Research Journal of Physical Sciences E-ISSN 2320–4796
Vol. **4(8),** 1-5, October **(2016)** *Res. J. Physical Sci.*

Studies of Gamma ray interaction on high Z elements in the Energy range of 100keV to 1500keV

Surung Bharat S.* and Pawar Pravina P.
Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad-431004, India
bharatsurung101@gmail.com

Available online at: www.isca.in, www.isca.me
Received 24th September 2016, revised 30th September 2016, accepted 3rd October 2016

Abstract

The protection from the high energy gamma radiation normally we use the materials having high density and atomic number so in this paper, we calculated the Linear attenuation coefficient, mean free path and Half Value thickness for the pure elements of high atomic number such as Tin, Antimony, Tungsten, Lead and Bismuth in the energy range from 100keV to 1500keV were measured by using NaI(Tl) Scintillation detector. The intensity of photons of ^{133}Ba, ^{22}Na, ^{137}Cs, ^{54}Mn and ^{60}Co radio-isotopes were measured by NaI(Tl) scintillation detector and results obtained are in good agreement with the values reported in the literatures and XCOM.

Keywords: Gamma radiations, NaI(Tl) Scintillation detector, Linear attenuation coefficient, Mean free path, Half value layer.

Introduction

The isotopes have importance in the many fields such as medical application, Radio-carbon dating, agriculture and industry. While handling the radio-isotopes and gamma radiations, the protection from such harmful radiation has become important. One of the fundamental parameter that is mass attenuation coefficient is characterizing the penetration and diffusion of gamma rays in the medium through which they passes. The interaction of photons of gamma radiation takes place in different processes in the medium like Photoelectric effect, Compton scattering and Pair production. The Linear attenuation coefficient and total interaction cross section are important in many fields such as radiation protection, shielding of various instruments, handling the radio isotopes, industrial, medical and agriculture. Due to the widely used number of isotopes and gamma radiations, the protection from such harmful radiation has become important. For the radiation shielding normally we used the material having more mass attenuation coefficient for the corresponding energies, Normally we uses the Lead for the shielding of gamma radiation but Bismuth is having greater atomic number than the Lead so can we used Bismuth for same purpose so we study on the same problem.

We calculated the mass attenuation coefficient of several elements having high atomic numbers such as Tin, Antimony, Tungsten, Lead and Bismuth. Total atomic cross sections of these elements are also calculated. The mass energy absorption coefficient gives the idea about energy of incident photons absorbed by the material and defines as fraction of incident photon energy translated into kinetic energy of charge particles via different process. Hubbell calculated the values of photon mass attenuation and energy absorption coefficients theoretical from 1keV to 20MeV[1-3]. Pawar and Bichile experimentally determined the mass attenuation coefficient, effective atomic number and electron density of some amino acids in the energy range 0.122–1.330 MeV[5]. Ladhaf and Pravina determined the mass energy absorption coefficient and effective atomic energy absorption coefficient for Carbohydrates[6]. Tupe et. al. studied the total attenuation cross sections of several elements at 360 and 511keV[7]. Kore and Pawar determine the mass energy absorption coefficient for the fatty acids as well as mass attenuation coefficient and effective atomic number for amino[8,9]. Gaikwad D.K. et. al. measured the attenuation cross sections of some fatty acids in the energy range 122 keV to 1330keV[10]. The pure elements has important due to the applications in shielding of the gamma radiation and making the instrument related with high energy and used in various fields.

Methodology

Linear attenuation coefficients: The linear attenuation coefficient (μ) of the material for thickness t of sample is given by

$$I = I_0 e^{-\mu t} \tag{1}$$

Where: I_0 and I are the incident photon intensity and transmitted photon intensities through the material respectively and solving the Equation-1, we get the following equation for the linear attenuation coefficient (cm^{-1}):

$$\mu = \frac{1}{t}\ln\left(\frac{Io}{I}\right) \tag{2}$$

The mass attenuation coefficients (cm^2 g^{-1}) were obtained from Equation-2 by dividing the density of the corresponding samples as follows,

$$\mu_m = \frac{1}{\rho t} \ln\left(\frac{Io}{I}\right) \quad (3)$$

Where: ρ (g/cm^3) density of the corresponding sample.

Mean free path: Mean free path is the average distance at which a single particle travels through the medium of given sample before interacting it with material and is calculated by the following equation

$$X_m = \frac{1}{\mu} \quad (4)$$

Half value thickness: The thickness of given material at which the energy of incident gamma radiation get half after passing through the material is defined as half value thickness. This is gives the information about the thickness which reduced the intensity by half of the incident intensity and it is used for the purpose of radiation shielding and calculated by using the relation,

$$\text{Half Value Thickness } (T_{1/2}) = \frac{\ln 2}{\mu} \quad (5)$$

Experimental set up and measurements: The experiment was carried out on interested elemental samples having high atomic number such as Tin, Antimony, Tungsten, Lead and Bismuth was prepared in the form of pallets. Measure the incident and transmitted photon energies by using narrow beam good geometry. The schematic arrangement of the experimental setup is shown in Figure-1, and the radio-isotopes which were used for the experiments are given in Table-1. These isotopes are provided by Bhabha Atomic Research Center, Mumbai. The detector used for the present work is NaI(Tl) scintillation detector having good resolution about 8.5% for the energy of 662keV, the signals from the detector were amplified and analyzed with 13-bit multichannel analyzer connected to the PC.

Table-1
The information of radio-isotopes used for the experiments

Isotopes	Half-life	Activity (mCi)	predominant energy (keV)
^{133}Ba	10.5 (Y)	2324	356
^{22}Na	2.6 (Y)	1973	511, 1270
^{137}Cs	30 (Y)	2622	662
^{54}Mn	0.83 (Y)	3054	840
^{60}Co	5.27 (Y)	3622	1170, 1330

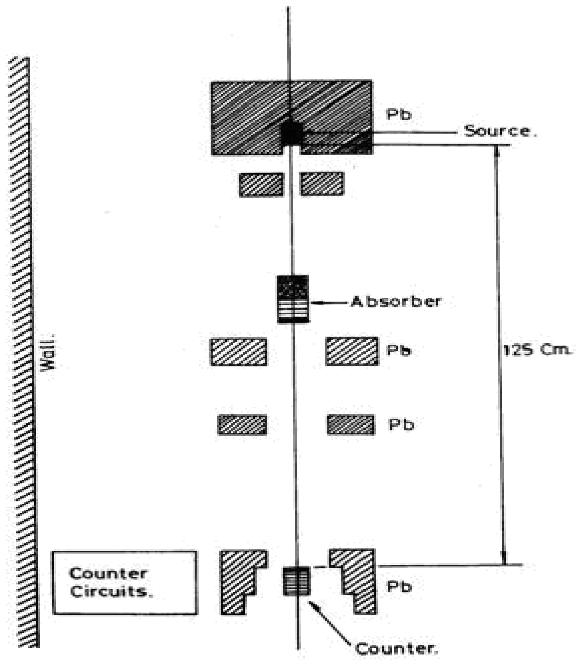

Figure-1
The schematic view of the experimental set up

The samples are prepared in the form of pallet by weighted in a sensitive digital balance of having a good accuracy of measurements about 0.001 mg. The mean of this set of values was considered to be the mass of the sample. The diameter of the pellets was measured by using the microscope and mean value of the mass per unit area was determined in each case. The sample thickness was selected in order to satisfy the following ideal condition as far as possible $2 \leq \ln (I_0 /I) \leq 4$ [9].

The elemental samples were irradiated by gamma rays of energies 360, 511, 662, 840, 1170, 1275 and 1330 keV in the air conditional lab by maintaining the temperature of the laboratory about 27^0C and measured the values of incident (unattenuated) photons intensity I_0 that is without samples and transmitted (attenuated) photons intensity I that is with samples and mean values are used for the calculation of mean free path and half value for all selected pure elemental materials.

All the elements used in the present study were of high purity (99.9 %), so the sample impurity is negligible for the measured data, the error due to the non-uniform thickness of samples is also negligible and also taken cared that physical condition remain constant.

Results and Discussion

The interaction process of photon within the material like photoelectric effect, scattering and pair production depends upon the energy of photons. Mostly at low photon energy the photoelectric effect predominant so the incident photon is absorbed by the electron which is related with the binding energy of electron and some photons are get scattered by losing its energy in Compton as well as Rayleigh scattering process. It is clearly seen that the μ values decreases as increases in the energy of photon given in Table-2 and plotted against energy of incident photon in Figure-2 and the mean free path of photon increases with increases in energy of incident photons given in Table-3 and plotted in Figure-3.

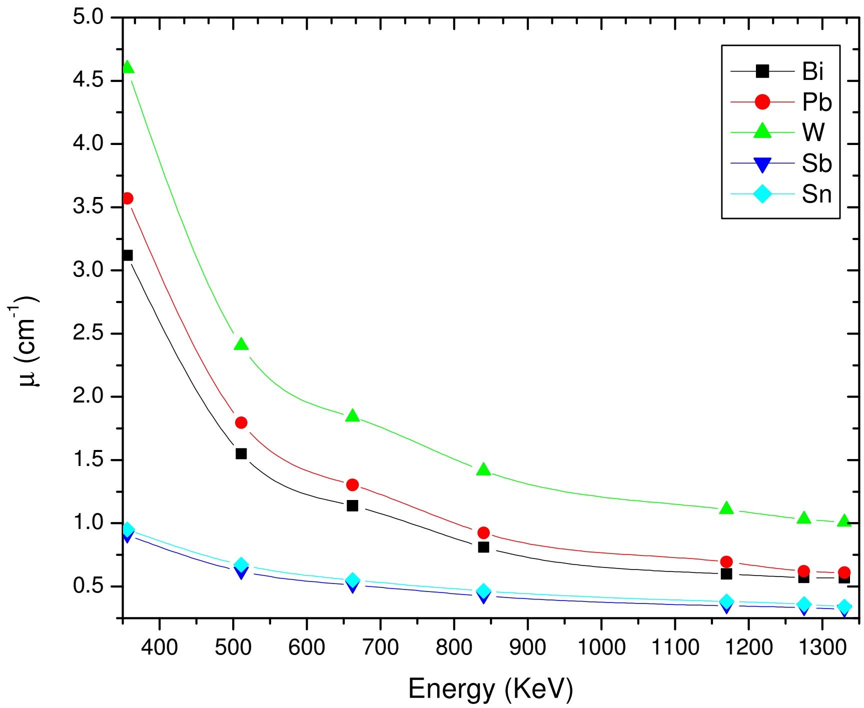

Figure-2

Plot of Experimental Linear attenuation coefficient (μ) versus incident photon energy

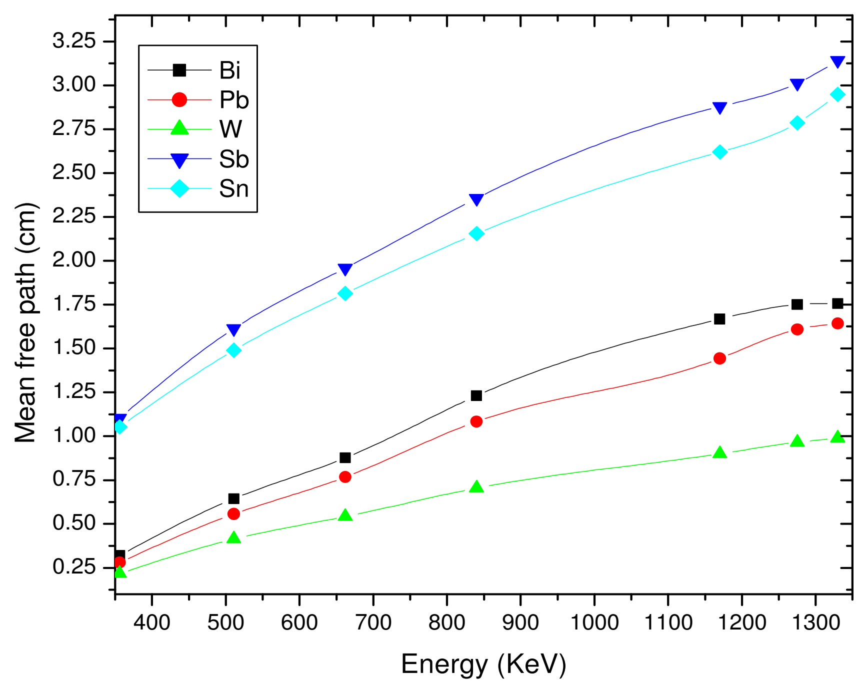

Figure-3

Plot of Experimental Mean free path (X_m) versus incident photon energy

Table-2
Values of linear attenuation coefficient (cm^{-1}) for photon energies from 100keV to 1500keV

Sr. No.	Element Energy	Tin		Antimony		Tungsten		Lead		Bismuth	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	356	0.950	1.019	0.906	0.950	4.597	4.977	3.570	3.599	3.118	3.202
2.	511	0.671	0.682	0.620	0.634	2.406	2.652	1.796	1.826	1.549	1.616
3.	662	0.551	0.564	0.511	0.517	1.840	1.964	1.303	1.308	1.138	1.154
4.	840	0.464	0.475	0.424	0.435	1.415	1.497	0.923	0.961	0.811	0.844
5.	1170	0.382	0.390	0.347	0.356	1.105	1.138	0.693	0.708	0.599	0.619
6.	1275	0.359	0.366	0.332	0.334	1.032	1.059	0.621	0.657	0.570	0.581
7.	1330	0.339	0.357	0.318	0.326	1.009	1.023	0.609	0.631	0.568	0.579

Table-3
Values of Mean free path (cm) for photon energies from 100keV to 1500keV

Sr. No.	Element Energy	Tin		Antimony		Tungsten		Lead		Bismuth	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	356	1.053	0.981	1.104	1.052	0.217	0.201	0.280	0.278	0.320	0.312
2.	511	1.490	1.466	1.614	1.577	0.415	0.377	0.557	0.548	0.644	0.618
3.	662	1.814	1.774	1.958	1.932	0.542	0.509	0.767	0.764	0.877	0.865
4.	840	2.155	2.106	2.356	2.301	0.705	0.668	1.083	1.040	1.231	1.182
5.	1170	2.621	2.566	2.879	2.810	0.900	0.879	1.443	1.412	1.667	1.612
6.	1275	2.786	2.733	3.013	2.995	0.966	0.944	1.609	1.523	1.750	1.716
7.	1330	2.948	2.802	3.142	3.071	0.989	0.977	1.642	1.585	1.756	1.724

Table-4
Values of Half value thickness (cm) for photon energies from 100keV to 1500keV

Sr. No.	Element Energy	Tin		Antimony		Tungsten		Lead		Bismuth	
		Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	356	0.730	0.680	0.765	0.730	0.151	0.139	0.194	0.193	0.222	0.216
2.	511	1.033	1.016	1.119	1.093	0.288	0.261	0.386	0.380	0.447	0.429
3.	662	1.258	1.230	1.357	1.339	0.377	0 .353	0.532	0.530	0.609	0.601
4.	840	1.494	1.460	1.633	1.595	0.490	0.463	0.751	0.721	0.855	0.821
5.	1170	1.817	1.779	1.996	1.948	0.626	0.609	1.000	0.979	1.158	1.120
6.	1275	1.931	1.895	2.088	2.076	0.671	0.655	1.115	1.056	1.216	1.192
7.	1330	2.044	1.942	2.178	2.129	0.687	0.677	1.138	1.098	1.220	1.198

Conclusion

It has been observed that the linear attenuation coefficient is depending upon the interaction process of gamma radiation within the material which is related to the energy of photon and atomic number of elements. In the photon interaction of matter, the values of linear attenuation coefficient (μ) decrease with increasing photons energy and depend upon the density of material but the mean free path increases with increases in the energy of photons and decreases with increasing the atomic number. It is also observed that the half value thickness of given samples normally decreases with increases the atomic number of materials and decreases with increases in the energy of incident photons.

These is important physical quantity and useful in the determination of mass attenuation coefficient, radiation dosimetry and other parameters. The work is useful for the shielding purpose, space radiation, medical and radiation therapy.

Acknowledgement

Special thanks to the Prof. G.K. Bichile for fruitful discussion.

References

1. Hubbell J.H. and Seltzer S.M. (1995). Tables of x-ray attenuation coefficients and mass energy absorption coefficients 1 keV to 20 MeV for Elements Z=1 to Z=92 and 48 additional substances of dosimetric interest. National Institute of Standards and Physics Laboratory, NISTIR 5632.

2. Hubbell J.H. (1969). Photon cross section, attenuation coefficient and energy absorption coefficient from 10keVto 100GeV. National Standards Reference Data system, NBS-29.

3. Hubbell J.H. (1982). Photon mass attenuation and energy absorption coefficients theoretical from 1keV to 20MeV. *Int. J. Appl. Radiat. Isot*, 33, 1369-1290.

4. Hubbell J.H. (2006). Review and history of photon cross section calculations supported by the National Institute of Standards and Technology. *Physics in Medicine and Biology*, 51, 245-262.

5. Pawar P.P. and Bichile G.K. (2013). Studies on mass attenuation coefficient, effective atomic number and electron density of some amino acids in the energy range 0.122–1.330 MeV. *Radiation Physics Chemistry,* 92, 22-27.

6. Ladhaf B.M. and Pawar P.P. (2015). Study on mass energy absorption coefficient and effective atomic energy absorption coefficient for Carbohydrates. *Radiation Physics Chemistry*, 109, 89-94.

7. Tupe V.A., Pawar P.P., Shengule D.R. and Jadhav K.M. (2012). Total attenuation cross sections of several elements at 360 and 511KeV. *Archives of Applied Science Research*, 4, 6, 2304-2307.

8. Prashant S.K., Pravina P. Pawar and T. Palani Selvam (2015). Evaluation of radiological data of some saturated fatty acids using gamma ray spectrometry. *RPC,* 15, 0033.

9. Kore P.S. and Pawar P.P. (2014). Measurements of mass attenuation coefficient, effective atomic number and electron density of some amino acids. *RPC*, 98, 86-91.

10. Gaikwad D.K., Pawar P.P. and Selvam T.P. (2015). Measurement of Attenuation cross sections measurements of some fatty acids in the energy range 122- 1330 keV. *Pramana*.

11. Creagh D.C. (1987). The resolution of discrepancies in tables of photon attenuation coefficients. *Nucl. Instrum. Methods A*, 255, 1-16.

12. Orha I., Salih E., Ismail H. and Guven C. (2005). Effective atomic numbers for CoCuNi alloys using transmission experiments. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 91, 485-491.