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Research Article

Compton scattering for elements with 20≤ Z≤ 68 in the external magnetic field

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Abstract
The Compton scattering cross-sections of 21 elements were examined for 59, 54 keV in an external magnetic field. The background corrections and detection efficiency measurements were made in the article. Experimental results are presented and compared with some suitable theoretical data obtained by some predictive methods.

Keywords: X Ray Spectroscopy **(**XRS), scattering, cross-section, magnetic field, Si(Li) detector

59,5 keV foton enerjisinde 20≤ Z≤ 68 aralığında değişen elementler için dış manyetik alanda Compton saçılması

Öz
Dış manyetik alanda 21 element için Compton saçılma tesir kesiti ölçümleri 59,54keV foton enerjisi kullanılarak incelendi. Makalede dedektör verimi ve background sayma düzeltmeleri yapılmıştır. Deneysel sonuçlar bazı yaklaşım metodları kullanılarak elde edilen teorik sonuçlarla karşılaştırılmıştır.

Anahtar kelimeler: XRS, saçılma, tesir-kesiti, manyetik alan, Si(Li) dedektör

1. Introduction

Scattering is divided into two as coherent and Compton. Photons scattering by atomic electrons is cognoscible Compton scattering if the simplifying approximation is invited that the target electrons are independent free and at rest. The Compton scattering cross-section of free electrons is described by the well-known Klein-Nishina equation (Klein O and Nishina Y. 1929). An accurate prediction of the effect of low gamma photons on the cross-section can only be made after considering the influence of the relevant electrons. This has been accomplished in the impulse approach with the introduction of the so-named Compton scattering function (Hubbell et al., (1975) have computed the values of S (x, Z). Some researchers have investigated the relationships between Kx-rays and Compton scattered photons to find the effect of electrons due to the scattering event (Allawadhi et al., 1978; Eichler et al., 1982; Basavaraju et al., 1987; Wolff et al., 1989; Saharsha et al., 1990; Şimşek, 2000). The subject of scattering is very important in reducing the effect of radiation, reactors, radiography, surgical physics, and crystallography (Yalçın et al., 2000). With this motivation, some researchers have explained

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the influence of external magnetic field on scattering; we have studied the Compton scattering cross sections for 21 elements at scattering angle 90^0 by using Si (Li) detector.

2. Experimental Method

The experimental setup is seen in Fig. 1. Pb and Al collimator was utilized between the detector and sample to prevent the interaction of X-ray emitted by the component elements of the detector and radioactive capsule. A grader filter of Pb to acquire a thin beam of gamma rays Compton scattered from the sample. This has also been used to absorb unwanted radiation from the detector shield.

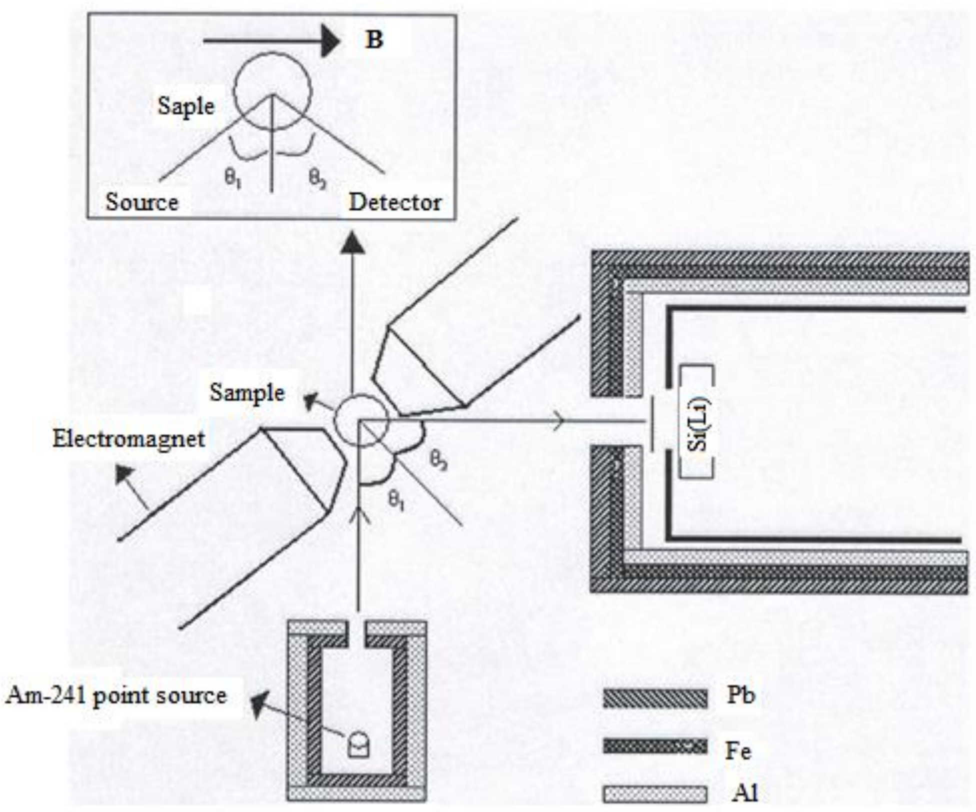

Fig. 1. The experimental set-up.

The detector-sample-source distances were adjusted to acquire the maximum count rate in the fluorescent and scattered peaks. The samples were accommodated placed between pole pieces of an electromagnet capable of generating a 0.8 T magnetic field at a distance of 2 mm and mounted in a sample holder. Thin foils seen in Table 1 were utilized as specimens. The purities of the samples used in the experiment were better than 99.99%. The net areas of Compton scattered photons were calculated with the help of appropriate computer programs.

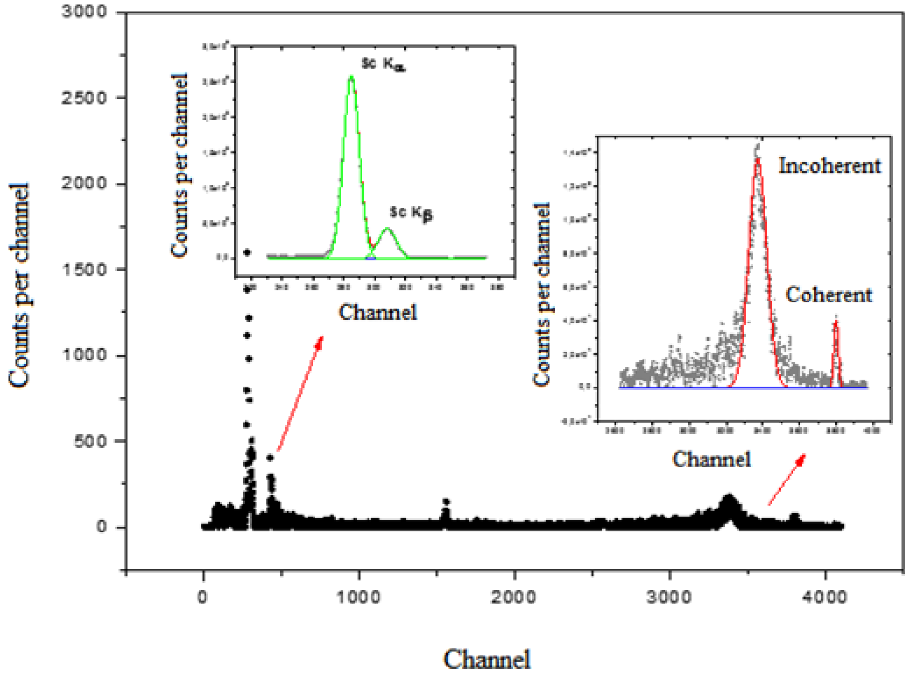

Fig. 2. Sample spectrum for the Sc.

Experimental cross sections were computed by using a technique presented by Şimşek, 2000. This method reduces to a considerable extent the experimental uncertainties included the estimation of solid angle, source strength, etc.

The theoretical calculations of Compton scattering differential cross sections were computed using the following expression given by Hubbell et al., 1975:

$$\frac{d\sigma_{inc.}}{d\Omega} = \frac{d\sigma_{KN}}{d\Omega} S(x, Z) \quad (1)$$

where $d\sigma_{KN}/d\Omega$ is the Compton scattering differential cross-section (Klein and Nishina 1929), *S(x,Z)* is Compton scattering function, $x = \sin(\theta/2)/\lambda \ (nm^{-1})$ is photon-momentum transfer, θ is the angle of scattering, and λ (nm) is the wavelength of the incident gamma rays.

The experimental cross-sections are calculated by using the following equation [Eq. (2)] (Şimşek 2000).

$$\frac{d\sigma_{inc.}}{d\Omega} = \frac{\sigma_K \omega_K}{4\pi} \frac{n_{inc.}}{n_K} \frac{\beta_K}{\beta_{inc.}} \frac{\varepsilon_K}{\varepsilon_{inc.}} \quad (2)$$

Here, σ_K is K shell photoelectric cross-section of the elements at the excitation energy (Scofield 1973), ω_K is the K shell fluorescence yield (Hubbell et al. 1994), n_K is the emitted K shell X-ray counting rate for the target under study, $n_{inc.}$ is the count rate for the Compton scattering photopeak for the target.

The self –absorption adjustment factor for published K X-rays (β_K) and Compton scattered photons ($\beta_{inc.}$) was calculated by the following equation:

$$\beta_{(m)} = \frac{1-\exp[-\mu_\gamma sec\phi_1+\mu_m sec\phi_2)t]}{(\mu_\gamma sec\phi_1+\mu_m sec\phi_2)t} \qquad m = K, inc. \tag{3}$$

where, μ_γ, $\mu_{inc.}$ and μ_K are total mass attenuation coefficients (Hubbell et al., 1995) at the primary photons (59.54 keV), published K X-ray and Compton scattered gamma photon, respectively. The value of ϕ_1 and ϕ_2 are between the angles of the sample normal and primary and emitted K X-rays, respectively.

The detector efficiency was evaluated using Am-241, Ba-133, and Cs-137 radioisotope testing sources (Lepy et al., 1993). The measured ε values are seen in Fig. 3. (ε_K) is the detector efficiency for fluorescent X-rays and was calculated using the fit equation.

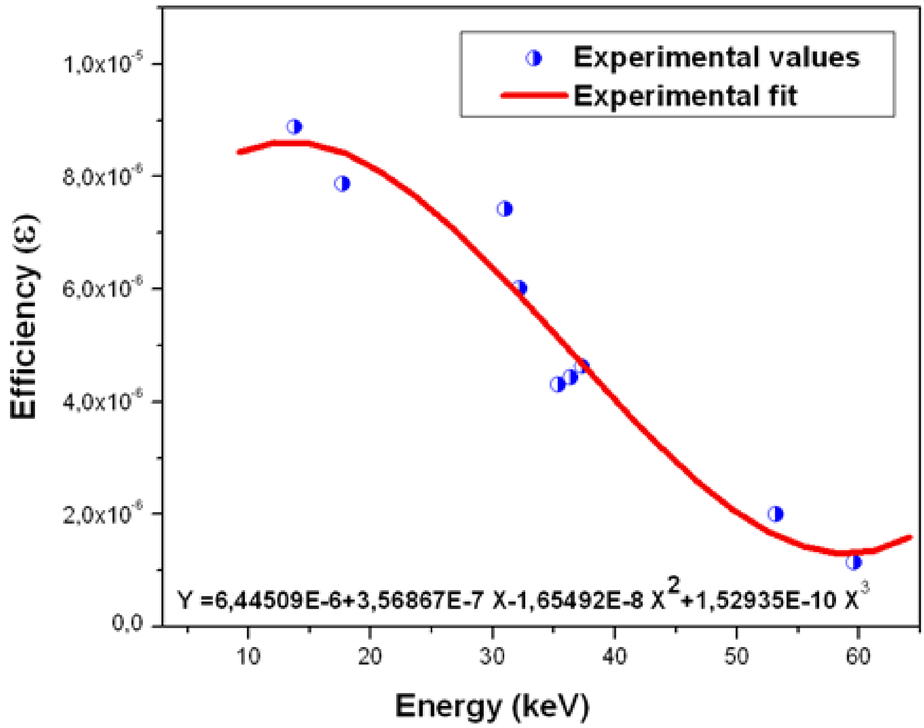

Fig. 3. Detector efficiencies as a function of energy

3. Result and Discussion

Experimental values using equation 2 and theoretical results are listed in Table 1. In addition, the available experimental results are checked with the theoretical results in Fig. 4. In this method process, differential cross-section measurement is exempted from welding intensity and solid angle measurements. In order to decrease the statistical error, the spectra have been recorded for a long time and approximately 10^4 (and more) counts were collected under the Compton scattering peak. Errors in the experiment are estimated to be less than about 8%. These errors are thought to be caused by different parameters used in equation 2. The experimental errors have evaluated photopeak areas % (2-3), the self-absorption correction factors % (1-3), the detector efficiency % (1-3).

Table 1. Comparison of the experimental and theoretical Compton scattering differential cross section of investigated elements.

Z	Element	Theoretical	Experimental	
			B=0T	B=0.8T
20	Ca	0.6167	0.6150±0.0021	0.6023±0.0019
21	Sc	0.7614	0.7534±0.0019	0.7339±0.0015
22	Ti	0.6746	0.6623±0.0012	0.6426±0.0016
23	V	0.7036	0.7002±0.0025	0.7121±0.0022
24	Cr	0.7325	0.7329±0.0016	0.7149±0.0014
25	Mn	0.7614	0.7602±0.0011	0.5739±0.0015
28	Ni	0.8478	0.8373±0.0054	0.8371±0.0062
29	Cu	0.8765	0.8756±0.0015	0.8970±0.0013
30	Zn	0.9050	0.9082±0.0032	0.8618±0.0028
31	Ga	0.9333	0.9286±0.0045	0.9013±0.0042
32	Ge	0.9614	0.9620±0.0010	0.9520±0.0012
39	Y	1.1524	1.1766±0.0068	1.0589±0.0084
40	Zr	1.1788	1.1614±0.0075	1.1193±0.0072
41	Nb	1.2051	1.2039±0.0026	1.0795±0.0022
42	Mo	1.2311	1.2361±0.0049	1.1577±0.0054
44	Ru	1.2826	1.2841±0.0022	1.1580±0.0025
45	Rh	1.3081	1.3077±0.0018	1.2950±0.0022
46	Pd	1.3333	1.3265±0.0084	1.1419±0.0076
47	Ag	1.3584	1.3551±0.0032	1.3607±0.0035
48	Cd	1.3834	1.3803±0.0040	1.0904±0.0038
64	Gd	1.7749	1.7889±0.0067	1.6364±0.0072
68	Er	1.8727	1.8794±0.0034	1.7059±0.0042

When Table 1 and Figure 4 are examined, it is seen that the harmony between theoretical and experimental values is better at B = 0. It is noteworthy that experimental values are lower than theoretical values at B = 0.8T. In the literature, no experimental results have been found for the Compton scattering in an external magnetic field, so the results were not compared with other experimental results. Experimental values for Compton scattering in the external magnetic field are lower than the theoretical values. This reduction is further evidenced by the increasing atomic number. Knowledge that is more experimental is needed to understand the effect of the magnetic field on scattering.

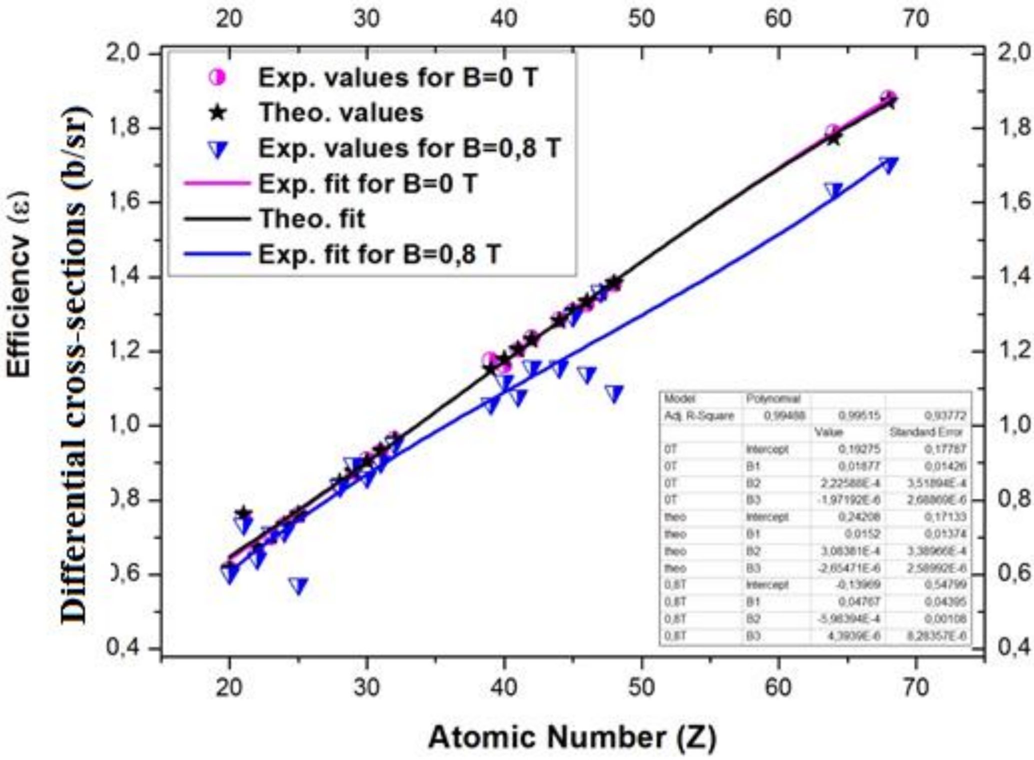

Fig. 4. Scattering cross-section as a function of atomic number

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