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Research Article

Angular Dependence of L_α/L_l, L_α/L_β and L_α/L_γ X-ray Intensity Ratios of Lead at 59.54 keV Photon Energy

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Abstract

L_α/L_l, L_α/L_β and L_α/L_γ x-ray intensity ratios of lead have been calculated at an angular range 85˚-135˚ at 59.54 keV photon energy by using a Si (Li) detector. The results showed that the L_α/L_β and L_α/L_γ intensity ratios decreased as the scattering angle increased. The correlations between the L_α/L_β and L_α/L_γ intensity ratios and scattering angles were also high. On the other hand the variation of L_α/L_l intensity ratio with the scattering angle is irregular.

Keywords: Intensity ratio, angular dependence, L X-rays**,** scattering angle.

Kurşunun 59.54 keV Foton Enerjisinde L_α/L_l, L_α/L_β ve L_α/L_γ X-Işını Şiddet Oranlarının Açısal Bağımlılığı

Öz

Kurşunun L_α/L_l, L_α/L_β ve L_α/L_γ x-ışını şiddet oranları bir Si(Li) dedektörü kullanılarak 59.54 keV foton enerjisinde 85˚-135˚ açı aralığında hesaplanmıştır. Sonuçlar saçılma açısı arttıkça L_α/L_β ve L_α/L_γ şiddet oranlarının azaldığını gösterdi. L_α/L_β ve L_α/L_γ şiddet oranları ve saçılma açıları arasındaki korelasyonlarda yüksekti. Saçılma açısı ile L_α/L_l şiddet oranının değişimi düzensizdir.

Anahtar kelimeler: Şiddet oranı, açısal bağımlılık, L x-ışınları, saçılma açısı.

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1. Introduction

X-rays are used in many areas with their short wavelengths and high energies. X-rays have a wide range of uses in the study of the molecular structures of complex organic substances, nuclear imaging, medicine and industry. Physical parameters, namely, cross-sections, x-ray emission measurements, vacancy transfer probabilities, fluoresence yields can be calculated from the x-ray relative intensities.

There are many studies where researchers experimentally calculated the intensity ratios of K and L x-rays for different elements. Some of the ones related to K x-rays (Aylikçi et. al., 2010; Doğan et al., 2016; Şakar et al., 2017; Cengiz et al., 2018; Perişanoğlu et al., 2020; Uğurlu and Demir, 2020). Some researchers have been investigated L x-ray intensity ratios (Turgut and Ertuğrul, 2004; Porikli, 2012; Wang et al. 2015; Akkuş et al. 2019; Cinan et al., 2021).

Lead is heavy metal that creates environmental pollution and has a toxic effect on human health. Lead is located in the 6th period in group 4A of the periodic table. With its high density, lead is used as a radiation shield in X-ray machines and nuclear reactors. It is used in various coatings with its features of being resistant to corrosion, absorbing sound and vibrations. Lead is also used in battery production, solder production and some special rust-resistant paints. It is also used in bullet cores because it is a heavy, abundant and cheap metal. Lead is also used in the manufacture of insulating wire, paint, solder, foil and various alloys.

In this stud, the variation of some different L x- rays intensity ratios of lead element with scattering angle was investigated.

2. Materials and Methods

In this study, Si (Li) detector with a resolution of 160 eV was used at 5.9 keV. The detector is shielded with a lead collimator. In experimental geometry, the scattering angle was changed from 85° to 135° with 10-degrees steps by moving the source and the sample together, keeping the angle of the gamma rays from the point source to 45° with the sample normal. The experimental geometry is given in Figure 1.

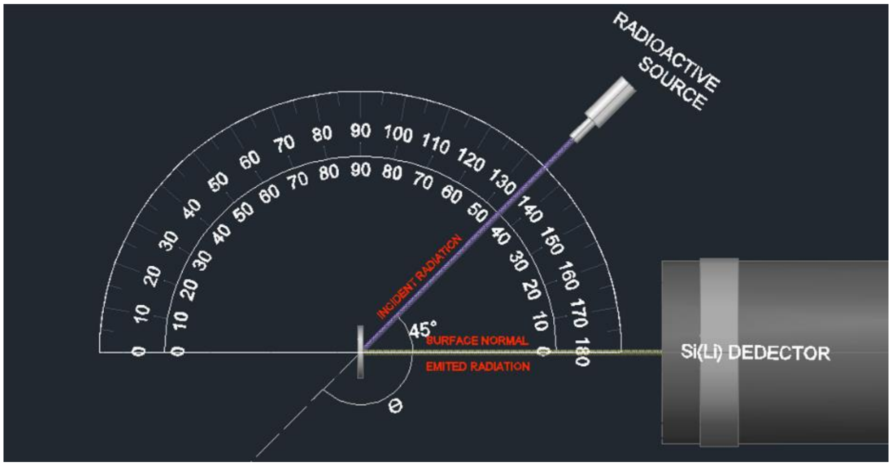

Figure 1. Experimental set-up

Measurements were taken with the computer on which the Genie-2000 program was installed. The L x ray spectra of lead at 105° is shown in Figure 2.

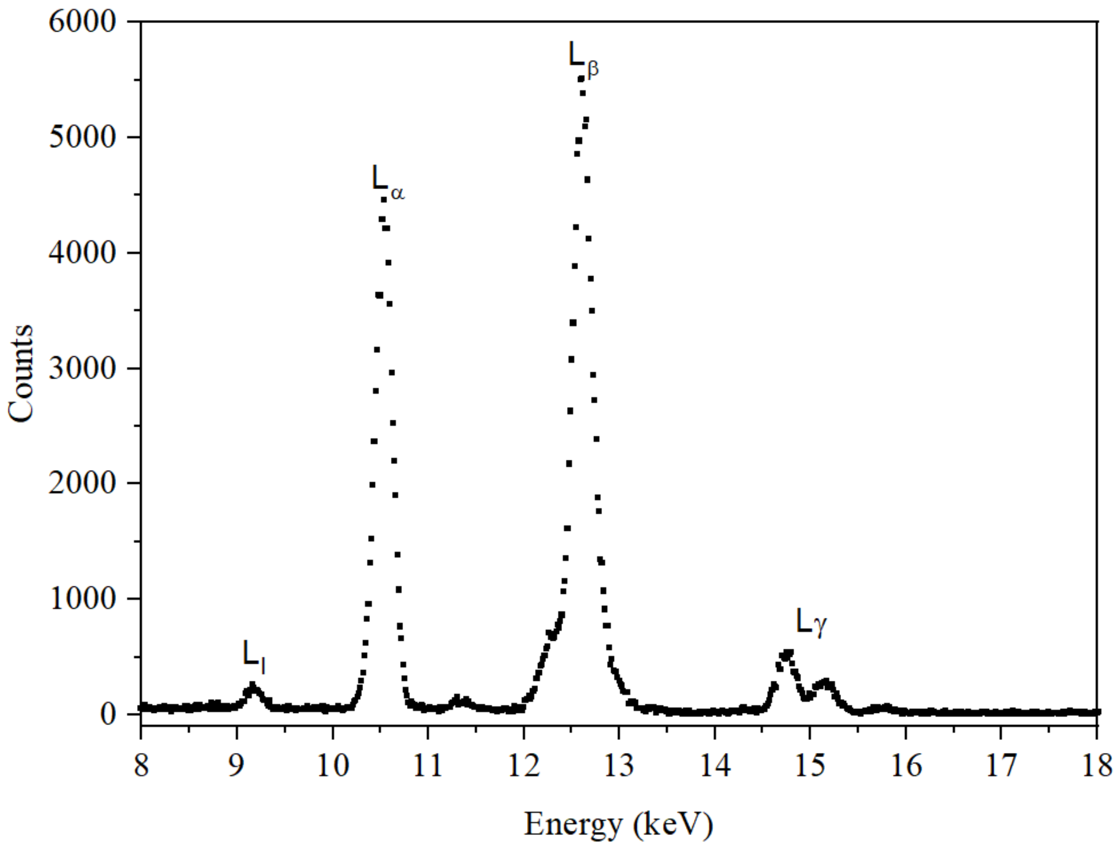

Figure 2. L x ray spectra of lead at 105°

In the present study, experimental L shell x-ray intensity ratios I_{L_α}/I_{L_i} were calculated using the relation

$$\frac{I_{L_\alpha}}{I_{L_i}} = \frac{N_{L_\alpha}}{N_{L_i}} \frac{\beta_{L_i}}{\beta_{L_\alpha}} \frac{\varepsilon_{L_i}}{\varepsilon_{L_\alpha}} \quad (1)$$

where N_{L_α} and N_{L_i} is the number of counts under L_α and L_i (i=l, β, γ) peaks, respectively. β_{L_i} and β_{L_α} are the sample self absorption correction factors, ϵ_{L_i} and ε_{L_α} are the efficiencies of detector for L_i and L_α series of x-rays.

The absorption correction factor is calculated as follows

$$\beta = \frac{1-exp\left[(-1)\left(\frac{\mu_i}{cos\theta_1}+\frac{\mu_s}{cos\theta_2}\right)t\right]}{\left(\frac{\mu_i}{cos\theta_1}+\frac{\mu_s}{cos\theta_2}\right)t} \quad (2)$$

where μ_i and μ_e are the total mass absorption coefficient of incident photons and emitted characteristic x-rays. The values of μ_i and μ_e are taken from WinxCom (Gerward et al., 2001), θ_1 and θ_2 are the angles of incident gamma ray and emitted L x-rays with the target normal. t is the mass thicknesses of the sample. The units of μ_i and μ_e are cm^2/g since the units of t is g/cm^2.

The $I_0 G\varepsilon$ values were determined by measuring the K x-rays obtained from spectroscopically pure targets for all scattering angle. The effective incident photon flux factor, $I_0 G\varepsilon$ was determined by using the following equation

$$I_0 G\varepsilon_{K_i} = \frac{N_{K_i}}{\beta_{K_i}\sigma_{K_i}t}$$

(3)

where N_{K_i} is the net number of counts under the K_β or K_α peaks, σ_{K_i} is the σ_{K_α} or σ_{K_β} fluorescence cross section. I_0 is the intensity of incident radiation, G is the geometrical factor, ε_{K_i} is the detector efficiency for K_i x-rays. The theoretical values of σ_{K_α} or $\sigma_{K\beta}$ fluorescence cross sections. The fitted curves for all scattering angles are shown in Figure 3.

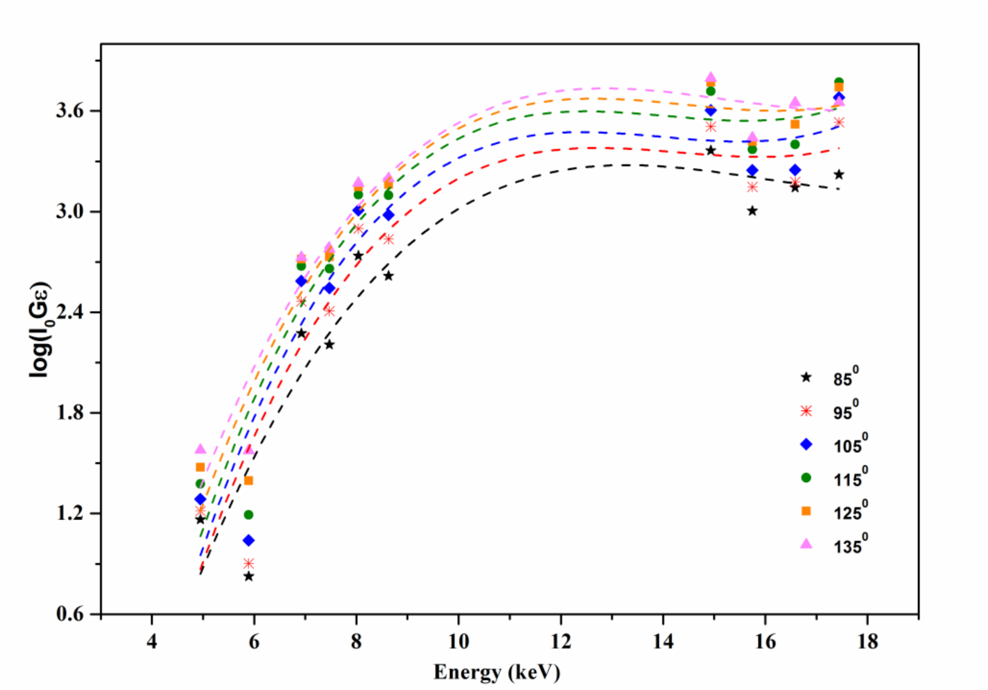

Figure 3. The variation of the factor $I_0 G\varepsilon$ as a function of energy for all scattering angles

3. Results and Discussion

The angular variation of L_α/L_l ratios with scattering angles is seen in Figure 4. It is seen that L_α/L_l ratios first increased and decreased, and then increased and decreased again. In summary the variation of L_α/L_l intensity ratio with the scattering angle is irregular.

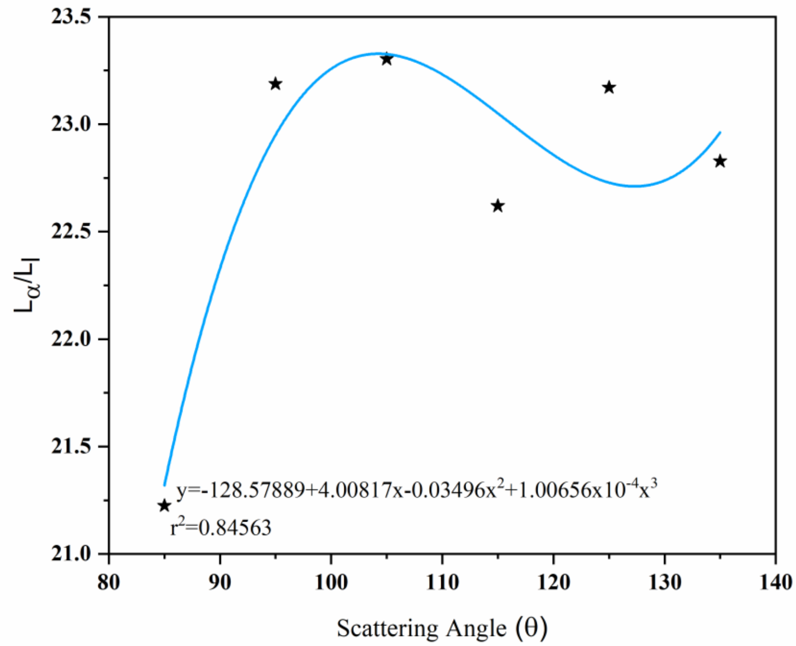

Figure 4. The variation of L_α/L_l with the scattering angles (θ)

The angular variation of L_α/L_β ratios with scattering angles is seen in Figure 5. When Figure 5 is examined, it is observed that the L_α/L_β intensity ratios decrease with increasing scattering angles.

The angular variation of L_α/L_γ intensit**y** ratios with scattering angles is seen in Figure 6. The L_α/L_γ intensity ratios decreased with scattering angles. The correlation coefficients for L_α/L_l, L_α/L_β and L_α/L_γ intensity ratios are found as 0.84568, 0.98994 and 0.98776, respectively. There is a good third order polynomial relation between the L_α/L_β , L_α/L_γ and scattering angles.

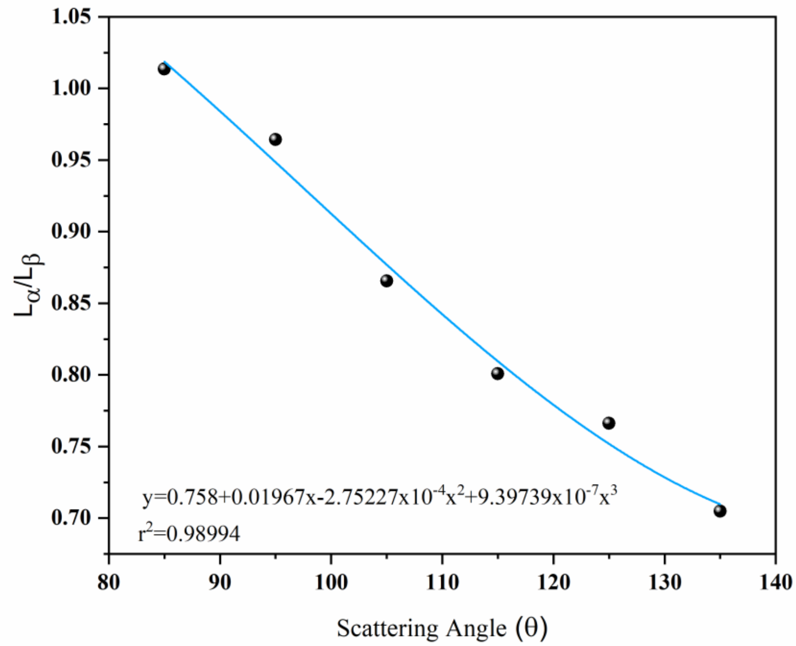

Figure 5. The variation of L_α/L_β with the scattering angles (θ)

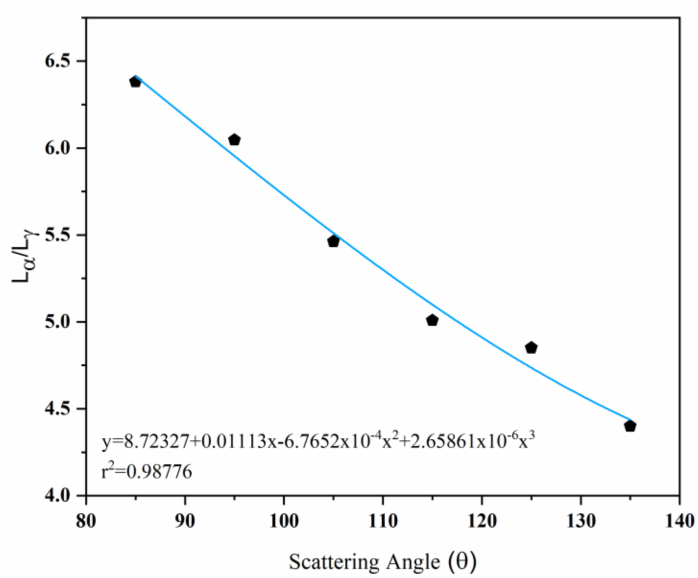

Figure 6. The variation of L_α/L_γ with the scattering angles (θ)

Many studies have been studied about angular distribution of different elements at different angles. In this study, some L x-ray intensity ratios between 85-135 degrees of lead element were calculated experimentally. In previous studies, it was observed that the L_l and L_α differential cross-sections depend on the angle, the L_β and L_γ differential cross sections do not depend on the angle (Akkuş et al.,2019). In this study, decreases were observed in relative intensity ratios (L_α/L_β and L_α/L_γ) with angle-independent components (L_β and L_γ) used.

The relative intensity ratio studies are very useful because when calculating the emission rates of x-rays emitted from the same atom, it is more convenient to calculate the intensity ratios of these lines rather than calculating the emission rates of each line individually (Ganly et al., 2016). To obtain more accurate results, especially in measurements related to L x-rays, we should increase the measurement times and calculate the areas of the L x-ray peaks more accurately.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

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