STUDY OF GAMMA RADIATION INTERACTION CROSS-SECTION WITH HIGH 'Z'AND HIGH DENSITY MATERIALS

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Abstract:The interaction of gamma radiation with matter is an interesting and useful subject to study. The energy range of gamma radiation is found to be around few KeV to GeV. Since being highly energetic the interaction of gamma radiation with matter is quite different than the charge particles. By having much knowledge about this subject we can study the most of the cosmic activities like Gamma ray bubble, Gamma ray bursts etc. This study is also useful in medical applications, experimental physics, reactor and particle physics for shielding purpose. In the present work we have studied the atomic interaction cross-section, mean free path,linear absorption coefficient and mass absorption coefficientof gamma radiations of different energies. For interaction purpose we have selected Lead and Mercury which are high 'Z' and high densitymaterials.In the present work,the gamma ray spectra were analyzed with help ofNaI (Tl) gamma ray spectrometer coupled to the8K M.C.A. and computer. The values of atomic interaction cross-section for 511KeV, 662KeV,1170KeV and 1330KeV gamma energies with Lead are found to be 4.52 $\times10^{-23}$ cm^2,3.06 $\times10^{-23}$ cm^2,1.75$\times10^{-23}$ $cm^2$and 1.72$\times10^{-23}$ respectively.The values of atomic interaction cross-section for 511KeV, 662KeV, 1170KeV and 1330KeV gamma energies with Mercury are found to be 4.91 $\times10^{-23}$ cm^2, 3.18 $\times10^{-23}cm^2$,1.62$\times10^{-23}cm^2$ and 1.58$\times10^{-23}cm^2$ respectively. The values of mean free path for 511KeV, 662KeV,1170KeV and 1330KeV gamma energies for Lead are found to be 0.67cm, 0.99cm,1.73 cm and 1.76 cmrespectively.The values of mean free path for 511KeV, 662KeV,1170KeV and 1330KeV gamma energies for Mercury are found to be 0.5cm, 0.77cm, 1.51cm and 1.55cm respectively. Present study indicates that for low energies; 511KeV and 662KeV, Mercury is found to be better absorber for gamma radiations whereas for high energies; 1170KeV and 1330KeV, Lead is found to be better absorber as compared to Mercury.

***Keywords*-NaI(Tl) Scintillation Gamma Ray Spectrometer, Lead material, Mercury, Gamma radiations,Interaction Cross-section and Mean Free Path.**

I. INTRODUCTION

The interaction of gamma radiation with matter is mainly concern with three processes; Photoelectric effect, Compton scattering and Pair production. However these processes are depends on the energy of incoming gamma radiations. If the energy of incoming gamma radiations is E_γ<0.01MeV then the photoelectric effect is more dominant and if the incoming gamma radiations energy is 0.01<E_γ<1.02MeV then the Compton scattering is more dominant, as the energy is exceed the value 1.02MeV the pair production become dominant.The basic properties which are studied in this are linear absorption coefficient and mass absorption coefficient.In this work we have also studied, the interaction cross-section and mean free path for gamma radiation energies 511KeV, 662KeV, 1170KeV and 1330KeV. For the interaction purpose the materials used are; Lead and Mercury. Where Lead is Solid and Mercury is Liquid. According to literature these elements are good absorber of gamma radiation because of their high atomic number and high density.The atomic cross-section, and mean free path of these interactions will provides us the brief idea about the interactions processes. By having much knowledge about this subject we can study the most of the cosmic activities like Gamma ray bubble, Gamma ray bursts etc. It is also useful in medical, experimental, reactor and particle physics.

II. RESEARCH METHODOLOGY

2.1 Sample Preparation and Experimental Set up

For the interaction purpose the material used are Lead and Mercury. Lead sheet with thickness ranging from 1mm to 11mm are used. Each sheet is having size rectangular of 7cm×6cm. The cylinder container is used for Mercury to place it between gamma ray detector and source with thickness increasing up to 1.1cm.

A sample of Lead material and Mercury under study was placed between gamma ray detector and sources having distance 10cm that is constant during whole experiment. Gamma ray intensity for each sample was counted for fixed time period of 120 second. In the present work NaI(Tl) gamma ray scintillation detector was used for measuring gamma radiations transmitted intensity through the absorber. The gamma ray spectrum was analyzed with help of 8K M.C.A. coupled to the NaI (Tl) gamma ray detector and computer. The standard gamma ray sources having energy 511KeV, 662KeV, 1170KeV and 1330KeV, provided by BARC, Mumbai were used in present work.

The gamma radiation interactions are studied by using NaI(Tl) gamma ray detector. Experimental set up is shown in figure 2.1

Figure 2.1-Set up of NaI(Tl) gamma ray spectrometer with 8k MCAcoupled to computer

2.2 Theoretical Background

The interaction of gamma radiation with lead sheet is studied by calculating the Linear Absorption Coefficient and Mass Absorption Coefficient using standard mathematical equations.If radiation of intensity 'I' is incident upon an absorbing layer of thickness 'dx'the amount of radiation absorbed 'dI' is proportional both to 'dx' and 'I', so that

$$dI = -\mu I dx \text{ or } I = I_o e^{-\mu_l x} \qquad (2.1)$$

This relation gives the intensity (number of quanta per unit area per second) of the beam of initial intensity 'I_0' after traversing a thickness 'x' of the homogeneous material.

Where, 'μ_l' is a constant of proportionality which is a characteristics property of the medium, known as Linear Absorption Coefficient. It is may be defined as "the fraction of the incident beam removed by an absorber of unit thickness". The Mass Absorption Coefficient 'μ_m' maybe obtained by dividing the Linear Absorption Coefficient by the density (ρ) of the absorbing material.

$$\mu_m = \mu_l/\rho \quad (2.2)$$

The ratio of the Linear Absorption Coefficient to the density (μ_l/ρ) is called the Mass Absorption Coefficient'μ_m' and has the dimensions of area per unit mass (cm^2/g). The units of this coefficients hint that one may think of it as the effective cross-sectional area of electrons per unit mass of absorber. The Mass Absorption Coefficient can be written in terms of the interaction cross-section, σ (cm^2).

$$\sigma = (\mu_m A)/N_0 \quad (2.3)$$

Where,'N_0'is Avogadro's number (6.023×10^{23}) and 'A' is the Atomic weight in amu.

The mean free path of the gamma radiation in material is given by the relation,

$$\text{Mean free path} = 1/\mu_l \qquad (2.4)$$

By using these standard mathematical equations we have calculated the Mass Absorption Coefficient, Mean free path and Interaction cross-section of interaction process.

III. Results And Discussions

The spectrums of gamma radiation interaction with Lead and Mercury are given below for the gamma energies511KeV,662KeV, 1170KeV and 1330KeV respectively.

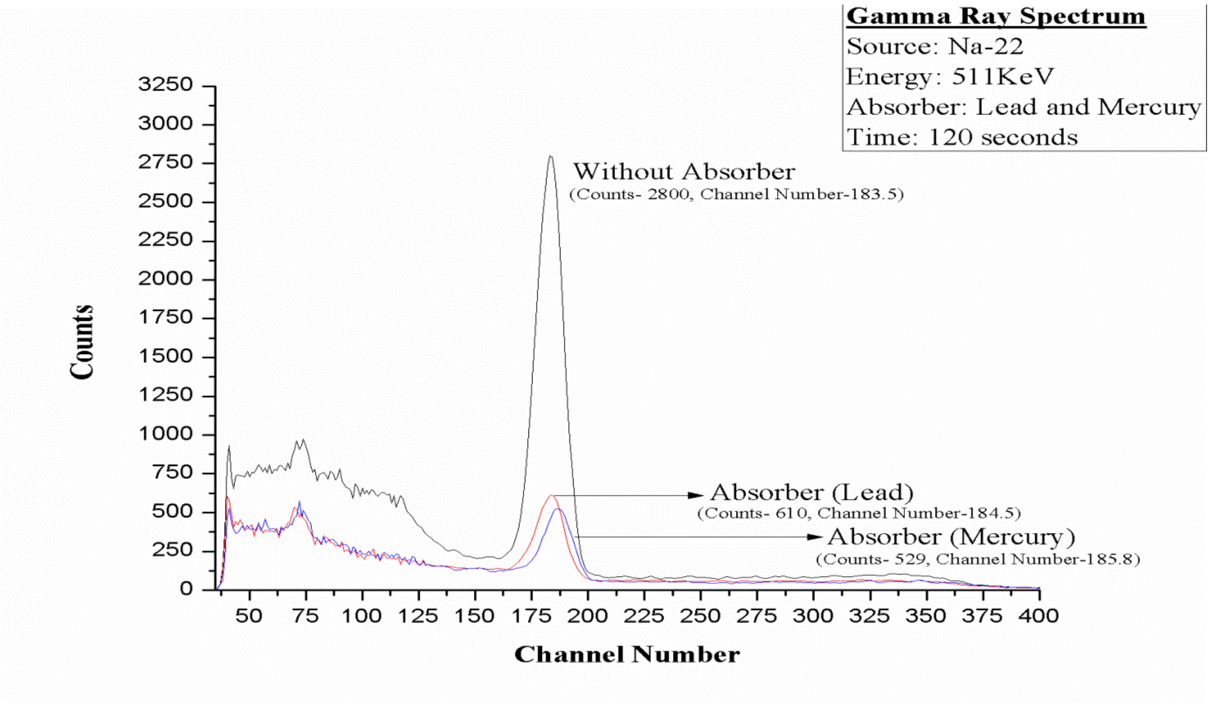


Figure 3.1- Spectrum of gamma radiation interaction with and without absorber for 511KeV energy

The spectrum shows that with the maximum thickness, 1.1cm for both the absorber and irradiation time 120 seconds, Mercury has absorb more intensity of incoming Gamma radiation of 511KeV energy.

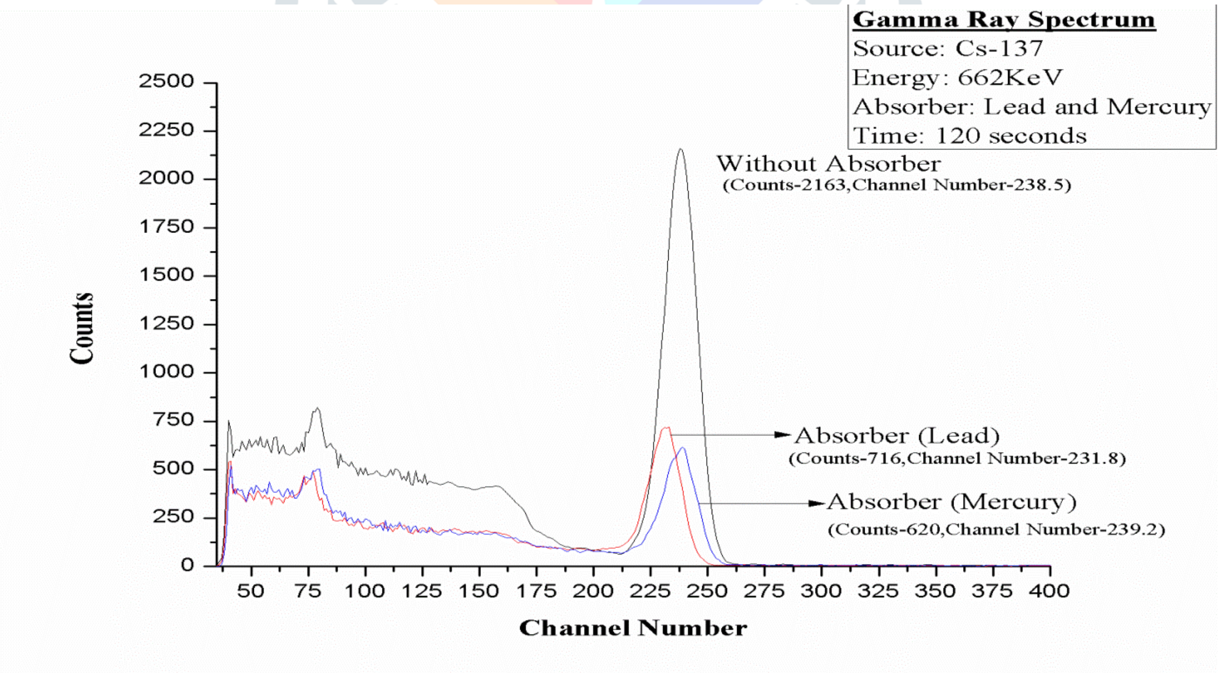


Figure 3.2- Spectrum of gamma radiation interaction with and without absorber for 622KeV energy

Similarly Gamma ray spectrum for 662KeV energy shows that with the maximum thickness, 1.1cm for both the absorber and irradiation time 120 seconds, Mercury has absorb more intensity.

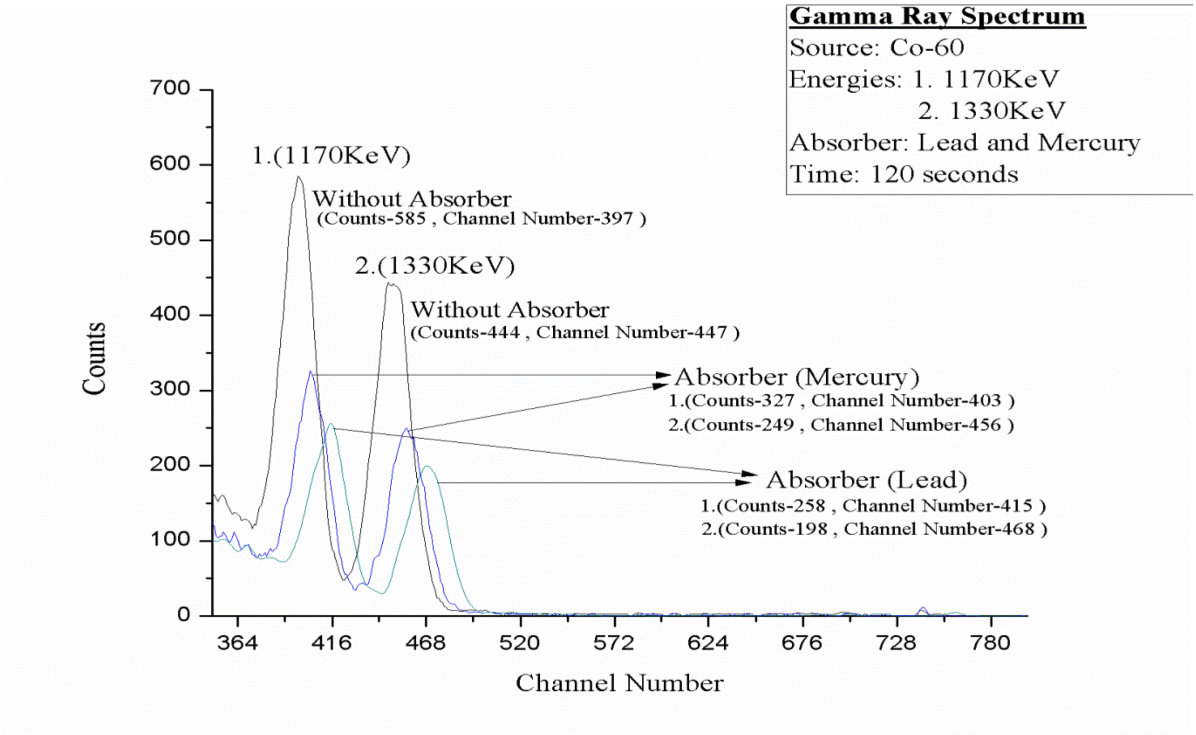


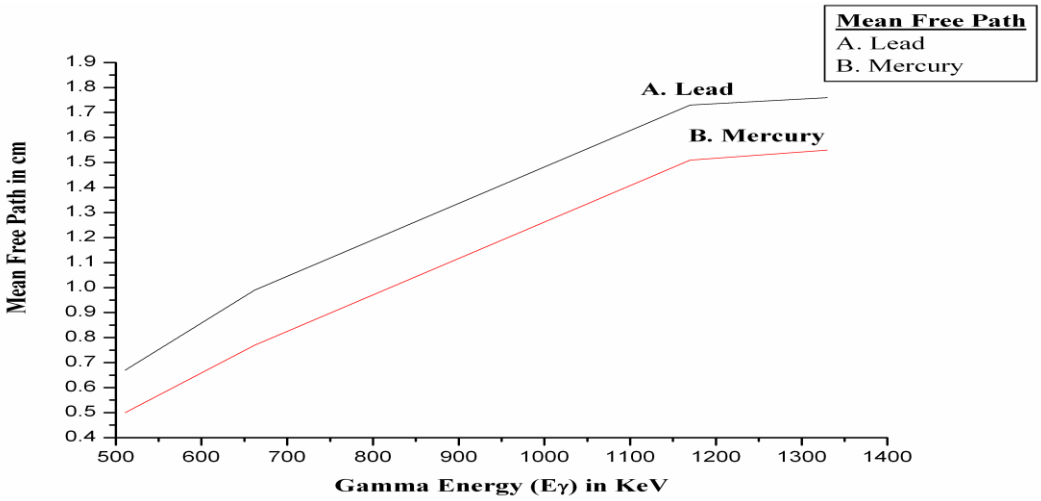
Figure 3.3- Spectrum of gamma radiation interaction with and without absorber for 1170KeV and 1330KeV energies

In case of high energies, 1170KeV and 1330KeV the Gamma ray spectrum shows that Lead absorb more incoming gamma ray intensity in comparison with Mercury.

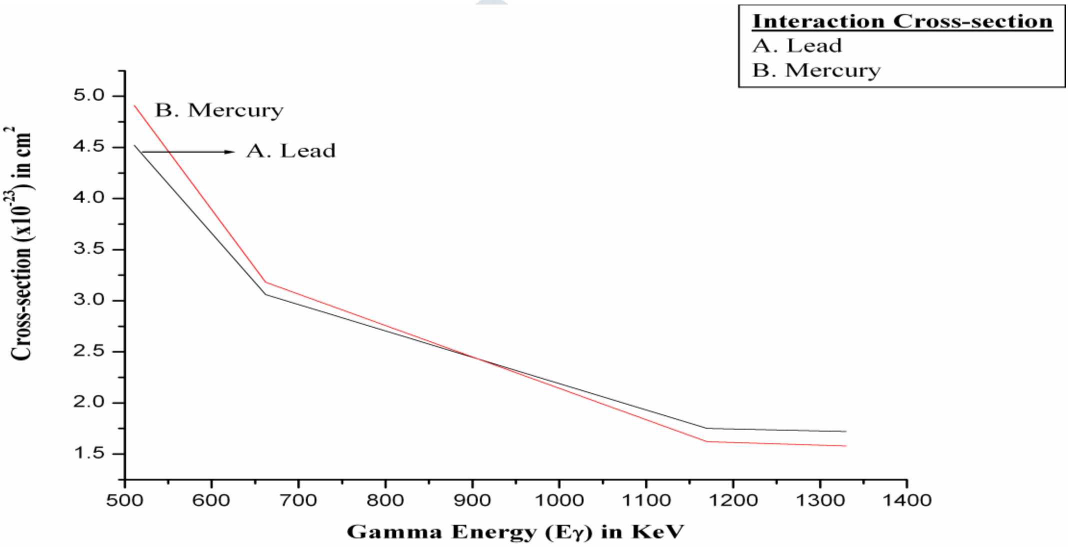
The values of Mass Absorption Coefficient, Mean free path and Atomic Cross-section of Gamma Radiation in Lead and Mercury are given in table 3.1

Table3.1-Mass Absorption Coefficient, Cross-section and Mean free path of gamma radiation's interaction with Lead and Mercury

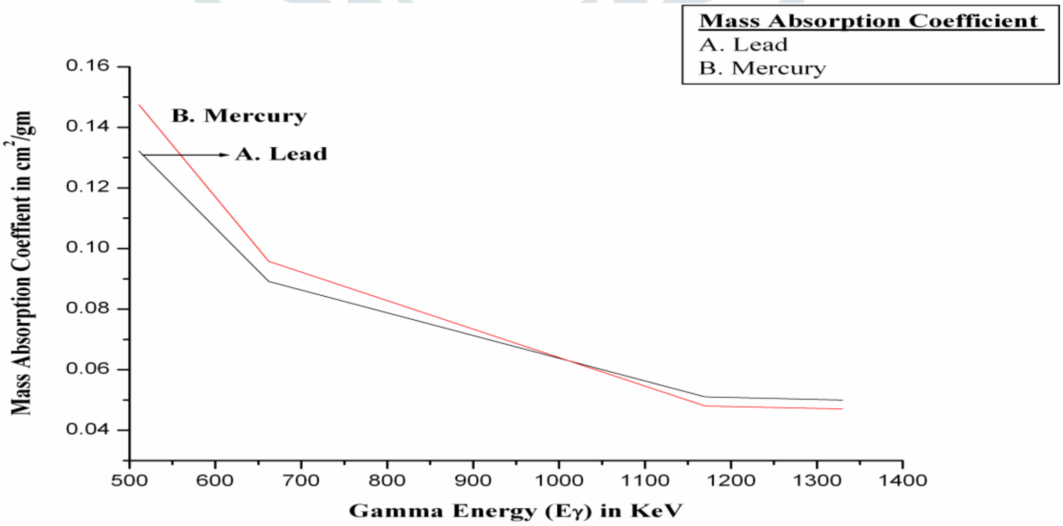
Energy (KeV)	**Absorbing Material**	**Mass Absorption Coefficient (cm^2/gm)**	**Cross-section in $\times 10^{-23}$ (cm^2)**	**Mean Free Path (cm)**
511	Lead	0.1322	4.52	0.67
	Mercury	**0.1475**	**4.91**	**0.50**
662	Lead	0.0891	3.06	0.99
	Mercury	**0.0958**	**3.18**	**0.77**
1170	**Lead**	**0.0510**	**1.75**	**1.73**
	Mercury	0.0488	1.62	1.51
1330	**Lead**	**0.0501**	**1.72**	**1.76**
	Mercury	0.0470	1.58	1.55



a) Mean Free Path versus Gamma Energy



b) Interaction Cross-section versus Gamma Energy



c) Mass Absorption Coefficient versus Gamma Energy

Figure 3.4- Graphs of Mass Absorption Coefficient, Mean Free Path and Interaction Cross-section versus Energy of Gamma Radiations

IV. Conclusions

Results in table3.1 and figure 3.4 shows that the interaction probability and mean free path of gamma radiations with matter are energy dependent. With increase in energy of gamma radiation, the interaction cross-section decreases and the mean free path or relaxation length increases. The gamma ray spectrum shown in figure3.1, 3.2 and 3.3 describes that the intensity of gamma radiation decreases with increasing thickness of the absorber. For energies 511KeV and 662KeV, it is concluded that for the each energy, mass absorption coefficient and atomic interaction cross-section are high and mean free path is smaller for Mercury. This clears that Mercury is the better absorber of gamma radiation than Lead for energies 511KeV and 662KeV. But in case of gamma energies 1170KeV and 1330KeV, mass absorption coefficient and atomic interaction cross-section are high and mean free path is large for Lead, hence for high energies Lead is better absorber than the Mercury.

V. Acknowledgment

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