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Mass attenuation coefficient and total atomic cross section in the energy range of 0.1MeV to 1.5MeV

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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 mass attenuation coefficient and atomic cross section 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 transmission experiments. 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: NaI(Tl) Scintillation detector, Mass attenuation coefficient, High energy photons.

1. Introduction
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 [Hubbell J.H., 1969] [4].
Hubbell calculated the values of photon mass attenuation and energy absorption coefficients theoretical from 1keV to 20MeV [Hubbell J.H., 1982] [5]. Ladhaf B.M. and Pravina P. Pawar determined the mass energy absorption coefficient and effective atomic energy absorption coefficient for Carbohydrates [Ladhaf B.M. and Pawar P.P., 2015] [8]. Kore P.S. and Pawar P.P. have been reported the mass energy absorption coefficient for the fatty acids [Prashant S. K., Pravina P. Pawar1 and T Palani Selvam2, 2015] [3]. Gaikwad D.K. *et al.* have been measured the attenuation cross sections of some fatty acids in the energy range 122 keV to 1330keV [Gaikwad D.K, Pawar P.P and Selvam T.P., 2015] [3]. 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.

2. 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 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, the signals 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 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 possible2 $\leq \ln (I_0 / I) \leq$ 4 [Creagh, D.C., 1987] [2].

The elemental samples were irradiated by gamma rays in the air conditional lab by maintaining the temperature of the laboratory about 27 ^{0}C 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 mass attenuation coefficients (μ_m) for all selected pure elemental sample.

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.

Table 1: Values of mass attenuation coefficient (cm^2/g) for photon energies from 100keV to 1500keV

Sr.	Elements	Tin		Antimony		Tungsten		Lead		Bismuth	
No.	Energy.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	356	0.130	0.139	0.136	0.1142	0.239	0.258	0.315	0.317	0.319	0.327
2.	511	0.092	0.093	0.093	0.095	0.125	0.137	0.158	0.161	0.158	0.165
3.	662	0.075	0.077	0.076	0.077	0.096	0.102	0.115	0.115	0.116	0.118
4.	840	0.063	0.065	0.064	0.065	0.074	0.078	0.081	0.085	0.083	0.086
5.	1170	0.052	0.053	0.052	0.053	0.058	0.059	0.061	0.062	0.061	0.069
6.	1275	0.049	0.050	0.050	0.050	0.054	0.055	0.055	0.058	0.058	0.059
7.	1330	0.046	0.049	0.048	0.049	0.052	0.053	0.054	0.056	0.058	0.059

Table 2: Values of total atomic cross section (b/atom) for photon energies from 100keV to 1500keV

Sr.	Elements	Tin		Antimony		Tungsten		Lead		Bismuth	
No.	Energy.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.	Theo.
1.	356	27.67	27.55	27.46	28.79	72.91	72.71	108.2	109.1	110.6	113.6
2.	511	18.14	18.44	18.78	19.22	39.7	41.95	54.44	55.33	54.97	57.33
3.	662	14.90	15.23	15.48	15.68	29.19	31.07	39.49	39.65	40.39	40.93
4.	840	12.54	12.84	12.86	13.17	22.44	23.68	27.98	29.14	28.77	29.95
5.	1170	10.31	10.53	10.52	10.78	17.57	18.00	21.00	21.47	21.24	21.96
6.	1275	9.701	9.889	10.06	10.12	16.37	16.75	18.83	19.90	20.23	20.63
7.	1330	9.168	9.645	9.646	9.869	16.00	16.19	18.46	19.13	20.16	20.53

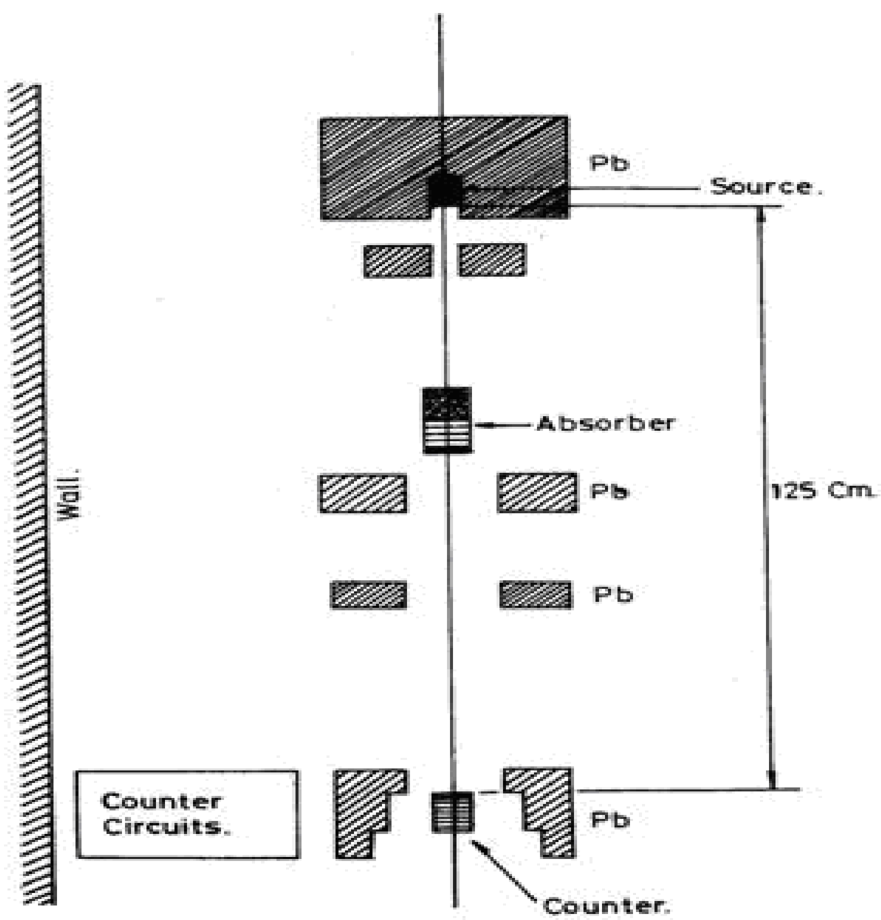

Fig. 1: The schematic view of the experimental set up.

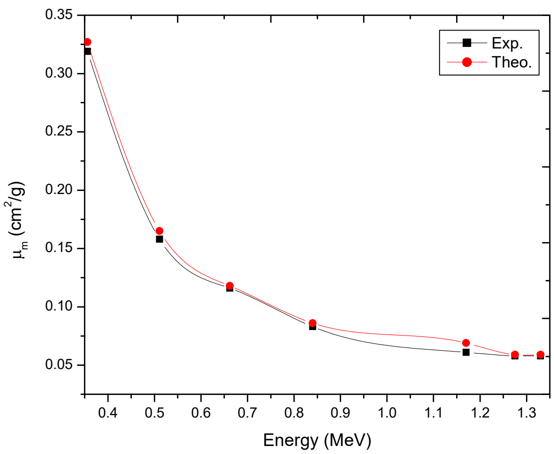

Fig. 2 Plot of mass attenuation coefficient (μ_m) versus photon energy for Bismuth (Bi)

3. 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 which is related to the sub-shell of atom 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, the mean free path of photon increases with increases in energy of photon given in table 4 and plotted in fig.4.

4. 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 shielding purpose, space radiation, medical and radiation therapy.

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