

Determination of the mass attenuation coefficient for Aluminum element using (Cu,Mo) X-rays tubes

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1- Introduction

The attenuation of x-rays in different materials provides us with information about the fundamental properties of matter at the atomic and molecular level. In particular, the relative and absolute measurements of mass attenuation coefficient are used to measure theoretical predictions of photovoltaic absorption using the wave function of Electron with the specified state [1,2], As well as investigating the dynamics of atomic processes, including Auger Transition [3,4], and provide us with information on the intensity of electronic cases (Density of Electronic States), molecular bonds and other solid state properties [5].

The diversity of studies is evidence of the wide variety of processes that influences x-ray attenuation, and in order to promote a better understanding of these processes it is necessary to make accurate measurements that allow each process to be individual for the study and to compare with theoretical models, while relative measurements are sufficient to perform some comparative theoretical calculations, absolute attenuation measurements provide us with an additional and decisive test with many requirements for theoretical predictions [6]. The difference in the specific calculations has an important success in predicting the precise expansion of absorption [7,8]. The x-ray Absorption

ABSTRACT

In this study the value of linear (μ_L) and mass (μ_m) attenuation coefficients of Aluminum element (Al) were determined by using x-ray Cu-tube of energies CuK_α (8.048) KeV, CuK_β (8.906) KeV, and Mo-tube of energies MoK_α (17.480) KeV and MoK_β (19.609) KeV. the voltage between the two electrodes are up to 35 KV. The measured values are compared with other experimental data showing a general agreement within a precision of 0.2% - 0.8%.

The mass attenuation cross-sections were thus derived and compared with other experimental data available on database of x-ray attenuation cross-sections. The agreement is always within $\pm 7\%$.

fine Structure (EXAFS) on the relative scale, but its compatibility is relatively small with the results of absolute measurements [9]. The lack of high-precision measurements and the limitations of theoretical prediction are real obstacles to understand x-ray interactions with matter [10]. Several independent measurements of x-ray attenuation coefficients have been published, and these measurements showed significant differences that led the International Union of Crystals (International Union of Crystallography) (IUCr) to the multi-lab project to explore the causes of these differences [11,12,13], The most important out come of the project was that these differences were the result of a lack of understanding of the wide range of sources of random and systematic inaccuracies. In a number of recent studies, it was noted that the dominant source of error in measuring the mass attenuation coefficient was the inaccuracy in determining the thickness of the absorbent material along the path of the x-ray beam transmission which ranges in accuracy between (2% -0.5%) [14,15]. Low energy photons are used in basic applied sciences [16]. X-ray attenuation is applied in the fields of health and medicine, and understanding how x-ray attenuation is the key to designing a protective kit for those working in the field of radiation of harmful energies [17]. x-ray

images are an important way for doctors to examine patients and diagnose their condition, but they have to check the appropriate energy for x-ray which is carried out through the human body but attenuated bone, it is also used in other fields, for example, the unknown substance can be identified by knowing the linear attenuation coefficient of that material by exposing it to X-ray at a particular energy, each element has a slightly different attenuation coefficient when exposed to x-ray such materials is very important in science science and archeology at a time when we need to examine a sample of a substance without destroying it completely (N.D.T) (Non-Distractive Testing) [18].

2- Theoretical Part

2-1- Attenuation

When x-ray passes through a medium of a deformation material, each photon such either does not react at all with the medium material or interacts with absorption excitation reactions, and the beam as a result of removing the interacting photons will undergo attenuation, and this attenuation may be (Intensity Attenuation) or (Energy Attenuation), as the intensity or energy decreases with the length of the path during this mean [19].

When a monochromatic photon beam (I_0) falls on the target of the thickness (dx), the decrease in intensity (dI) occurs such that[20]:

$$dI = -\mu I_0 dx \dots\dots (1)$$

μ is the proportionality constant (denotes –the attenuation coefficient). Hence we obtain:

$$I = I_0 e^{-\mu x} \dots\dots (2)$$

The amount $e^{-\mu x}$ represents the probability that the photon will intersect the distance (x) within the interceptor (attenuated) medium without interaction, and that it may react after the distance x is directly crossed, (μ) in its intensity with the length of the distance, since ($I < I_0$), equation (2) becomes as follows:

$$I/I_0 = e^{-\mu x} \quad (3)$$

Thus, μ can be calculated by equation (3) to be as follows:

$$\mu = \ln(A) / x \quad (4)$$

where A is attenuation ratio (I_0/I) and (x) samples thickness in cm.

When measuring the thickness of the attenuated material (x) in cm units, the calculated attenuation coefficient shall be in units (cm^{-1}) called linear attenuation coefficient (μ_L), and depends on: - Photon energy falling. Atomic number (Z) of the attenuated medium [21]. When measuring the thickness of the attenuated material in the units (cm^2 / gm), we will obtain mass attenuation coefficient which depends on the photon energy and the atomic number of the interceptor and the mean density [22].

The relationship of the mass attenuation coefficient (μ_m) with the linear attenuation coefficient (μ_L) is [23]: -

$$\mu_m = \mu_L / \rho = \ln(I_0 / I) / \rho x \quad (5)$$

Where (ρ) is the density of the interceptor medium.

Finally, the total attenuation cross-section [barn/atom] can be directly derived from equation (5) the following equation:

$$\sigma(E) = \frac{M}{N_A \rho} \mu(E) \quad (6)$$

Where $\frac{\mu}{\rho}(E)$ ($\text{cm}^2 \text{g}^{-1}$) is the mass attenuation coefficient at the energy E (KeV), M (g/g-atom) the atomic weight and N_A (atoms/g-atom) is the Avogadro number.

3- Relationship Between Logarithm Absorption and Thickness

Equation (2) can be graphically illustrated by the relationship between the x-ray absorption logarithm value and the sample thickness X (cm), for all samples of different thickness used in the energy of various values (8.906, 17.48) KeV. The linear attenuation coefficient (μ_L) values were obtained through the linear equations of the output of the graph representation, and the figures from (1) to (4) represent the linear relationship between the x-ray absorption and the thickness X (cm), and the slope of the straight line of equation represent the practical value of the linear attenuation coefficient, The mass attenuation coefficient (μ_m) was obtained by dividing the linear attenuation coefficient on the element density, ρ ($2.7 \text{ gm} / \text{cm}^3$). From the figures we notice that the attenuation coefficients increased with increasing the thickness, This was in a good agreement with the results obtained by CQTran [24,25].

The total attenuation cross-sections obtained in this work are reported in table (1) for the K_α and K_β lines, respectively.). Table (1) also shows the practical values of linear and mass attenuation coefficients for Aluminum, they are also agreement with compared with the data reported in the compilation prepared by Saloman et al [26].

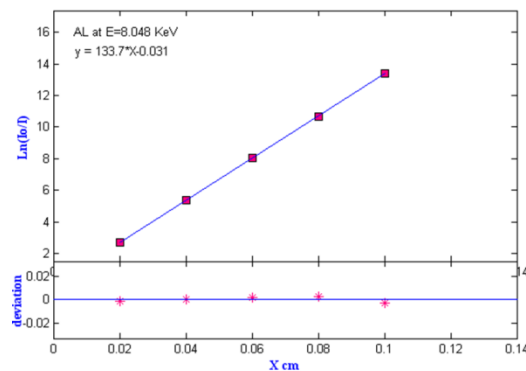


Figure (1) The relationship between absorption logarithm and thickness and standard deviation

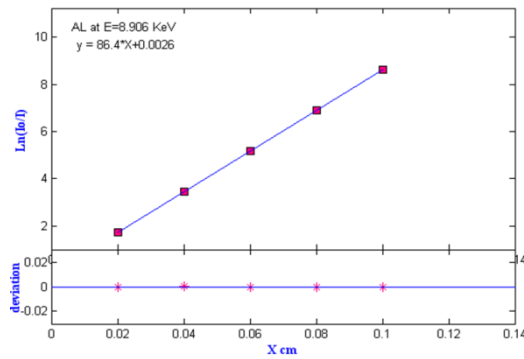


Figure (2) The relationship between absorption logarithm and thickness and standard deviation.

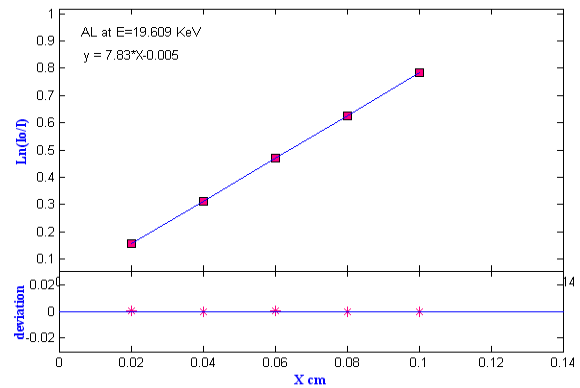


Figure (4) The relationship between absorption logarithm and thickness and standard deviation

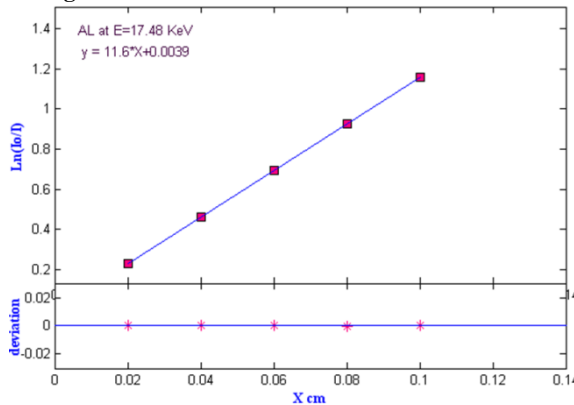


Figure (3) The relationship between absorption logarithm and thickness and standard deviation

Table (1) The practical values of linear attenuation coefficient and standard deviation of samples

E (keV)	Av. μ_L (cm^{-1})	R. S. D = $\frac{\sigma \mu_L}{\bar{X}}$	Av. μ_m (cm^2/g)	μ_m^* [27]	$\sigma(E)$	$\sigma(E)^*$ [27]
8.048	133.7	0.002	49.51	50.00	2237	2250
8.906	86.4	0.006	32.00	33.81	1448	1521
17.48	11.6	0.008	4.296	4.405	196	198
19.609	7.83	0.003	2.900	2.931	131	132

4- Results and Discussion

The empirical data are mentioned in table (1). The total empirical uncertainty of the measurement amount accredited on the uncertainty thickness and the density which are summarized quadratic, whilst the uncertainty of the I_0 and I measured, The empirical uncertainty for K_β lines is in commonalty above than that of K_α lines because of the preceding reported lowest x-ray radiation intensity.

It must to be stressed that the experimental uncertainty claimed in this work is higher than that claimed by other authors, The comparison between experimental and calculated values, the latter obtained using the XCOM code and data base (Hubbell, 1996), Most of the measured coefficients agree better than within 75% with the theoretical data. The remaining data presents discrepancies larger than 5% up to 18%. The largest discrepancies are observed at the lowest K_α and K_β X-ray energies. This is due to the fact that at higher energy both the K_α and K_β lines are more intense than the X-ray lines

References

of lower energy. This fact, together with the available sample thickness, serve to satisfy Eq. (1) more easily. In addition, some mass attenuation coefficients are measured near absorption edges. The availability of the proper sample thickness was indeed one of the most serious problems faced in performing the measurements.

5- Conclusion

- 1- The logarithm of absorption is linearly increased with the rise in the thickness of Aluminum.
- 2- The linear and mass attenuation coefficient of aluminum decreases with maximize the energy of x-ray,
- 3- The cross section of aluminum decreases with increasing the energy of x-ray,
- 4- The experimental and calculated values were compared it is showing agreement within $\pm 4\%$. The total attenuation cross-sections were derived as well and compared with the compilation of Saloman et al. (1988) showing, with a few exceptions, a general agreement within $\pm 7\%$.

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ايجاد معاملات التوهين الخطية والكتلية للاشعة السينية في الالمنيوم عند الطاقات 8.048 الى 19.609 كيلو الكترون فولت

احمد محمد خضر ، محسن حسن علي

قسم الفيزياء ، كلية التربية للعلوم الصرفة ، جامعة تكريت ، تكريت ، العراق

الملخص

تم في هذا البحث ايجاد معاملات التوهين الخطي والكتلي للألمنيوم عند الطاقات CuK_α (8.048KeV), CuK_β (8.906 KeV), MoK_α (17.480 KeV) باستخدام جهاز توليد الاشعة السينية 35KV لمصادر طاقات الاشعة السينية من النحاس (Cu) MoK_β (19.609 KeV) والمولوبيديوم. كما تم مقارنة القيم التي تم ايجادها مع قيم تجريبية اخرى وتبين ان هنالك توافق جيد وبنسبة خطأ بين (0.2% - 0.8%), كذلك تم ايجاد قيم المقطع العرضي لتوهين الاشعة السينية ووجد ان هنالك توافق ضمن $\pm 7\%$.