Measurement Of The Mass Attenuation Coefficient From 81keV to 1333 keV For Elemental Materials Al, Cu And Pb

Slavica Gjorgieva[1] and Lambe Barandovski[2]

[1]SOU "Kosta Susinov", Kej 8 th of September 8, Rsadovish, Macedonia
[2] Institute of Phusics, Faculty of Natural Sciences and Mathematics, Ss Cyril and Methodus University, POB 162, 1000 Skopje, Macedonia

Apstract. The mass attenuation coefficients (μ/ρ) for 3 high psurity elemental materials (Al, Cu and Pb) were measured in the γ-ray energy range from 81 keV up to 1333 keV using ^{22}Na, ^{60}Co ^{133}Ba and ^{133}Cs as sources. Well shielded detector (NaI (Tl) semiconductor detector) was used to measure the intensity of the transmitted beam and any photon absorbed or deflected appreciably does not each the detector if the detector is far away from the absorber. The measured values are compared with the theoretical ones obtained by Seltzer (1993).

INTRODUCTION

The linear attenuation coefficient (μ) describes the fraction of a beam of x-rays or gamma rays that is absorbed or scattered per unit thickness of the absorber. This value basically accounts for the number of atoms in a cubic cm volume of material and the probability of a photon being scattered or absorbed from the nucleus or an electron of one of these atoms. Although a large number of possible interaction mechanisms are known for gamma rays in matter only three major types play an important role in radiation measurements: photoelectric absorption, Compton Scattering, and pair production.

When gamma-ray beam passes trough the materials each of the interaction processes removes the gamma-ray photon from the beam either by absorption or by scattering and can be characterized by a fixed probability of occurrence per unit path length in the absorber. The sum of these probabilities is simply the probability per unit path length that the gamma-ray photon is removed from the beam

$$\mu = \tau(Photoelectric) + \tau(Compton) + \tau(Pair), \tag{1}$$

and is called the linear attenuation coefficient. The number of transmitted photons I is then given in terms of the number without an absorber I_0 as:

$$I = I_0 e^{-\mu x} \tag{2}$$

Since a linear attenuation coefficient is dependent on the density of a material, the mass attenuation coefficient is often reported for convenience. Normalizing μ by dividing it by the density of the element or compound will produce a value that is constant for a particular element or compound. This constant (μ/ρ) is known as the mass attenuation coefficient and has unit of cm^2/g [1,3]:

$$\mu_m = \frac{\mu}{\rho} \tag{3}$$

EXPERIMENTAL PROCEDURE

The measurements of the linear attenuation coefficient (μ) and the mass attenuation coefficient (μ/ρ) was done using NaI (Tl) – scintillation detector (ORTEC, model 3m3/3-X), using preamplifier (ORTEC, model 276), amplifier (CANBERRA, model 2022) and multichannel analyzer (ORTEC, model ASPEC-27). MAESTRO Windows-32MCA, software for pick analysis was also used.

Monoenergetic gamma rays, from ^{22}Na, ^{60}Co, ^{133}Ba and ^{133}Cs sources were collimated into a narrow beam and allowed to strike a detector after passing through an absorbers of aluminum copper and lead of variable thickness (Fig. A).

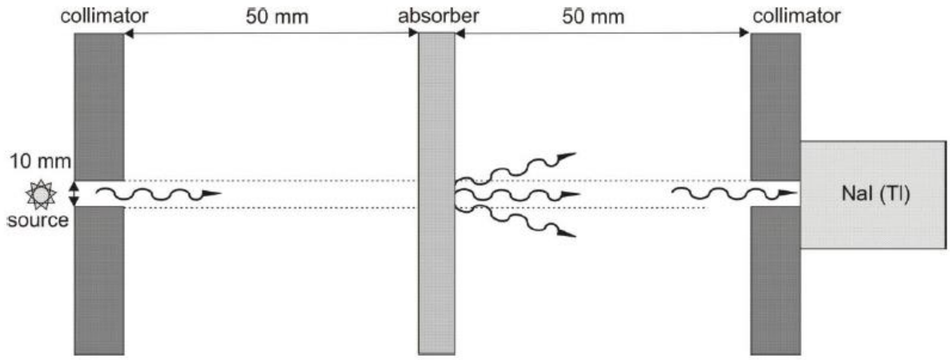


FIGURA 1. Experimental arrangement for measuring the attenuation coefficient of gamma radiation under condition of good geometry.

The attenuation of the intensity received by the detector as the absorber thickness is increased measures the total probability per unit length of the interaction processes. The usual semilogarithmic plot of transmitted intensity, I, versus thickness of absorber, x, follows a straight line, indicating exponential decay of the intensity.

The slope, μ, of the straight line represents attenuation coefficient, namely, the probability scattering, that a photon be removed from the incident beam per unit thickness of material traversed [4,5].

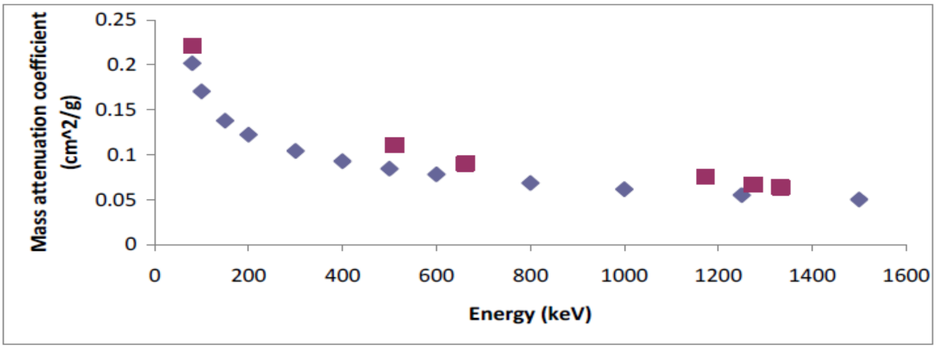
RESULTS AND DISCUSSION

The measured values of the mass attenuation coefficient for aluminum copper and lead for different energies of the gamma rays emitted from the sources are presented in Table 1. The results are also plotted on the graphs above (Fig.2 (a), (b) and (c)). On the same graphs theoretical data for the mass attenuation coefficient abtained bySeltzer (1993) are plotted as well. From the data it can be seen that there is a good agreement between the experimental data obtained in this research and theoretical data [1,5].

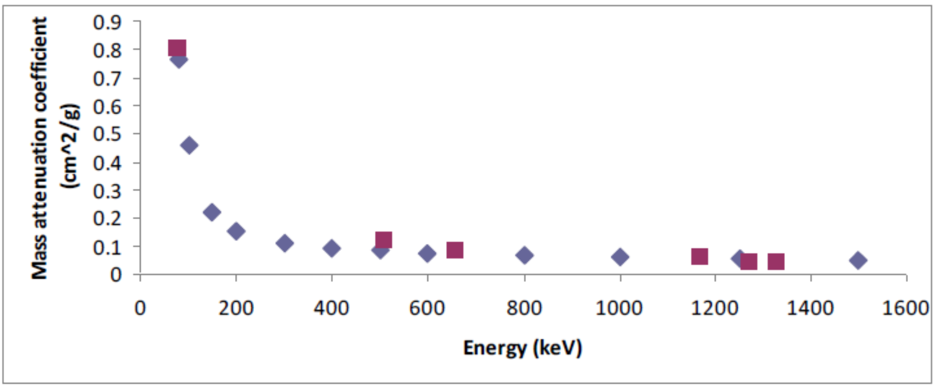
In the cases where Al and Cu are used as the attenuation materials experimentally obtained values are higher than the theoretical ones which is not case when lead is used as attenuation material. The explanation for this can be found in the fact that scintillation detectors are additionally shielded and the shield is contributing in the processes of attenuations of the gamma beam.

TABLE 1. Experimental mass attenuation coefficient for aluminum copper and led

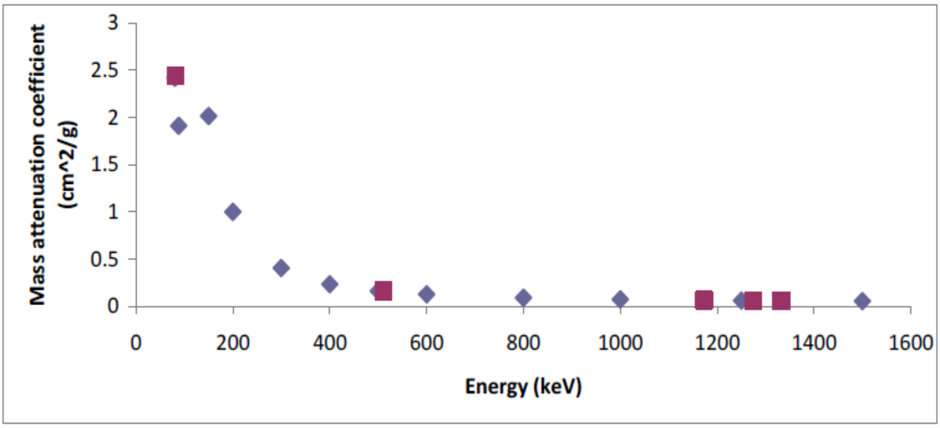
	Aluminum	Copper	Lead
Energy [MeV]	Mass attenuation coefficient [cm^2/g]	Mass attenuation coefficient [cm^2/g]	Mass attenuation coefficient [cm^2/g]
81	0.2215	0.7946	2.4298
511	0.1107	0.1168	0.1627
662	0.0905	0.0892	0.1179
1173	0.0751	0.0540	0.0627
1275	0.0667	0.0391	0.0551
1333	0.0637	0.0806	0.0559



(a)



(b)



(c)

FIGURE 2. (a) Mass attenuation coefficient of aluminum. (b) mass attenuation coefficient of copper. (c) mass attenuation coefficient of lead

CONCLUSION

The mass attenuation coefficients for 3 high purity elemental materials Al, Cu and Pb were measured in the gamma energy range from 81 up to 1333 keV using a NaI(Tl) scintillation detector. The experimental values were compared with the theoretical data obtained by Seltzer (1993). The comparison of the data showed high agreement between the abtained experimental values and theoretical values measured by Seltzer (1993) for high energies. Higher differences in the measured and theoretical values are abserved for low energies especially in the cases where aluminum and copper were considered as absorbers.

The method can be successfully used for determination of the linear and mass attenuation coefficients for other materials and compounds.

REFERENCES

1. F. G. Knoll, Radiation detection and measurement (Jonh Wiley and Sons 2000), pp.53-55.
2. S. M. Seltzer, Rad. Res, 136. 147-170 (1993).
3. J. E. Turner, Atoms. Radiation and Radiation Protection (127 Windham Road Oak Ridge. TN 37830. USA 2007), pp.173-192.
4. F. A. Attix, Introduction to Radiological physics and Radiation Dosimetry (University of Wisconsin Medical School. Medison. Wisconsin 1986), pp. 38-44.
5. S. Gjorgieva, ’’Measurement of the linear attenuation coefficient usin scintillation detector and GM counter’’, Diploma thesis, University of Skopje, Faculty of natural sciences and mathematics, Macedonia 2012