Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 3 Issue 6, June - 2016

Measurement of Linear Attenuation Coefficients of Compounds of Some Essential Major Elements

Burcu AKÇA
Computer Engineering, Faculty of Engineering,
Ardahan University, Ardahan, Turkey
burcuakca@ardahan.edu.tr

Salih Zeki ERZENEOĞLU
Department of Physics, Faculty of Sciences,
Atatürk University, Erzurum, Turkey
salih@atauni.edu.tr

***Abstract*— In this study, the linear attenuation coefficients of $NaO_2C_2H_3$, Na_2CO_3, NaF, $NaNO_3$, Na_2SO_3, Na_2SO_4, NaCl, $Mg(NO_3)_2$, MgO, $CaSO_4$, CaF_2, $CaHPO_4$, $CaO_6C_6H_{10}$, $FeCl_2$, $FeCl_3$ and $Fe_2(SO_4)_3$ compounds of some essential major Na, Mg, Ca and Fe elements have been measured using EDXRF (Energy Dispersive X-Ray Fluorescence Spectrometer). The experimental results are compared with theoretical results of WinXCom and FFAST.**

***Keywords*—Linear Attenuation Coefficient, Essential Major Element, EDXRF, WinXCom, FFAST.**

I. INTRODUCTION

The attenuation and scattering occurs result of the interaction with matter of electromagnetic radiation. Therefore, the attenuation, scattering coefficients and cross sections are very important. Because, these parameters explains the interaction with matter of electromagnetic radiation. In this study examined the interaction with compounds of some essential major elements electromagnetic radiation. Essential elements are those that are required by an organism to it does maintain normal physiological function. Without the essential elements, the organism cannot complete its normal life cycle or achieve normal healthy growth; many such elements are key components of metalloenzymes or are involved in crucial biological functions, such as oxygen transport, free radical scavenging or hormonal activity. For human health purposes, the essential elements can be sub-classified according to the concentration (trace or major) in which they are found in body fluids and tissues [1]. In the literature, a variety of experimental data relevant to the linear attenuation coefficients of different samples available. Several of the studies in the literature are as follows. The linear attenuation coefficients and three interaction processes have been computed for liver, kidney, muscle, fat and for a range of X-ray energies from 1 keV to 150 keV [2]. A general formula to quantitatively relate the apparent linear attenuation coefficient values in cone-beam phase contrast tomography to sample's linear attenuation coefficients and refractive indices [3]. The linear attenuation coefficient values of regular and irregular shaped fly ash materials have been measured without knowing the thickness of a sample using a new technique namely "two media method" [4]. The X-ray linear attenuation coefficient was measured for materials containing elements hydrogen to calcium [5]. The near K-edge linear attenuation coefficients for stoichiometric crystalline and amorphous gallium arsenide has been present tabulated [6]. Solution technique is developed for the measurement of linear and mass attenuation coefficients of salts for gamma-rays and from them elemental attenuation coefficients are estimated [7].

According to the literature results, there aren't experimental data of linear attenuation coefficients for these compounds at 59.5 keV photon energy. This study was formed first experimental data. The aim of this work completes this deficiency of the literature and other studies create basis.

II. METHODS

The experimental geometry in the present study is shown in Fig. 1. The 59.5 keV γ-rays were emitted from a filtered low-energy photon point source of Am-241. The intensity of the source is 100 mCi. The experimental linear attenuation coefficients of samples have been measured by using energy dispersive X-ray fluorescence spectrometer (EDXRF). The powder samples were compressed into pellets for 10 s at 15 ton by using a manual hydraulic press. Target had a diameter of 13 mm.

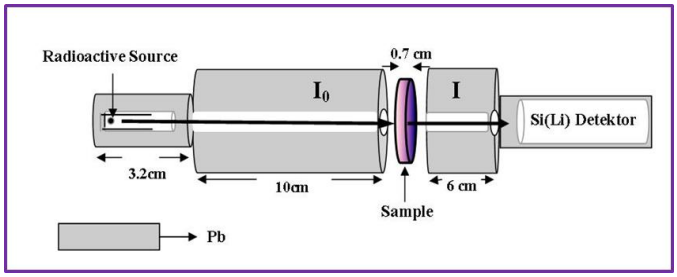

Fig. 1. Experimental arrangement.

Linear attenuation coefficient (μ) is the fraction of attenuated incident photons per unit thickness of a material. It represents the fraction of photons removed from a monoenergetic beam per unit thickness of material. Its complement is the transmitted portion of the beam. It is expressed numerically in units of 1/cm. The linear attenuation coefficient of a material can be measured experimentally using the application of Beer-Lambert's law with standard transmission method by adopting narrow beam geometry. As seen Fig. 1; a parallel beam of monoenergetic photons

passing through sample is attenuated due to absorption and scattering. Attenuation due to absorption follows the Beer-Lambert's rule

$$\mu = -\left[\frac{ln(I/I_0)}{t}\right] \quad (1)$$

where, I_0 and I are the unattenuated and attenuated photon intensities, respectively, μ (cm^{-1}) is the linear attenuation coefficient of the sample and t thickness of sample. The best linear attenuation coefficients to obtain the powder samples were prepared for three different mass (g) and thickness (cm). lnI-t graphs have been drawn by using Origin Pro8. Slope of graphs *have been obtained linear attenuation coefficients. Sample graph for* $Mg(NO_3)_2$ *is shown in Fig 2.*

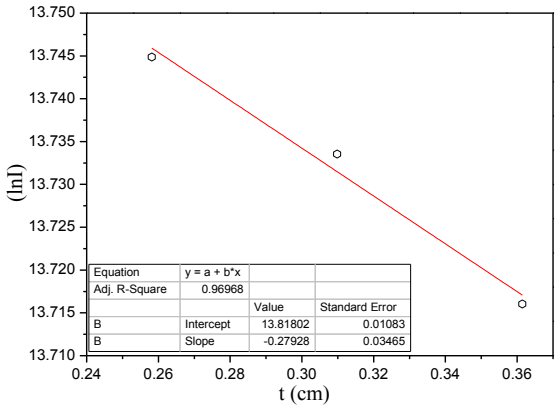

Fig. 2. *Sample a graph for* $Mg(NO_3)_2$.

The intensities of γ*-rays were measured using a high-resolution Si(Li) detector (FWHM of 160 eV at 5.96 keV) and the data were collected into 4096 channels of a multichannel analyzer. The spectra were collected for a period of 1000 s. The net counts without absorber* (I_0) *and with absorber* (I) *were obtained at the same and experimental conditions. A typical spectrum of 59.5 keV* γ*-rays passed through MgO is shown Fig. 3. Theoretical values of linear attenuation coefficients for* $NaO_2C_2H_3$, Na_2CO_3, *NaF,* $NaNO_3$, Na_2SO_3, Na_2SO_4, *NaCl,* $Mg(NO_3)_2$, *MgO,* $CaSO_4$, CaF_2, $CaHPO_4$, $CaO_6C_6H_{10}$, $FeCl_2$, $FeCl_3$ *ve* $Fe_2(SO_4)_3$, *have been obtained using WinXCom [8] and FFAST [9].*

In this study; effort has been made to be reduced error sources in transmission measurements. In an ideal transmission experiment, all photons must be sent on absorber sample with a paralel beam. But, in experimental studies, there is systematic, operational etc., errors every state. The errors in the present measurements are mainly due to counting statistics, nonuniformity of the absorber, impurity content of the samples and scattered photons reaching the detector. These errors are attributed to the deviation from the average value in the I and I_0 *(<1.3%), sample thickness (<0.7%), the mass of sample (<0.2%), systematic errors (<0.8%).*

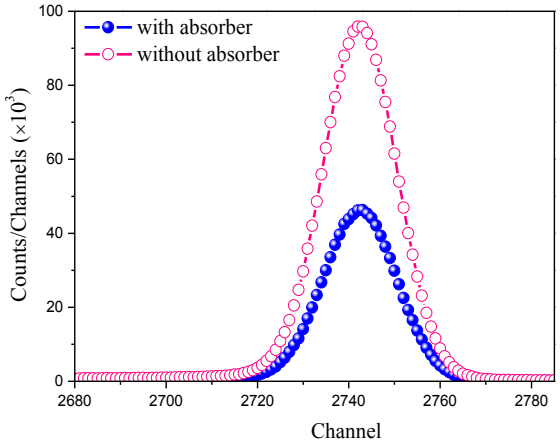

Fig. 3. Representative spectrum of 59.5 keV γ-rays passed through MgO.

III. Results and Discussion

In the present study, the linear attenuation coefficients for compounds of some essential major elements have been measured using EDXRF. The experimental results are compared with theoretical results of WinXCom and FFAST. WinXCom program base on mixture rule which gives the attenuation coefficients of any substance as the sum of the appropriately weighted contributions from individual atoms. The mixture rule can be interrogated because this rules negligible effects with each other of atoms in compound.The values in the FFAST data set are calculated by different methods than the WinXCom data set and may produce different results. WinXCom (1 keV to 100 GeV) databases were developed for radiological physics and dosimetry and are based on the same theoretical calculations, which will be referred to as the WinXCom data set. The FFAST database was produced for x-ray diffraction, interferometry, crystallography, and related areas and covers energies from 1-10 eV to 0.4-1.0 MeV.
The experimental and theoretical linear attenuation coefficients for compounds of some essential major elements are gives Table 1. The experimental effective atomic numbers (Z_{eff}) are listed Table 1 [10]. Also, the relative deviations (RD) between the experimental and theoretical values (the values of WinXCom and FFAST) are presented in the last two columns in Table 1 at $\pm\sigma$, (σ is the standard deviation). They have been calculated using the following equation:

$$RD = \frac{[\mu_{theo} - \mu_{exp}]}{\pm\sigma} \quad (2)$$

The maximum errors in linear attenuation coefficient were determined from errors in intensities without (I_0) and with (I) sample and thickness (t) using the following propagation of error formula:

$$\Delta(\mu) = \frac{1}{t}\sqrt{\left(\frac{\Delta I_0}{I_0}\right)^2 + \left(\frac{\Delta I}{I}\right)^2 + \left(\ln\frac{I_0}{I}\right)^2\left(\frac{\Delta t}{t}\right)^2} \qquad (3)$$

The maximum errors for experimental linear attenuation coefficient added $\pm$ next of values. The maximum errors are presented in the third column in Table 1.

Table 1. The experimental and theoretical linear attenuation coefficients for compounds of some essential major elements

Samples	$Z_{eff\,(Exp)}$ [10]	μ_{Exp} (cm^{-1})	$\mu_{WinXCom}$ (cm^{-1})	μ_{FFAST} (cm^{-1})	$RD_{WinXCom}$	RD_{FFAST}
$NaO_2C_2H_3$	5.808	0.318±0.008	0.309	0.318	-1.208	-0.031
$NaNO_3$	8.086	0.427±0.025	0.452	-	1.000	-
Na_2CO_3	9.450	0.554±0.038	0.521	0.537	-0.871	-0.450
NaF	9.897	0.584±0.111	0.592	0.611	0.074	0.245
Na_2SO_4	11.648	0.635±0.062	0.678	0.699	0.695	1.036
Na_2SO_3	12.364	0.755±0.053	0.686	0.707	-1.308	-0.909
NaCl	14.230	0.744±0.056	0.783	0.805	0.686	1.076
$Mg(NO_3)_2$	7.921	0.279±0.007	0.293	0.301	1.937	3.033
MgO	10.042	0.816±0.111	0.834	0.844	0.160	0.250
$C_6H_{10}CaO_6$	6.474	0.398±0.010	0.419	0.428	2.030	2.893
$CaHPO_4$	12.290	1.037±0.097	1.087	1.111	0.515	0.763
CaF_2	14.569	1.275±0.162	1.393	1.423	0.726	0.913
$CaSO_4$	15.698	1.270±0.104	1.137	1.164	-1.286	-1.019
Ca	19.317	1.003±0.017	1.040	1.056	2.185	3.121
$Fe_2(SO_4)_3$	15.661	1.499±0.173	1.653	1.696	0.892	1.139
$FeCl_3$	20.537	1.998±0.070	2.079	2.131	1.167	1.912
$FeCl_2$	22.126	2.481±0.136	2.503	2.566	0.165	0.628
Fe	26.839	9.982±1.769	9.668	9.903	-0.178	-0.045

Our experimental results agree with, generally, both the WinXCom and FFAST, there tends to be an overall better agreement with the WinXCom. Such results have been observed by earlier investigators [10, 11–13]. In composite materials like alloys, soil, plastic, biological material etc., for photon interactions, the atomic number cannot be represented uniquely across the entire energy region, as in the case of elements, by a single number. This number in composite materials is called "effective atomic number", and it varies with energy [14]. As seen Table 1, the linear attenuation coefficients increase as the effective atomic number is increase for compounds of Fe and Mg elements. But, these results haven't observed for compounds of Na and Ca. The experimental and theoretical linear attenuation coefficients versus the experimental effective atomic number for compounds are graphically presented in Fig. 4. As examined in Fig. 4. there is an overall better agreement between experimental and theoretical values.

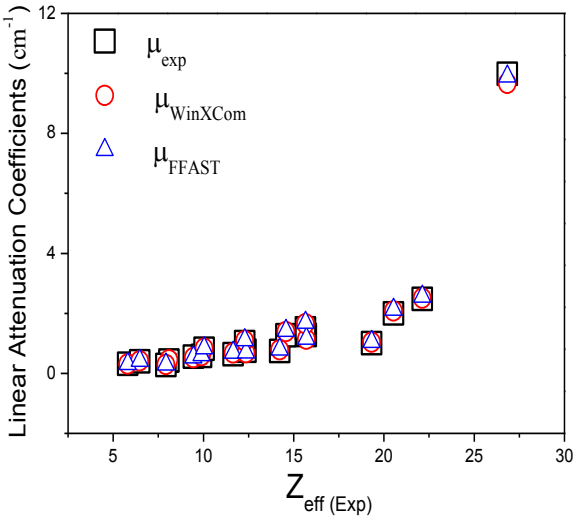

Fig. 4. Linear attenuation coefficients versus experimental effective atomic numbers of compounds.

IV. Conclusions and Recommendations

In this study, the linear attenuation coefficients for compounds of some essential major elements have been measured more sensitive with narrow-beam geometry. Also, the best linear attenuation coefficients (better agreement for theoretical) obtained more sensitive using ln I-t graph. These measurements can repeated for different energies, elements, compounds and methods. The experimental values can compared in other theoretical values except of WinXCom and FFAST. Although the linear absorption coefficient depend on thickness, varies from substance to substance and provides information about the nature of the substance. The big linear attenuation coefficients consider for samples have large absorption. Contrary to it, the small linear attenuation coefficients consider for samples have transmission. Generally, attenuation coefficients recall roentgen logic. So especially medicine mainly used in many areas. It provides us to have an idea about the structure of the material.

References

[1]. Parsons, PJ, Fernando, B Jr, Spectrochimica Acta Part B., 62:992-1003, 2007.

[2]. Boke, A, Radiation Physics and Chemistry, 102:49-59, 2014.

[3]. Yan, AM, Wu, XZ, Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions With Materials And Atoms, 269: 1841-1843, 2011.

[4]. Singh, S, Kumar, A, Thind, KS, Mudahar, GS, Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions With Materials And Atoms, 266: 1116-1121, 2008.

[5]. Midgely, SM, Radiation Physics and Chemistry, 72: 525-535, 2005.

[6]. Owens, A, Mosselmans, JFW, Peacock, A, Radiation Physics and Chemistry,66:1-6, 2003.

[7]. Teli, MT, Mahajan, CS, Nathuram, R, Indian Journal Of Pure & Applied Physics, 39: 816-824, 2001.

[8]. Gerward, L, Guilbert, N, Jensen, K B, Levring, H, Radiat. Phys. Chem. 71, 653-654, 2004.

[9]. Chantler, CT, Olsen, K., Dragoset, R.A., Chang, J., Kishore, A.R., Kotochigova, S.A., Zucker, D.S., 2005. X-ray form factor, attenuation and scattering tables (Version 2.1). National Institute of Standards and Technology, <http://physics.nist.gov/ffast>.

[10]. Akça B, Erzeneoğlu S, Sci. Technol. Nucl. Ins. 2014:1-8, 2014.

[11] B. S. Sidhu, A. S. Dhaliwal, K. S.Mann, and K. S. Kahlon, Annals of Nuclear Energy, 42: 153–157, 2012.

[12] N. Chanthima and J. Kaewkhao, Calculation of mass attenuation coefficient and related parameters Of BaO-SiO2 glass system By WinXCom and FFAST, Proceedings of the 38th Congress on Science and Technology of Thailand (STT38 2012), Chiang Mai,Thailand.

[13] J. L. Glover, C. T. Chantler, Z. Barnea, N. A. Rae, and C. Q. Tran, Journal of Physics B: Atomic, Molecular and Optical Physics, 43:1-15, 2010.

[14]. Prasad, G S, Parthasaradhi, K, Bloomer, W D, Radiat. Phys. Chem. 53:449-453, 1998.