MULTIDISCIPLINARY RESEARCH

Prof. Rajani Shikhare

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Studies of shielding properties of Iron oxides (Fe_2O_3) in the energy range of 122-1330KeV.

PRADIP S. DAHINDE
Department of Physics
R.B. Attal Arts, Science &
Commerce College,
Georai, Tq. Georai,
Dist. Beed - 431127

Abstract :

In the present article the shielding properties of iron oxide such as half value layer (HVL), tenth value layer (TVL) and mean free path (Mfp) are the most frequently used important parameter for describing not only the penetrating ability of specific radiations but also the penetration through specific objects or material. In this current investigation we find out the values of linear attenuation coefficient (μ), mean free path (MfP), half value layer (HVL) and tenth value layer (TVL) for iron oxide (Fe_2O_3) in the energy range of 122-1330 keV were calculated. The transmitted intensity of gamma ray photons which is librated by radioactive isotopes were measured by using the NaI (Tl) scintillation detector and results obtained are in good agreement with the values presented in the current study.

Keywords:

Mean free path (MFP); half value layer (HVL); tenth value layer (TVL)

Introduction:

The interaction of photon of gamma radiation with different matter it takes place lots of processes in the material like photoelectric effect, incoherent scattering, coherent scattering and pair production and which is totally based on the energy of incident photon [Berger, M.J., Hubbell, J.H., 1987]. The values of partial photon interaction processes such as photoelectric effect, Compton scattering, pair production and all these are present in the XCOM from Berger and Hubbell (1987). Practically and theoretically it is observed that the value of the linear attenuation coefficient depends on the incident photon energy and also depends on density ρ.

The knowledge of photon interaction with different substances has becoming more essential the reason behind it is the large applications of radioactive sources in different field like medicine, industrial, biological, chemical and other field. The oxide substances have wide range of applications almost in different field. The investigation of interaction of gamma radiation with different oxide material is of great interest from theoretical and experimental point of view also. The linear attenuation coefficient of iron oxides in the energy range of 122-1330 keV are calculated. These values are calculated and compared with theoretical values calculated using XCOM program (Berger M.J. and Hubbell J.H., 1987,1999).are found to be good agreement between each other . Absorbed radiation can cause biological damage in living tissues and DNA Shielding is the basic very useful method for radiation protection (A. Akka[0] 2015).

It is very difficult to attenuate the radiation completely; the radiation shielding characteristic should also be studied. Half-value layer (HVL), tenth-value layer (TVL), and mean free path (mfp) are very important parameters that are measured for gamma-ray shielding (O. Gundogdua,", U.A. Tarimb and O. Gurlerb 2016).

The HVL indicates the thickness of an absorber material that will reduce the incident gamma radiation to half of its original intensity, while the TVL indicates the thickness of an absorber that will reduce the incident gamma radiation to a tenth of its original intensity [I. Akkurt, H. Akyýldýrým, B. Mavi, S. Kilincarslan, C. Basyigi 2010]. In this current study the HVL, TVL and mfp parameters for iron oxide are calculated for the energy of 122KeV to 1330KeV. HVL and TVL and mfp values are very useful for gating the knowledge of penetrating ability of particular radiations through specific material.

2. Calculation Methods :

2.1 Mass attenuation coefficient :

The inverse exponential power law that in the present work we study some theoretical parameters of some oxide that have been used to determine the mass attenuation coefficient μ_m. And other related parameters which are based on it. A parallel beam of the measured intensity I of the transmitted monoenergetic X-ray or γ-photons passing through matter is related to the incident intensity I_0 is usually referred to as Beer-Lambert law is given by the relation.

$$I = I_0 e^{-\mu_m X} \quad \text{.........} \quad (1)$$

Where, I_0 and I are incident and transmitted photon intensities respectively, X is mass per unit area (g/cm^2), μ_m is mass attenuation coefficient (cm^2/g) given by the following equation for a compound or mixture of elements (Jackson D. F. and Hawkes D.J., 1981; Hubbell and Seltzer, 1995): Solving the Eq. (1), we get the following equation for the linear attenuation coefficient (cm^{-1}):

$$\mu = 1/t \ln(I / I_0) \quad \text{.........} \quad (2)$$

2.2 Half value layer (HVL) and Tenth value layer (TVL):

The values of HVL and TVL thicknesses are calculated by using Eq.4 and Eq.5, respectively. The HVL and TVL are very important factor for calculations of sheling.

$$HVL = X_h = \ln 2/\mu, \quad \text{.........} \quad (4)$$

$$TVL = X_t = \ln 10/ \mu. \quad \text{.........} \quad (5)$$

2.3 Mean free path:

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

$$X_m = 1 / \mu. \quad \text{.........} \quad (6)$$

3. Experimental Details :

We investigated here the incident and also the transmitted photon energies with the help of narrow-beam good geometry set up. Fig. 1 shows the schematic view of experimental set up. In this current investigation we use the different radioactive sources suchas, Co^{57} (122 keV), Ba^{133} (356 keV), Na^{22} (511 and 1275 keV), Cs^{137} (662 keV), Mn^{54} (840 keV) and Co^{60} (1170 and 1330 keV) which is obtained from Bhabha Atomic Research Centre, Mumbai, India. The emission of gamma radiation by these radioactive sources were collimated and detected with the help of NaI (Tl) scintillation detector. Stability and reproducibility of the arrangement were checked before and after each set of runs. In order to minimize the effects of small-angle scattering and multiple scattering events on the measured intensity, the transmitted intensity was measured by setting the channels at the full-width half-maximum position of the photo-peak.

Pellet shaped uniform thickness of iron oxides (Fe_2O_3) under investigation were confined in a cylindrical plastic container with diameter similar to that of the sample pellet. The diameters of the sample pellets were determined using a traveling microscope. The attenuation of photons in the empty containers was negligible. Each sample pellet was weighted in a sensitive digital balance with an accuracy of 0.001 mg several times to obtain the average value of the mass. The mass per unit area was determined in each case using the diameter of the pellet and mean value of the mass of the pellet. The sample thickness was selected in order to satisfy the following ideal condition as far as possible (Creagh D.C., 1987):

$$2 \leq \ln\left(\frac{I_o}{I}\right) \leq 4.$$

The Mass attenuation coefficients (μ/ρ) of all the samples of oxides were determined from the measured values of incident photon intensity I_0 (without sample) and transmitted photon intensity I that is with samples and mean values are used for the calculation of linear attenuation coefficients (μ) for all selected oxide sample. The experiments were conducted in an air-conditioned room to avoid possible shifts of the photo-peaks. Room temperature of 26 ± 1^0C was maintained throughout the experimental period. The different sources of error, other than multiple scattering and meaning statistics, are small-angle scattering, sample impurity, nonuniformity of the sample, photo built-up effects, dead time of the counting instrument, and pulse pile effect which were evaluated and reduced.

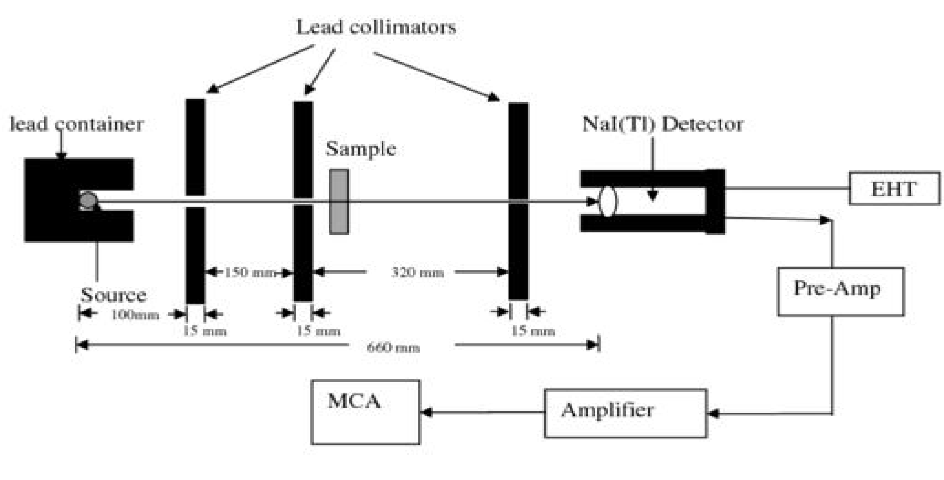

Fig.(a) Narrow beam good geometry set up.

In the presented investigation, uncertainty in the mass per unit area and the error due to nonuniformity of the sample are <0.05% for all energies of interest. Optimum values of count rate and counting time were chosen to reduce the effects of photon built-up and pulse piles. The photon built-up effect, which is a consequence of the multiple scattering inside the sample, depends on the atomic number and sample thickness, as well as the incident photon energy. A built-in provision for dead time correction was present in the MCA used during this investigation.

Sr.No.	Energy range keV	μ Expt.	μ Theo.	HVL Expt.	HVL Theo.	TVL Expt.	TVL Theo.	MfP Expt.	Mfp Theo.
1.	122	0.8544	0.8649	8.8110	0.8012	2.6949	2.6622	1.1704	1.1562
2.	356	0.5346	0.5242	1.2962	1.3220	4.3071	4.3925	1.8705	1.9076
3.	511	0.4403	0.4455	1.5739	1.5555	5.2296	5.1685	2.2711	2.2446
4.	662	0.3826	0.3774	1.8112	1.8362	6.0182	6.1012	2.6136	2.6497
5.	840	0.3721	0.3616	1.8624	1.9164	6.1881	6.3678	2.6874	2.7654
6.	1170	0.3302	0.3554	2.0987	2.0661	6.9733	6.8652	3.0284	2.985
7.	1275	0.2830	0.2935	2.4487	2.3611	8.1363	7.8453	3.5335	3.4071
8.	1330	0.2411	0.2463	2.8743	2.8136	9.5503	9.3487	4.1476	4.0600

4. Results and Discussions :

In the current article the values of linear attenuation coefficient *μ* of iron oxide (fe_2O_3). The deviation between experimental and theoretical values of *μ* (cm^{-1}) studied in the range 122- 133^0 keV photon energies are shown in

Table 1, and those for all oxide samples are plotted in Figure (b).

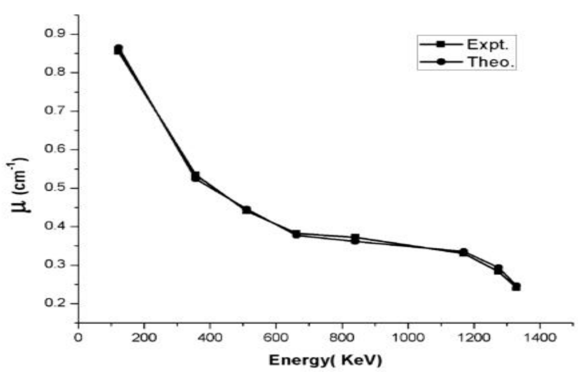

Fig.(b) Typical plot of linear attenuation coefficient (μ) versus photon energy.

It can be observed from the figure and table that m decreases with increasing photon energy. It is observed that he experimental values of m agree with the theoretical values calculated using the XCOM program. The estimated total uncertainty in the measured experimental values of m was found to be in the range of 3-4%.

The another important parameter The half-value layers, tenth-value layers and mean free paths of iron oxide for different radiation energies levels from 122KeV to 133^0KeV have been obtained and are presented in Table.

The mean free path, half value layer and tenth value layer of iron oxide increases with increases in energy of photon. It is clearly seen that the lower the values of half-value layers and tenth-value layers, the higher are the radiation shielding material in terms of the thickness requirements.

5. Conclusion :

The current article was carried out to obtain knowledge about the linear attenuation coefficient, μ and other related parameters like half value layer (HVL), tenth value layer (TVL) and mean free path (mfp) for the iron oxide (fe_2O_3). It has been found that ì is an extremely useful and sensitive physical quantity for the determination of these parameters for iron oxide, are determined in the chosen energy range (122-133^0 keV) which is emitted by the radioisotopes ^{60}Co, $^{57}C_o$, ^{133}Ba, ^{54}Mn, ^{22}Na, and ^{137}Cs. From the current investigation it is found that it is completely based on the number and also the nature of those atoms. In the current work, it has been found that the radiological data on linear attenuation coefficient (ì) and other parameters like HVL, TVL and MFP are very beneficial in industrial, biological, technological, shielding and other applications, solar cell and recently in sensors field.

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