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ALPHA PARTICLE RANGE & X-RAY ABSORPTION MEASUREMENTS ON THIN FOILS[1]

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Abstract

Alpha particles from ^{241}Am and x-rays from ^{57}Co have been used in range and absorption studies using thin copper foils. The theory and advantages of the two methods in measuring foil thicknesses are discussed, as well as the data analysis. The photoelectric cross section of copper at a photon energy of 15 keV has been obtained from the analysis of the x-ray data. Such a study, incorporated in an undergraduate laboratory, may serve to elucidate the fundamental difference of the interaction processes involved.

Introduction

In recent years more and more practical applications of absorption methods have been made, including the determination of sample thickness and thickness variations, the detection of interior defects, the identification of constituent elements of samples, and many others (Clark, 1940). A study of the absorption of photons and charged particles in a student laboratory situation may also serve to evince the basic difference in the interaction of charged particles and photons with matter. The equipment necessary to perform such a study is within the means of many departments, since it only requires a charged particle detector, an x-ray detector such as a proportional counter, associated amplifiers, a single channel analyzer and a scaler.

The absorption of charged particles is primarily via the electromagnetic interaction between the incident particle and the atomic electrons in the absorber. This results in many inelastic collisions and a subsequent decrease in the energy of the incident particle. The incident particle may either suffer energy degradation in passing through the absorber or be completely absorbed, depending upon the thickness of the absorber. Only in cases where the incident particle passes through the absorber can information such as absorber thickness be obtained.

In contrast, the absorption of a low energy photon in matter may be a "one shot" process whereby the photon is removed from the incident beam by a single encounter with an atomic electron in the absorber in a process known as the photoelectric effect. Thus for an incident beam of monoenergetic photons, only the intensity is degraded by the absorber, the energy of the remaining photons being unaltered by passage through the absorber. The probability of a photon being removed from the incident beam depends upon the absorbing material, the energy of the photon beam, and the thickness of the absorber. Thus, knowing the probability of absorption for a given material, it is straightforward to determine the absorber thickness.

In the present experiment, the thicknesses of several thin copper foils have been determined from both alpha particle energy loss measurements and x-ray absorption measurements. Using the alpha particle results as the standard, the photoelectric cross section for copper has been determined from the absorption measurements.

Theory

The determination of foil thickness from alpha particle energy loss measurements is based upon quantum mechanical stopping power calculations. (Whaling, 1958)

For low energy x-rays one may neglect all interaction processes other than the photoelectric process in relating the intensity diminution to the absorber thickness.
As a result the intensity reduction may be written as

$$\frac{dI}{dx} = -\sigma I \qquad (1)$$

where the photoelectric cross section σ is dependent on the energy of the x-ray and on the absorber material. The above result can be integrated to yield

$$x = \frac{-1}{\sigma} \ln(I/I_0), \qquad (2)$$

where I_0 is the incident x-ray intensity.

Results and Discussion

A thin source of ^{241}Am provided a beam of 5.48 MeV alpha particles for the energy loss measurements. The detector used in these measurements was a silicon surface barrier detector. ^{57}Co was used as a source of low energy (14.4KeV) x-rays in the absorption measurements and the x-rays were detected by a Ge(Li) detector.

The thickness determinations from alpha measurements were accomplished by expressing the energy loss of a given energy alpha particle by the relation

$$\Delta E(\text{MeV}) = dE/dx(\text{MeV}\cdot\text{cm}^2/\text{mg}) \text{ x foil thickness } (\text{mg/cm}^2).$$

From the measured energy losses and the values for dE/dx, the foil thicknesses were thus obtained. The results are shown in Table 1.

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