Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2012, 4(1):118-124

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Photon interaction cross-section of elemental solids Ag, Cu and Fe in the energy range 0.360MeV-1.33MeV

[*]V. K. Barote, [1]C. M. Kale, [2]A. A. Pandit and [3]K. M. Jadhav

[*]Department of Physics, S.D. Mahavidyalaya, Soegaon, Dist Aurangabad
[1]Department of Physics, Yashawantrao Chavan Mahavidyalaya Sillod, Dist Aurangabad
[2]Department of Physics, Indraraj Arts, Com. and Science college Sillod, Dist Aurangabad
[3]Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, (M.S.) India

---

ABSTRACT

The photon interaction cross-section of thin uniform multiple foil attenuators (Ag, Cu, Fe) were determined in the energy range 0.360MeV-1.33MeV with a view to study the effect of atomic numbers and photon energy on absorption coefficient under collimated narrow beam geometry set-up. The measurements were taken for the linear absorption coefficient (μ), mass absorption coefficient (μ/ρ) and total photon interaction cross-section of different elemental solids of uniform thickness 0.15 cm, on NaI(Tl) detector using scintillation counter. The result shows that; as atomic number increases linear attenuation coefficient (μ), mass attenuation coefficient (μ/ρ) and total σ_{Total} photon interaction cross-section understudy decreases with increase in Photon energy.

Keywords: Linear attenuation, Mass attenuation, Total Photon interaction.

INTRODUCTION

The interaction of photon through material is of wide interest in industrial, medical and agriculture studies. With the advent of nuclear era, large number of isotopes and radiations generating equipments have came into existence. As a result, the protection from harmful radiation has become eminent. One of the important factors needed in radiation protection and shielding is the gamma ray attenuation coefficient. The present studies are aimed to protect individuals from harmful gamma radiation which has led us to present studies. Apart from this, the need of shield to protect against gamma radiation has further lead to extensive measurements on attenuation coefficient in different multi-elemental materials. There is an important parameter for characterizing the penetration and diffusion of gamma rays in the medium which is called mass attenuation coefficient. This parameter mainly depends on the photon energy, the nature of the material and the medium through which radiation passes. Till date, several investigators have carried out the systematic studies of attenuation coefficients by using narrow beam geometry [1-3] from time to time. The accurate values of photoelectric cross-section for photon radiation in several materials are needed in solving various problems in radiation physics and radiation dosimetry. The photon cross-section data which are most often used are the compilation of reports from National Bureau of Standard, USA [4]. It is evident to note that most of the data are based on theoretical compilation and only a few are based on experimental measurements. Such a comparison is necessary to ensure that theoretically predicted values do indeed agree with experimental results [5]. This is particularly true in the case of low energy photons. Although a number of experimental measurements are reported in the literature [6], the work actually carried out is limited to a few energy points and materials. Further the experimental techniques used by different workers are not identical; hence it is difficult to inter compare the experimental results [7]. When photons are transmitted through a well collimated geometry properly aligned using LASER beam, the multiple scattered photons are not only minimized but also, prevented from reaching the detector and so are not measured. However, as the collimator size and sample thickness increases, the probability of multiple scattered photons reaching the detector increases. Thus, along with the unattenuated photons the multiple scattered photons are also measured.

The attenuation of gamma radiation through elements is interesting from its application point of view in industrial, medical and agricultural fields. Large numbers of researchers have studied linear attenuation coefficient and mass attenuation coefficient of several elements with a view to understand the attenuation of gamma rays and provide the experimental data for various applications [8]. The attenuation of gamma rays in elements has been studied for variable energy and using narrow beam geometry. The study of attenuation coefficient of several elements can throw light on shielding properties and to find the density of materials. Taking into considerations the importance of gamma ray attenuation we have carried out systematic investigations of linear attenuation and mass attenuation coefficient of several elements such as Silver, Copper and Iron, for variable energy 0.360 MeV–1.33 MeV using narrow beam geometry technique. The elemental solids (moderate to high atomic numbers) under investigations are pure and have a thickness of 0.15 cm. The results obtained on linear attenuation, mass attenuation coefficient and total photon interaction cross-section of Silver, Copper and Iron are presented in the paper.

EXPERIMENTAL SECTION

The linear attenuation coefficient, mass attenuation coefficient and total photon interaction cross-section of Silver, Copper and Iron for varying energy have been measured using narrow beam geometry technique. The experimental set-up of narrow beam geometry used in the present measurement is shown in Fig.1.

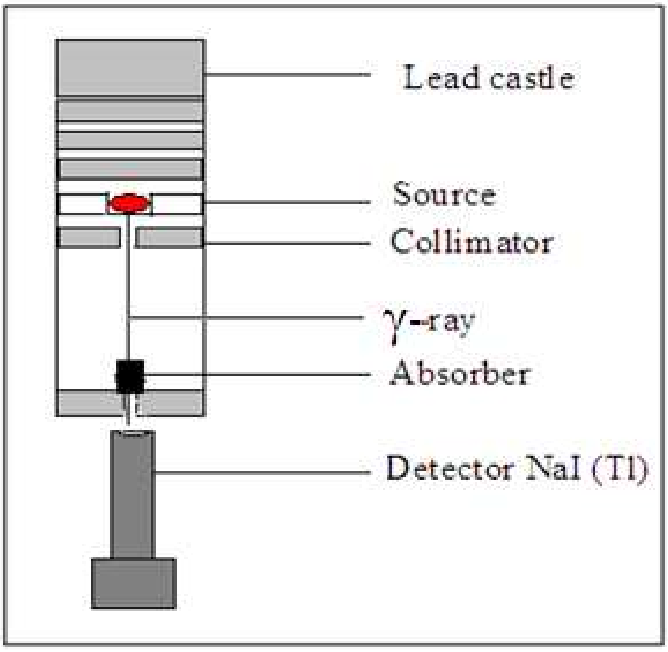

Fig.1 Schematic Apparatus used for the measurement of γ-ray absorption coefficient

The mono-energetic gamma radiations are derived from several radioactive sealed sources having photon energies ranging from 0.360 MeV to 1.33 MeV. The counting setup consists of source holder, incident and transmitted photon beam passing through collimators of Lead, well aligned. To minimize radiation exposure and background radiation contribution, the radioactive source was kept in a Lead source holder and placed subsequently in the Lead castle which is well shielded from all sides [9].

The transmitted photon beam is detected by a NaI(Tl) scintillation gamma photo spectrometer. The optimum voltage of 800 Volt was chosen to provide good resolution characteristic for the isotopes used. The detector was calibrated for various photon energies using radioactive isotopes Ba^{133}, Cs^{137}, Na^{22} and Co^{60}. The photon transmission measurements were done under a narrow beam counting geometry employing high resolution scintillation detector. The NaI(Tl) detector was used in the present work. The NaI(Tl) scintillation detector used in the present work is 4.5 cm in diameter and 5.0 cm thick and is supplied by Nucleonix Enterprises, India. The experimental set-up consists mainly of two collimators of diameter 0.2 cm which is well aligned by LASER beam so as to provide a scatter free collimated photon beam. To establish the optimum collimation condition, the gamma ray spectra of Cs^{137} source were taken with the incident and transmitted collimated beam and were found to be identical and had unchanged energy resolution characteristic. The photon spectra thus taken establish that the energy of transmission photon did not change appreciably due to scattered or fluorescent radiation emanating from the collimators. A provision was made midway between the collimators to introduce absorbers which were in the form of thin uniform foils. The entire system was arranged vertically over the NaI (Tl) detector, ensuring that the central axis of incident and transmitted collimator are coaxial.

The source holder was kept over the collimator so as to allow, a narrow well collimated photon beam from the collimator incident normally on the thin absorber. The gamma spectrums from each source of photon energy 0.360 MeV to 1.33 MeV were recorded on the single channel analyzer pre set to record counts under the full energy absorption peak as shown in Fig 2.

The transmitted photons from the absorbers were accumulated for a set time so as to provide statistical variation within one percent. For absorption study of gamma ray, thin and uniform foils of high purity 99.9% of Silver, Copper and Iron were used in the present study.

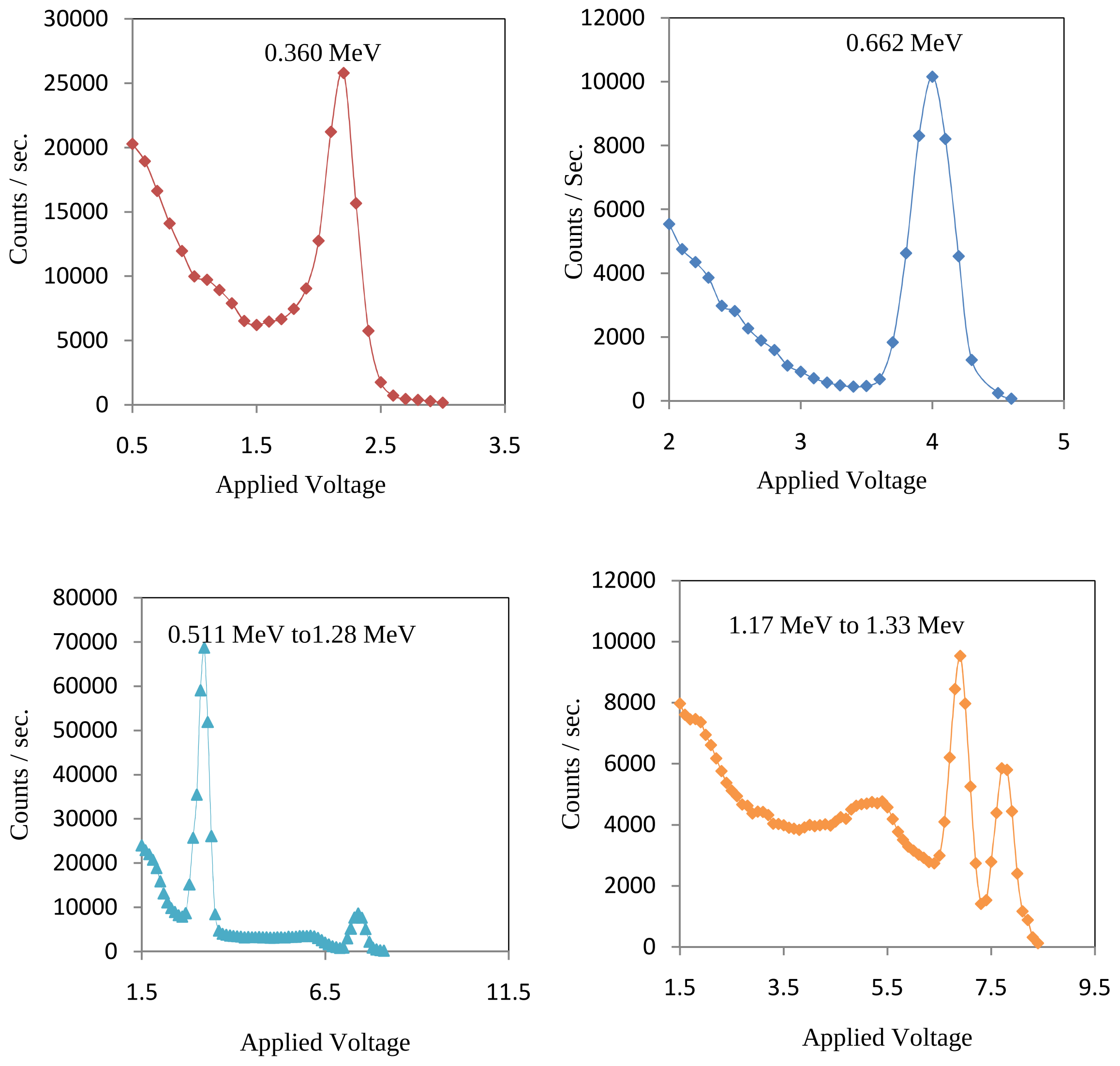

Fig.2 Gamma spectra of Ba^{133}, Cs^{137}, Na^{22}, and Co^{60}

The areal densities of absorbers were obtained by comparing their weight measured on a micro balance, with their area. The counts under the full energy absorption peak of the recorded spectrum were taken without and with absorbers placed in sequence. The photon spectrum was recorded several times for each additional foil of thickness ranging from 0.15 cm to 1.50 cm. For each added foil thickness, average counts under the full energy absorption peak were obtained. The entire counting system was arranged in a dust free room to minimize contribution from scattered photon and also from contamination arising from the atmosphere and sealed radioactive sources stored in the laboratory. Care was taken to maintain, temperature variation due to environmental change as minimum so as to avoid any shift in the photo peak position of recorded gamma spectra. The average number of transmitted photon through different absorber foils were corrected for background and plotted against thickness to represent a linear curve on a semi-log graph paper. The slope of the graph provides the accurate value of linear attenuation coefficient μ (cm^{-1}) for specific gamma energy and absorber. Thus, experimental values of linear attenuation coefficient obtained using 0.2 cm diameter collimator were checked for contribution from scattered photons arising from different collimators of varying sizes.

RESULTS AND DISCUSSION

Linear attenuation coefficient

The probability of multiple scattered photon leads to the variation in the attenuation coefficient due to changes in thickness of multiple foil staging and variation in gamma ray energies. There is definitely some kind of correlation between absorber thicknesses due to attenuation coefficient gets affected. The linear attenuation coefficient μ (cm^{-1}) for collimator diameter 0.2 cm is calculated using following relation and experimental results are given in Table 1.

$$I = I_o \exp[-\mu t] \quad (1)$$

where, I and I_o are the photon intensities with and without absorber respectively, and 't' is thickness of the foil expressed in centimeter.

Table 1Linear attenuation coefficient (μ) in the energy range (0.360 MeV-1.33 MeV) for Ag, Cu and Fe

Energy (MeV)	Linear attenuation coefficient μ(cm^{-1}) Ag	Cu	Fe
0.360	0.7045	0.5362	0.4777
0.511	0.5421	0.4365	0.3674
0.662	0.4844	0.3823	0.3225
1.170	0.3745	0.3052	0.2621
1.280	0.3362	0.2825	0.2445
1.330	0.3147	0.2557	0.2245

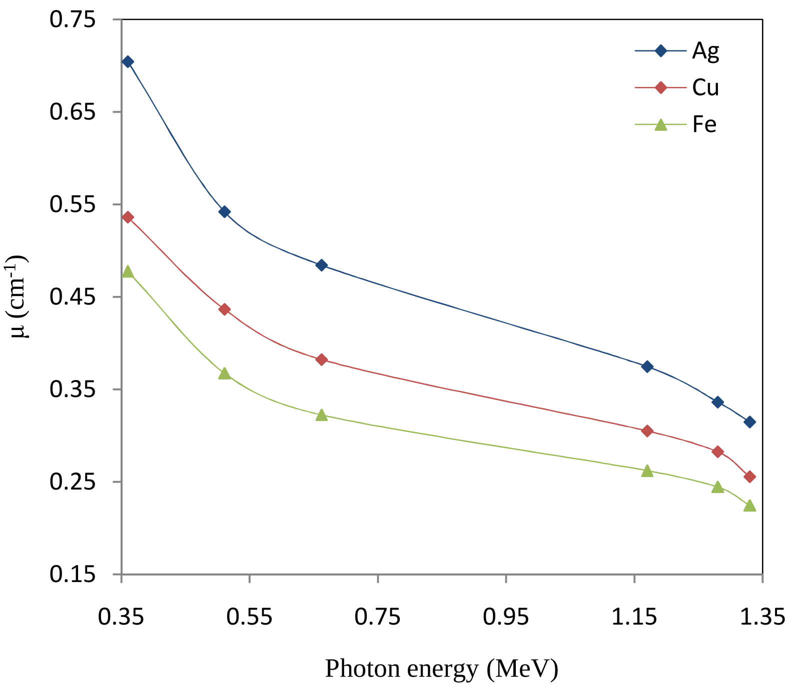

Fig 3 Plots of photon attenuation coefficient (μ) v/s photon energy (MeV) for Ag, Cu and Fe (0.2 cm collimation)

Table 1 illustrates the variation of linear attenuation coefficient as a function of gamma ray energy for collimator diameter (0.2 cm). From these results, it is seen that the linear attenuation coefficient decreases exponentially with increasing gamma energy and increases with atomic number of the absorber (for pure elements Ag, Cu, and Fe). The linear attenuation coefficient increases for all energies under study indicating identical trends in the results reported in the literature [10].

Fig 3 represents the variation of linear attenuation coefficient as a function of photon energy for collimator diameter 0.2 cm for Silver, Copper and Iron. From these plots it is observed that linear attenuation coefficient of all the elements under investigation decreases exponentially as photon energy increases.

Mass attenuation coefficient

The ratio of the linear attenuation coefficient μ (cm^{-1}) to the density ρ (gm cm^{-3}) is called the mass attenuation coefficient (μ/ρ) and has the dimension of area per unit mass (cm^2/gm). In the present study, the mass attenuation coefficient has been calculated using the following relation,

$$\mu_m = \mu/\rho \quad (cm^2/gm) \qquad 2$$

where, ρ- is the density of the thin absorber and
μ-is the linear attenuation coefficient.

The mass attenuation coefficients for moderate to high atomic number of (Ag, Cu and Fe) under study are given in table 2 for varying photon energy.

Table 2 Mass attenuation coefficient (μ/ρ) in the energy range (0.360 MeV-1.33 MeV) for Ag, Cu and Fe

Energy	Mass attenuation coefficient μ/ρ(cm^2.gm^{-1})		
(MeV)	Ag	Cu	Fe
0.360	0.0672	0.0601	0.0580
0.511	0.0517	0.0489	0.0468
0.662	0.0462	0.0428	0.0411
1.170	0.0357	0.0342	0.0334
1.280	0.0320	0.0316	0.0312
1.330	0.0300	0.0298	0.0286

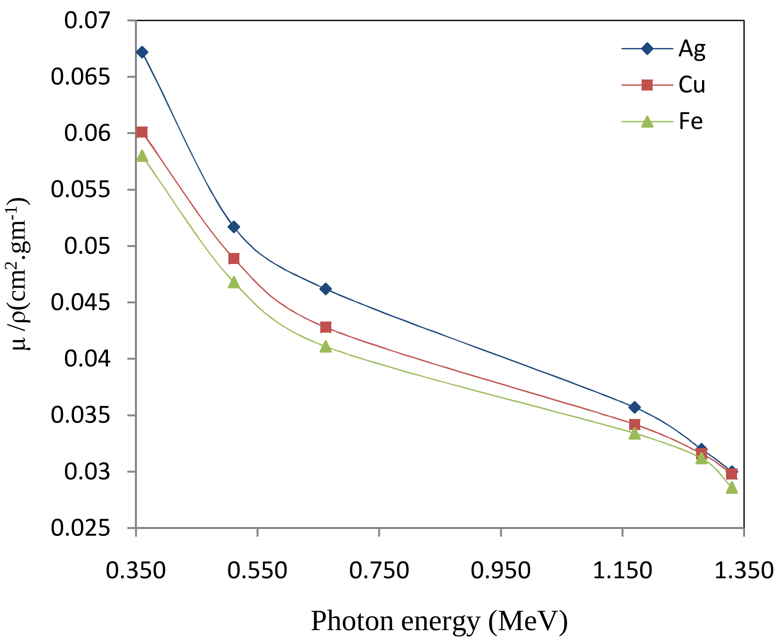

Fig 4 Plots of photon attenuation coefficient (μ/ρ) v/s photon energy (MeV) for Ag, Cu and Fe (0.2 cm collimation)

From table 2 it is observed that, as the photon energy increases, the mass attenuation coefficient of all elements under study decreases. Our results are in accordance with the literature reports [11]. The variations of mass attenuation coefficient with photon energy for all the elements under study are shown in Fig4.

The common feature of all these plots is that they exhibit similar trend. The mass attenuation coefficient decreases exponentially with increasing photon energy from 0.360 MeV to 1.33 MeV. As the photon energy increases, intensity of gamma ray increases, this causes decrease in mass attenuation coefficients. It is observed from these plots that maximum value of mass attenuation coefficient is associated with Silver element that has high atomic number and high density. The minimum value of mass attenuation coefficient is observed in case of Iron with low atomic number and density.

Total photon interaction cross-section

The mass attenuation coefficients (cm^2/gm) have been converted into the total photon interaction cross-sections, expressed in units of barns/atom by using the relation (3) given below. The values obtained from varying photon energy for collimator diameter (0.2 cm) are given in Table 3.

$$\sigma_{tot} = \mu_m \left(\frac{A}{N_A} \right) \times 10^{24} \quad (3)$$

Table 3 Total photon interaction cross-section (σ_{total}) in the energy range (0.360 MeV-1.33 MeV) for Ag, Cu and Fe

Energy (MeV)	Total photon attenuation coefficient σ_{Total} (barn / atom)		
	Ag	**Cu**	**Fe**
0.360	11.94	6.287	5.297
0.511	9.186	5.115	4.274
0.662	8.208	4.477	3.753
1.170	6.343	3.577	3.050
1.280	5.685	3.305	2.849
1.330	5.330	3.117	2.612

It is observed that the total photon interaction cross- section of all the elements under study decreases, as the photon energy increases. The variation of total photon interactions cross-section with photon energy is shown in Fig 5.

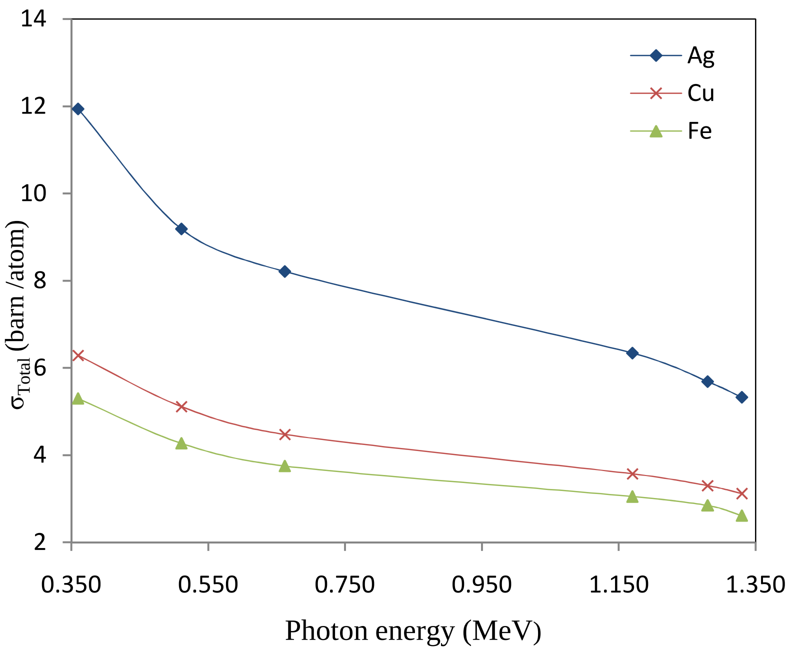

Fig 5 Plots of total photon attenuation coefficient (σ_{total}) v/s photon energy (MeV) for Ag, Cu and Fe (0.2 cm collimation)

From figure it is seen that, as atomic number increases from iron to Silver, the total photon cross-section also increases. Our experimental results on total photon interaction cross-section as a function of photon energy are in analogues with the literature reports [12].

CONCLUSION

In the present measurements results reported is predominantly experimental and therefore no comparison is needed. The experimental measurements described were preferred in collimation geometry and provide a set of data on attenuation coefficients, mass attenuation coefficients and total photon interaction cross section. From the above measurements, it can be concluded that the effect of multiple scattered photons in the measurements of attenuation coefficient of elemental solids is significant in Silver, Copper and Iron and can further be minimized by using well collimated narrow beam counting geometry. As most accurate values of attenuation are needed in radiation dosimetry, diagnostic and therapeutically applications attempt should be made to minimize multiple scattered contributions while evaluating the attenuation coefficient values correctly. Finally, it is concluded that the attenuation coefficient can be measured more accurately for health care, and radiation dosimetric applications.

From our studies on linear attenuation coefficient, mass attenuation coefficient and total photon interaction cross-section as a function of photon energy on various elements (Ag, Cu and Fe) it can be concluded that the collimator size largely affects the attenuation of gamma ray in elements under investigation. The best results of attenuation coefficients are observed for 0.2 cm diameter of collimator. Based on our results, it can be concluded that

1) The linear attenuation coefficient increases exponentially with increasing photon energy.
2) The linear attenuation coefficient increases from moderate (Fe) to high atomic number (Ag).
3) The mass attenuation coefficient increases exponentially with increasing photon energy.
4) The mass attenuation coefficient increases from moderate to high atomic number.
5) The total photon interaction cross-section increases with increasing photon energy. The increase is exponential in nature.
6) The total photon interaction cross-section increases from moderate to high atomic number.
7) For effective attenuation coefficient, the collimator diameter of 0.2 cm size is most suitable.

Acknowledgements
One of the authors is thankful to Prof. Dr. R. G. Kulkarni and Prof Dr. K. M. Jadhav for providing a valuable guidance

REFERENCES

[1] S A Colgate, *Phys, Rev* 87, **1952,** 592.
[2] M Wiedenback, *Phys, Rev* 126, **1962,** 1009.
[3] A L Conner, H F Atwater, E H Plasman and J.H.McCarry, *Phys., Rev*, A1 **1970,** 539.
[4] E B Saloman and J H Hubbell, National Bureau of Standard Report No. NBSIR, **1986,** unpublished 86-3431.
[5] J H Scofield, Lawrence Livermore Laboratory Reprt No. UCRL, **1973,** unpublished 51326.
[6] K Parthasaradhi and H H Hansen, Phys, Rev. A 10, **1974,** 563.
[7] P P Pawar *J. Chem. Pharm.Res.***2011,** 3(5); 267-273
[8] S Gopal and B Sanjeevaiah, New. Instrumentation Methods 107, **1973,**221.
[9] Gurdeep S Sidhu, Karmjit Singh, Parjit Singh and Gurmel S Muduhar, *Pramana Journals of Physics*, 53, (5) **1999,** 851-855.
[10] A A Tajuddin, C S Chong, A Shukri, T Bandyopadhay and D A Bradely. Appl. *Radiat. Isot.* Vol.46, No. 2, **2010,** 113-115.
[11] J H Hubbell, *Phy, Med. Bio*, **1999,** 44