently calculated values of Scofield (1973). The errors associated with the cross sections are discussed. The dependence of these cross sections with atomic number and incident gamma ray energy is given. The variation of the total to K-shell photoelectric cross section ratios with atomic number and gamma ray energy is given. Possible conclusions are drawn on the basis of our present experimental findings.