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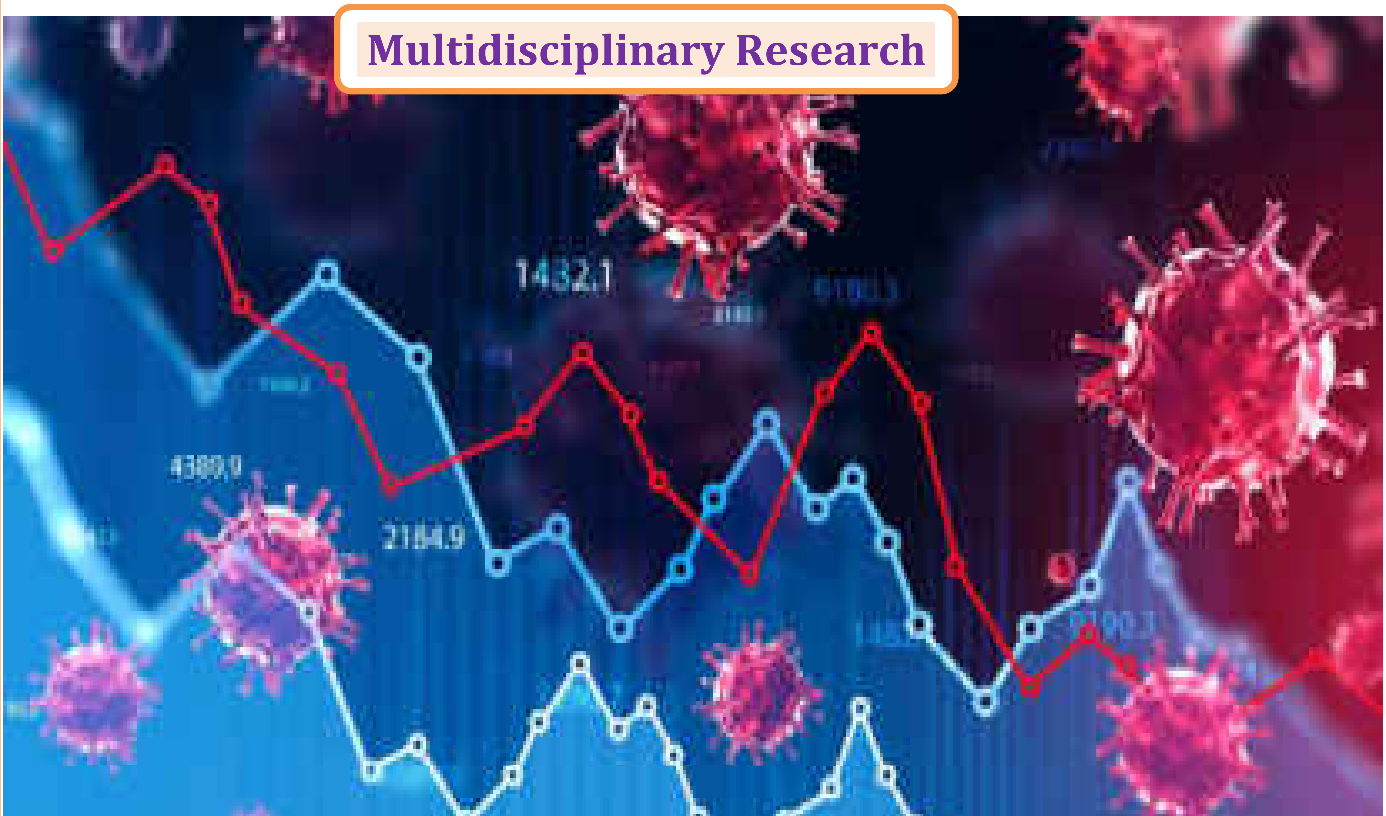

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Studies on Effects of Gamma Radiation on Iron Oxide in the Energy Range 122-1330 Kev

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Abstract:

In the presented research article the important Radiological parameters like Mass attenuation coefficient (µm), total cross-section (σt), electronic cross-section (σe), Molar Extinction coefficient (ε) and Effective atomic number (Z_{eff}) have been determined and investigated for iron oxide (Fe_2O_3 with the help of NaI (Tl) scintillation counter and compared the experimental data with the help of XCOM program. The gamma radiation photons were detected with the help of NaI (Tl) detector having resolution power of 8.2 % at 662 keV, in this experiment we using radioactive gamma ray sources such as 57Co, 133Ba, 137Cs, 54Mn, 60Co and 22Na. Data of μ_m for the iron oxide decrease with increasing photon energy. An experiment is done to avail the radiological data on iron oxide (Fe_2O_3) and to check the effects of gamma radiation produced on material with different energy ranges. It is observed from the current investigation that the investigated data found to be immense applications in the field of radiation industry, dosimetry, polymer industry etc.

Keywords:-Mass attenuation coefficient, effective electron density, poly-isobutylene.

Introduction:

Now days the use of applications of radiation & radiological data increases everyday accordingly large number of people were exposed to the harmful radiations and they may affected due that radiation. The analysis of mass attenuation coefficient (µm), total cross-section (σt) & electronic cross-section (σe) found too much importance in many fields such as medical field, shielding structural modification, agriculture industry and many more (R. R. Bhosale, D. K. Gaikwad, P. P. Pawar & M. N. Rode 2016). Every day the study on the dissymmetric substances has been increased. Many scientist studied and observed the effects and properties produced by gamma-ray using various research methods (Chen, S.; Bourham, M.; Rabiei, A. Radiat. Phys. Chem. 2012, J. Zsigrai, Tam C N, Andrev B. NIM B. 2015). Radiation induced effects in different investigated materials (Singh, T.; Kaur, P.; Singh, P.S. Asian J. Chem. 2009).

The iron oxide can be used in different fields such as industry, pigments, medical field etc. From the present current observation it can be clear that mass attenuation coefficient (µm) is the important parameter to study other radiological parameters such as atomic cross-sections (σt), electronic cross-sections (σe), a work is performed to find out the radiological effects produced due to gamma-radiation on iron oxide literature which is not found for the present material. The results obtained in the present work could be helpful in the radiation shielding against gamma radiation.

Effective atomic number (Z_{eff}) plays an important role in the determination of a substitute material for an element associated with the required energy (Hine, 1952). The energy absorption in a given matter can be measured by knowing the certain constants. Therefore the essential constants are Z_{eff} and also the electron density N_{eff} of the material. It is found that effective

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atomic numbers and electron densities are useful in many technological applications (Prdip Dahinde, pravina p. Pawr and R.R Bhosale, K.S.R. Sastry, S. Jnanananda 1958). No a day many scientist are interested in the determination of mass attenuation and different useful parameters of complex molecules in the different energy range from 5 to1500 keV this energy range of photons are widely applicable in the field of medical and biological applications (Hubbell, 1999) via different methods (Murut Kurudirek, 2013, 2014a, 2014b, 2014c, 2015; Midgley, 2004, 2005; Manohara and Hanagodimath, 2007; Demir et al., 2012; Murat Kurudirek and Tayfur Onaran, 2015; Danial Salehi et al., 2015).

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 mono-energetic 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.

$$I = I_0 e^{-\mu_m X} \qquad (1)$$

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):

$$\mu = 1/t \ln(I/Io) \qquad (2)$$

3.2 Total atomic cross section:

Total attenuation cross section (σ_t) is a fundamental parameter to describe the photon interaction with matter. The value of mass attenuation coefficient (μ_m) is used to determine Total atomic cross section (σ_t) by using the following relation (Hubbell, 2006; Erzeneoğlu et al., 2006).

$$\sigma_t = \frac{A}{N_A X} \ln(I_o / I) \qquad (3)$$

Where, *A* is molecular weight and N_A is Avogadro's number (6.02486×10^23).

3.3 Molar Extinction coefficient:

Molar Extinction coefficient (ε) is a measure of how strongly a chemical species attenuates light at a given wavelength.

The value of Molar Extinction coefficient (ε) is determined by using the following equation.

$$\varepsilon = 0.4343 N_A \sigma_t \qquad (4)$$

3.4 Electronic cross section

The electronic cross section (σ_e) is for an element is expressed by following relation

$$\sigma_e = \frac{\sigma_t}{\overline{Z}} \qquad (5)$$

Where $\overline{Z}$ is mean atomic number.

3.5 Effective atomic number:

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Effective atomic number (Z_{eff}) is also a important parameter and it is given by the equation as,

$$Z_{eff} = \frac{\sum_i W_i f_i A_i (\mu / \rho)_i}{\sum_i f_i (A_j / Z_j)(\mu / \rho)_j} \quad (8)$$

Where f_i is the mole fraction of each constituent element (provided $\sum_i f_i = 1$) and A_i is the atomic weight. In this study all the quantities are directly used (Manohara et al., 2008).

3. Experimental Details :

We measured incident and transmitted photon energies by using a narrow-beam good geometry set up. Fig. (a) Shows the schematic view of experimental set up. In this study we use the radioactive sources, 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. The Signals from the detector (2"×2") NaI (Tl) crystal having energy resolution of 8.2% at 0.662 MeV gamma rays from the decay of Cs^{137} after suitable amplification were recorded in an EG&G ORTEC 13-bit plug-in-card coupled with a PC/AT. 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 oxide (Fe_2O_3) under current 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):

$$2 \le \ln(\frac{I_o}{I}) \le 4.$$

The Mass attenuation coefficients 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 selected sample Fe_2O_3. The experiments were conducted in an air-conditioned room to avoid possible shifts of the photo-peaks. Room temperature of 26 ± 1°C was maintained throughout the experimental period. Other sources of error, excluding multiple scattering and counting statistics, are small-angle scattering, sample impurity, no uniformity of the sample, photo built-up effects, dead time of the counting instrument, and pulse pile effect which were evaluated and reduced.

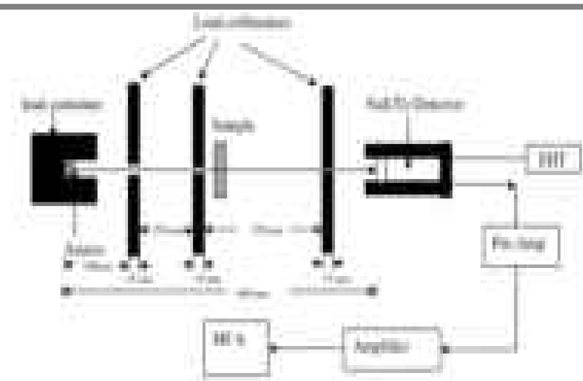

Fig.(a) Narrow beam good geometry set up.

No small-angle scattering corrections were applied to the measured data. All the four oxides samples used in this study were of high quality sigma Aldrich and of high purity (99.9 %) without high-Z impurities. Hence, sample impurity corrections were not applied to the measured data.

In the presented investigation, uncertainty in the mass per unit area and the error due to no uniformity of the sample are <0.04% 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 in this current investigation.

Table1: Gamma-ray parameters for iron oxide

Sr. No.	Energy range keV	μ_m Expt.	μ_m Theo.	σ_t Expt.	σ_t Theo.	σ_e Expt.	σ_e Theo.	ε Expt.	ε Theo.	Z_{eff} Expt.	Z_{eff} Theo.
1.	122	0.163	0.165	43.21	43.74	2.175	2.202	11.302	11.441	19.81	19.86
2.	356	0.102	0.100	27.04	26.51	1.475	1.440	7.072	6.934	18.33	18.33
3.	511	0.084	0.085	22.26	22.53	1.247	1.256	5.825	5.893	17.85	17.85
4.	662	0.073	0.072	19.35	19.08	1.099	1.084	5.061	4.990	17.55	17.55
5.	840	0.071	0.069	18.82	18.29	1.067	1.056	4.922	4.784	17.24	17.24
6.	1170	0.063	0.064	16.70	16.96	0.991	1.003	4.580	4.436	16.84	16.84
7.	1275	0.054	0.056	14.31	14.84	0.864	0.883	3.743	3.881	16.74	16.74
8.	1330	0.045	0.044	12.19	12.46	0.730	0.743	3.188	3.259	16.68	16.68

4. Results and Discussions:

In the Present investigation, the values of mass attenuation coefficient μ_m of investigated Iron oxides (Fe_2O_3). The variation between experimental and theoretical values of μ_m for iron oxide studied at 122, 360, 511, 662, 840, 1170, 1275- and 1330-keV photon energies are shown in Figure (b).

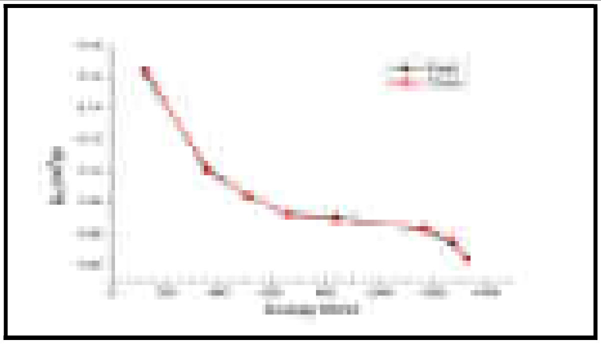

Fig.(b) Typical plot of mass attenuation coefficient versus photon energy.

It can be observed from the figure and table that μ_m decreases with increasing photon energy. It is observed that the behavior of σ_t and σ_e with photon energies is almost similar to that of μ_m. Molar extinction coefficients of Iron oxides are calculated using Eq. (4) is presented in table. It can be observed that ε initially decreases and tends to be almost constant at higher gamma ray energy and vary with the wavelength of the incident photons for all the samples.

5. Conclusion:

It can be clearly observed from the present work that the iron oxide used in this experimental work shows good attenuation at lower energy levels photons and can be used as gamma ray shielding material. The investigated and calculated values of radiological parameters from XCOM could be found beneficial uses viz. electronics industry, constructions, plastic industry, agriculture industry, medical field etc.

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