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Research Article

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Effective atomic number and electron densities for L Arginine LR at several photon energies

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ABSTRACT

Effective atomic number (Z_{eff}) and electron densities (N_e) have been determined for LArginine LR at 122, 356, 511, 662, 1170, 1275 and 1330 keV Gamma ray energies. The gamma rays were detected by using a well-type scintillation spectrometer .Results were compared with theoretically calculated values and fairly good agreement was found between them within an average experimental error. The variation of effective atomic number and electron densities have been plotted as a function of photon energy. The effective atomic number and effective electron densities are found to nearly remain constant as a function of energy.

Keywords: Effective atomic number, electron densities, Gamma-rays. L Arginine LR.

INTRODUCTION

The study of interaction of photons with matter finds wide application in areas such as industry, medical, radiation, dosimetry and radiation shielding. Extensive data on experimental photon interaction cross section measurements is available. A careful review of these measurements indicates that the studies are exhaustive in respect of pure element. However, measurements on photon materials are meagare.The mass attenuation coefficient, effective atomic number electron density, and photon mean free path are basic parameters which are required in solving various problems associated with the application areas of X rays and gamma rays. The mass attenuation coefficient, the effective atomic number and the electron density are basic quantities that are required in determining the penetration of X rays and gamma ray photons in matter. These parameters for biological samples are of significant interest.

The photons of energies from 122 to 1330 keV emitted from radioactive sources Co^{57} (0.122), Ba^{133} (0.356), Cs^{137} (0.662),Co^{60} (1.170, 1.330) and Na^{22} (0.511, 1.280) MeV are widely used in radiation biology in various applications particularly during diagnostics and therapy[1]. Hence in recent years, several experimental and theoretical investigations have been carried out to understand the nature of interaction of different biological molecules [2-9]. The three major gamma ray interaction processes viz photoelectric, Compton and coherent scattering and pair production can be expressed as a function of photon energy hν and atomic number Z of the element. At a given photon energy[7,10-12] the interaction is proportional to Z^n Where n is between 4&5 for photoelectric effect, 1 for Compton effect and 2 for pair production. The values of Z_{eff} for human tissues and other biological materials have been measured or calculated by investigators [1,13-15].Recently we have studied the effect of gamma ray interaction on different types of H,C,N&O based biological important compounds[16-18].

In composite materials like alloys, soils, plastic, biological materials etc,for photon interactions, the atomic number cannot be represented uniquely across the entire energy region, as in the case of elements by a single number. This number in composite materials is called "effective atomic number" and it varies with energies. Effective atomic number for gamma rays interactions for materials composed of various elements cannot be expressed by single number for each of the partial interaction process the number has to be weighted differently. The effective atomic number is a useful parameter for the interpretation of the attenuation of X ray or gamma ray radiation by complex medium The parameter "effective atomic number has physical meaning. The scattering and absorption are related to the density and effective atomic number of the material. The effective atomic number and the electron density of composites material are very useful parameters in the dosimetric calculation of radiation dose in radiotherapy and also in other medical emerging techniques. These parameters (Z_{eff} &N_e) have physical meaning and their value helps to characterize potentially useful material. The aim of present work is to determine the effective atomic number for L Arginine LR in energy range122 to1330keV.

Theory:

If a narrow parallel beam of monoenergetic X-ray or gamma photons passing through matter of thickness X is placed in the path of a beam of gamma or X ray radiations, then the intensity of the beam will be attenuated according to the Beer-Lambert law,

$$I = I_0 e^{-\mu x}$$

Where I_0 and I are the unattenuated and attenuated photon intensities respectively and the μ is the linear attenuation coefficient (cm^{-1}). The mass attenuation coefficient $(\mu/\rho)_c$ for any compound or mixture of elements (assumed homogeneous) is calculated using the mixture rule.

$$(\mu/\rho)_c = \sum_i W_i(\mu/\rho)_i \qquad (2)$$

Where W_i&$(\mu/\rho)_i$ are the weight fractions and mass attenuation coefficient of i^{th} constituent element, respectively. For a chemical compound the fraction by weight is given by,

$$Wi = n_iA_i / \Sigma_i n_iA_i \qquad (3)$$

Where A_i is the atomic weight of the i^{th} element, and n_i is the total number of atoms of the constitute elements. Theoretical values of effective atomic number Z_{eff} and Electron density N_e (10^{24} electrons g^{-1}) are calculated using an expression of the form

$$Z_{eff} = 0.28\ A_{eff}^{(1.329-0.0471nE)}\ E^{0.092} \qquad (4)$$

Here, E is in keV [19-27]. Using the values of Z_{eff} ,the effective electron density N_e is calculated using the expression

$$N_e = N_A\ Z_{eff} / A_{eff} \qquad (5)$$

Where N_A is the Avogadro's number.

EXPERIMENTAL SECTION

The authors measured the linear attenuation coefficient of the L Arginine LR sample by performing vertical narrow beam geometry. The diameter of the collimator is1.18cm. L Arginine LR foils of uniform thicknesses was placed below the source at a distance of 12.3 cm and 9.0 cm above the detector .To increase the thickness of L Arginine LR absorber foil, place the L Arginine LR absorber foils of known thickness (0.13 gm/cm^2) one by one between the source and the detector. The Sodium Iodide detector [0.75"x2"] was connected to PC based 8k-MCA.The authors measured (μ/ρ) for L Arginine LR foils at seven photon energies 0.122,0.356,0.511,0.662, 1.170, 1.275 and 1.330 MeV. Five standard gamma sources Co^{57} (0.122), Ba^{133} (0.356), Cs^{137} (0.662),Co^{60} (1.170, 1.330) and Na^{22} (0.511, 1.280) MeV are used. The results are shown in table 1.

The L Arginine LR samples under investigation were confined in cylindrical plastic containers or inner diameter 2.5 cm. It was found that the attenuation of the photon beam by the material of the empty containers was negligible. Each sample thus prepared was weighed in an electrical balance exactly to the third decimal place. The weighing was repeated a number of times to obtain concordant values of the mass. A mean of this set of concordant values was taken to be the mass of the sample. The inner diameter of each container was determined separately with the help of a traveling microscope by the usual method. Using the mean values of the mass and the inner diameter, the mass per unit area of each sample was determined. The thickness of the samples (mass per unit area) was chosen such that a $\mu t < 0.6$ [27] criterion was satisfied at each energy, in order to minimize the effects due to multiple scattering.

Table 1 Effective Atomic number Z_{eff} and Electron density N_e (10^{24} electrons g^{-1}) of L Arginine LR from 122 to 1330 keV.

Sr. No.	Energy keV	Z_{eff}	N_e (10^{24} electrons g^{-1})
1.	122	3.5488	0.3191
2.	356	3.5576	0.3199
3.	511	3.5610	0.3202
4.	662	3.5623	0.3203
5.	1170	3.5681	0.3208
6.	1275	3.5691	0.3209
7.	1330	3.5694	0.3209

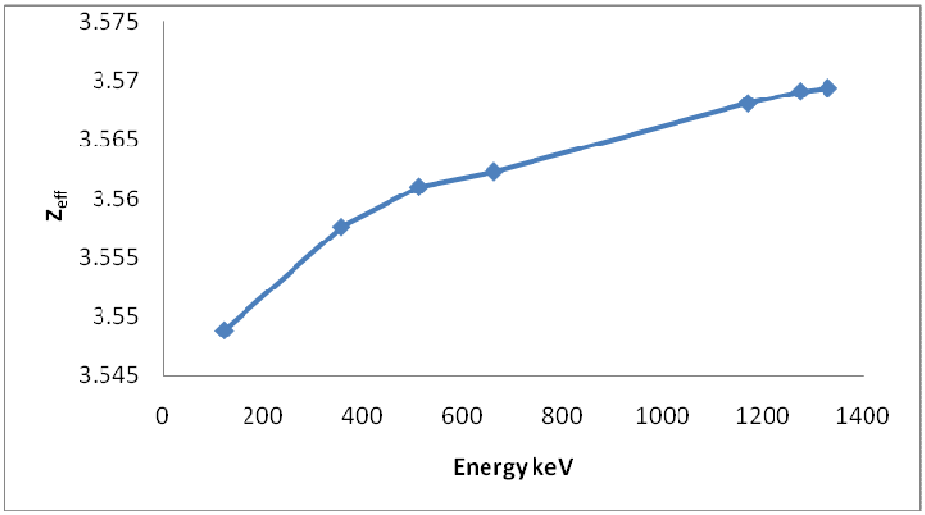

Fig-1 The variation of Effective Atomic number Z_{eff} vs photon energy of L Arginine LR from122 to 1330 keV.

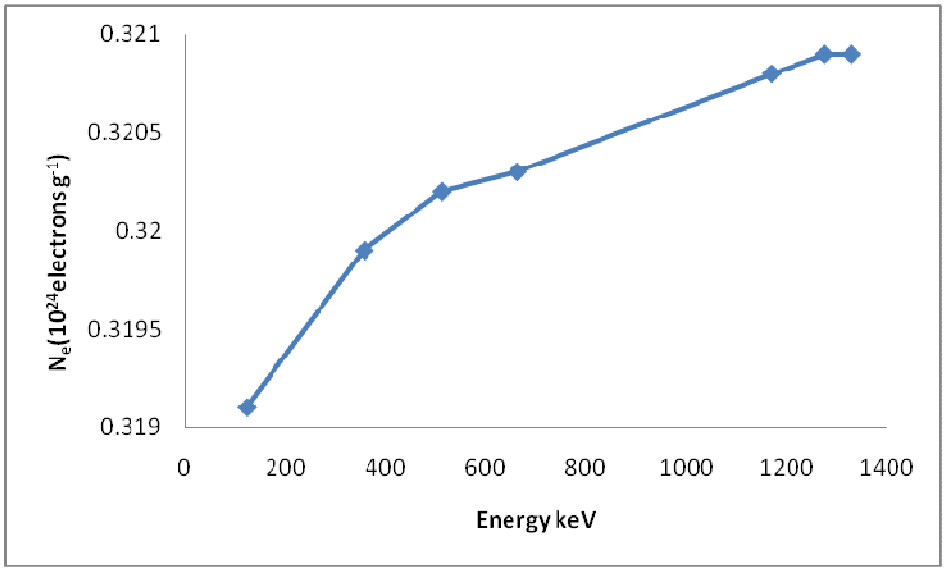

Fig-2 The variation of Electron density N_e (10^{24} electrons g^{-1}) vs photon energy of L Arginine LR from 122 to 1330 keV.

CONCLUSION

The theoretical values of effective atomic number Z_{eff} and electron density N_e (10^{24} electrons g^{-1}) for L Arginine LR are calculated. The agreement presently measured values with theory confirms the theoretical considerations of the contribution of various processes such as photoelectric effect, the Compton scattering and the pair production. The measured values of effective atomic number Z_{eff} and electron density N_e (10^{24} electrons g^{-1}) of L Arginine LR are useful in medical field. The data is useful in radiation dosimetry and other fields. To decide the radiation to be delivered without any harm to normal cells it is necessary to have a precise knowledge of gamma ray photon attenuation and consequent absorption. The conclusion of this work also confirms the results of our studies on other H,C,N&O based biomolecular system. The ratio of Z_{eff}/ A_{eff} was 0.53 for L Arginine LR containing H,C,N&O elements in the energy region from 122 to 1330 keV. Then the value of effective atomic number of the sample containing H,C,N&O is almost constant in the energy region122 to 1330 keV.The effective atomic number,Z_{eff} and the corresponding electron density N_e of the sample have been calculated in the energy region from 122 to 1330 keV using Win XCom [1], and its underlying data base of atomic photon-interaction cross sections [22]

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