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Mass attenuation coefficient and total atomic cross section for elements in the energy range of 100 keV to 1500 keV

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Abstract
The mass attenuation coefficient has an essential role in the shielding purpose and radiation dosimetry. In this paper we calculated the mass attenuation coefficient and total atomic cross section for the elements of Sulfur, Silicon, Sodium and Carbon. The mass attenuation coefficient and total atomic cross section in the energy range from 100keV to 1500keV were measured. The transmitted intensity of photons emitted by radioactive isotopes of ^{133}Ba, ^{22}Na, ^{137}Cs, ^{54}Mn and ^{60}Co measured using the NaI(Tl) scintillation detector and results obtained are in good agreement with the values reported in the literatures.

Keywords: NaI(Tl) Scintillation detector, Mass attenuation coefficient, total atomic cross section, Gamma radiation.

Introduction

The isotopes have importance due to the wide uses in the many fields like radiation dosimetry, medical physics, 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 important for characterizing the penetration and diffusion of gamma rays in the medium through which they passes. This mainly depends on the photon energy, the nature of the material and the density of medium [1, 2]. The interaction of photon of gamma radiation takes place in different processes in the medium like photoelectric effect, incoherent scattering, coherent scattering and pair production and depends upon the energy of photon [3-5].

Absorption coefficient is measure of the average fraction of incident photon energy translated into kinetic energy of charge particles via photo effect, scattering and pair production. Hubbell calculated the values of photon mass attenuation and energy absorption coefficients theoretical from 1keV to 20MeV [6]. Ladhaf B.M. and Pravina P. Pawar determined the mass energy absorption coefficient and effective atomic energy absorption coefficient for Carbohydrates having elements Carbon, Hydrogen and Oxygen [7]. Kore P.S. and Pawar P.P. measured the mass energy absorption coefficient for the fatty acids [8].Gaikwad D.K. et al. determined the attenuation cross sections measurements of some fatty acids [7].The mass attenuation coefficients are widely used in the many fields related to the radiation, for the pure elements it is of importance like the applications in radiation shielding, protecting from high energy radiation, scientist working with such harmful radiation and in the research field.

2. Experimental set up and measurements

The experiments were carried out on interested low atomic number elementals such as C, Na, Si and S was prepared in the form of pallets. Measured the incident and transmitted photons energies by using narrow beam good geometry gamma ray spectrometer. The schematic arrangement of the experimental setup is shown in fig. 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, thesignals from the detector were amplified and analyzed with 13-bit multichannel analyzer connected to the PC.

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 KBr press machine was used to make the pallets of measured samples. 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 (Creagh, D. C., 1987)

$2 \leq \ln (I_0 / I) \leq 4$

The elemental samples were irradiated by gamma rays of energies 122, 360, 511, 662, 840, 1170, 1275 and 1330Kev in the air conditional lab by maintaining the temperature of the laboratory constant and measured the values of incident photon intensity I_0 that is without samples and transmitted photon intensity I that is with samples and mean values are used for the calculation of mass attenuation coefficients (μ_m) for all selected elemental samples.

The nature of absorbing and scattering for the gamma-rays makes stringent demands on geometry, which includes a source of mono-energetic gamma radiation travelling in the small well collimated beam, an observer which is just sufficiently wide to cover the solid angle between source and adjusted distance of sample from the detector is as possible as minimum to minimize the scattering,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.

3. Tables and Figures

Table 1:the information of radio-isotopes used for the experiments.

Isotopes	Half-life (Years)	Activity (mCi)	predominant energy (keV)
^{133}Ba	10.5	2324	356
^{22}Na	2.6	1973	511
^{137}Cs	30	2622	662
^{54}Mn	0.83	3054	840
^{60}Co	5.27	3622	1170
^{22}Na	2.6	1973	1275
^{60}Co	5.27	3622	1330

Table2: Values of mass attenuation coefficient (cm^{-2}/g) for photon energies from 100keV to 1500keV

Sr.No.	Elements	Sulfur		Silicon		Sodium		Carbon	
	Energy	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	122	0.1658	0.1773	0.1548	0.1652	0.1467	0.1470	0.1375	0.1441
2.	356	0.1012	0.1026	0.1000	0.1019	0.0965	0.0971	0.1005	0.1007
3.	511	0.0858	0.0874	0.0869	0.0871	0.0828	0.0833	0.0855	0.0868
4.	662	0.0772	0.0781	0.0776	0.0779	0.0741	0.0746	0.0769	0.0777
5.	840	0.0693	0.0697	0.0688	0.0695	0.0661	0.0667	0.0684	0.0695
6.	1170	0.0585	0.0593	0.0584	0.0592	0.0573	0.0568	0.0581	0.0592
7.	1275	0.0558	0.0561	0.0550	0.0560	0.0534	0.0536	0.0557	0.0560
8.	1330	0.0551	0.0546	0.0531	0.0545	0.0521	0.0523	0.0540	0.0545

Table 3: Values of total atomic cross section (b/atom) for photon energies from 100keV to 1500keV

Sr.No.	Elements	Sulfur		Silicon		Sodium		Carbon	
	Energy	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	122	8.8268	9.4390	7.7012	7.2185	6.8548	6.8408	2.7420	2.8726
2.	356	5.4608	5.3876	4.6631	4.7503	4.4999	4.5267	2.0042	2.0087
3.	511	4.5676	4.6535	4.0523	4.0606	3.8853	3.8611	1.7050	1.7300
4.	662	4.1099	3.7089	3.6186	3.6318	3.4782	3.4554	1.5335	1.5500
5.	840	3.6894	3.1549	3.2082	3.2417	3.0823	3.1084	1.3640	1.3854
6.	1170	3.1144	2.9850	2.7233	2.7588	2.6720	2.6466	1.1586	1.1801
7.	1275	2.9707	2.9850	2.5647	2.6104	2.4901	2.5013	1.1108	1.1167
8.	1330	2.9334	2.9068	2.4761	2.5416	2.4295	2.4369	1.0769	1.0867

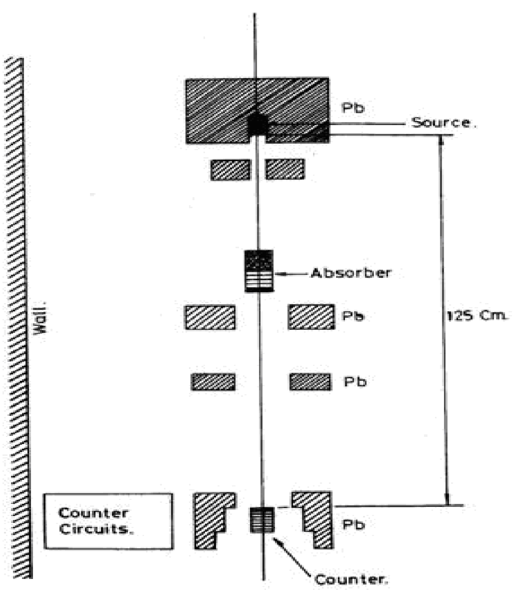

Fig 1: The schematic view of Scintillation counter

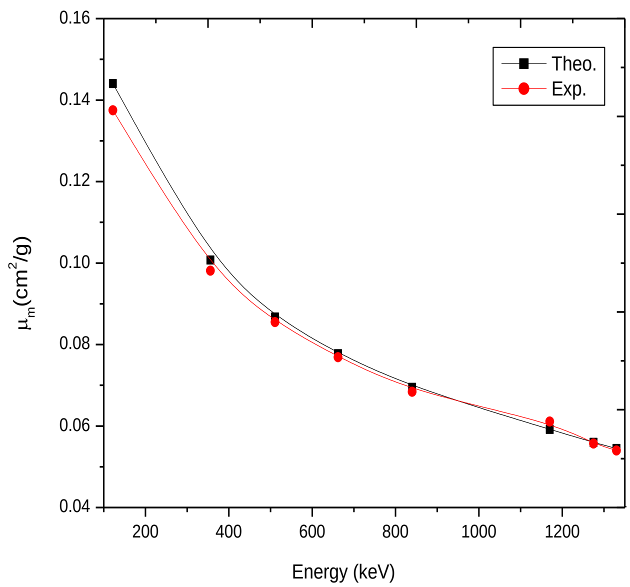

Fig 2: Variation of μ_m versus photon energy for Carbon

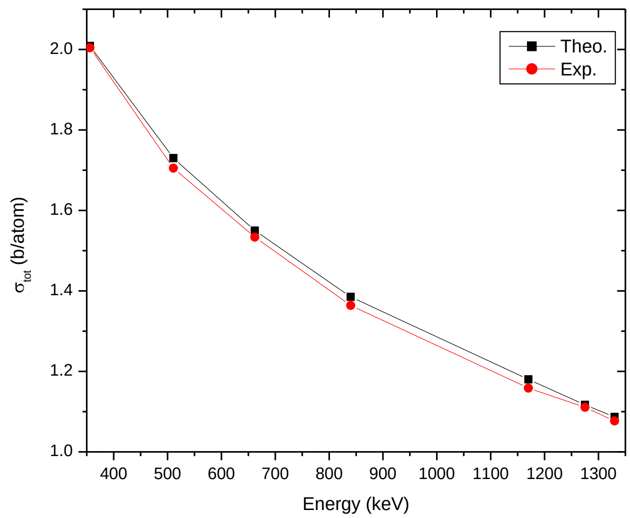

Fig 3: total crosses section against incident photon energy for Carbon.

4. Results and Discussion

The mass attenuation coefficient is depending upon the interaction process of photon within the material like photoelectric effect, Compton scattering, Rayleigh scattering and pair production. 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_m values decreases as increases in the energy of photon given in table 2 and plotted against energy of incident photon in fig.2. The total atomic cross section decreases as increases the energy of photon and is given in table 3 and plotted against energy of incident photon in fig.3.

5. Conclusions

It has been observed that the mass 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 mass attenuation coefficient (μ_m) decrease with increasing photon energy. The total attenuation cross section (σ_t) varies with energy and is identical to that of μ_m but the mean free path increases with increases in the energy of photon and decreases with increasing the atomic number. The work is useful for the medical, radiation therapy, shielding, space radiation.

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7. References

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