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Effect of weight fraction of different constituent elements on the total attenuation coefficients of some amino acids in the energy range 10 KeV to 1500 KeV

Pravina Pawar and G. K. Bichile

Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad

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ABSTRACT

The total attenuation coefficients,$\sigma_{tot,}$ of biological materials such as amino acids have been studied as a function of weight fraction of constituent elements (hydrogen, carbon, oxygen and nitrogen).It is observed that in low energy region, the total attenuation coefficients,σ_{tot} is having higher value and as energy increases σ_{tot} values goes on decreasing. Also initially as weight fraction increases σ_{tot} values increase and then remain constant. The results have been presented in graphical form.

Keywords. Weight fraction; attenuation coefficient; biological material.

INTRODUCTION

The study of absorption of X-rays and γ-radiations in materials of common use and biological importance has been an important subject in the field of radiation physics. X-rays and γ –rays find wide spread applications in medical radiography and industrial non-destructive testing by virtue of their ability to penetrate matter and interact with all constituent atomic species. These properties are described by the exponential attenuation law. Their penetration and diffusion in materials can be characterized by the study of a parameter namely photon attenuation coefficient. A large number of photon attenuation measurements and theoretical calculations have been made for different materials. [1-8].

The attenuation coefficient studies have been performed as a function of different parameters. The study of absorption of γ-radiations in materials of biological importance has been an important subject in the field of radiation physics. Theoretical and experimental data on the transmission and absorption of γ-rays in biological, shielding and dosimetric materials assumed great importance by virtue of their various applications in the field of medical physics and radiation biology, as well as in many other areas related with human bodies. Complex biological molecules such as carbohydrates, proteins, lipids, enzymes, vitamins and hormones perform a variety of physiological functions in biological system [9] .These complex molecules have as their building blocks, carbohydrates, amino acids, fatty acids etc.,which are essentially H-,C-,N- ,O- based compounds . Since photons of energy from 1500 keV down to about 10 KeV are widely used in medical and biological applications [10]. Therefore, a thorough knowledge of the nature of interaction of biological molecules such as amino acids, carbohydrates, fatty acids etc. is highly desirable over this energy region .Hence, in recent years, several research studies have been performed to understand the nature of interaction of such biologically important molecules with photons in this energy region in terms of a parameter called total attenuation coefficient [11-23].

In this paper, we report theoretical values of total attenuation coefficient (cross- sections) of some amino acids in the energy region 10 keV to 1500 keV.and discuss the variation of σ_{tot} as a function of weight fraction of C-,H-,N- and O and energy.

Gamma radiations interact with matter predominantly by photoelectric effect, the Compton scattering and pair production process [24]

When a monoenergetic beam of gamma photons is incident on a target, some photons are removed from the beam due to the process mentioned above. Thus the transmitted beam is attenuated. Photon linear attenuation coefficient is nothing but the measure of a medium's ability both to absorb and to diffuse radiation. The extent of attenuation depends, for the given elemental target, on the photon energy. If a beam of monoenergetic gamma photons of intensity I_0 is incident on a target of thickness t, the transmitted intensity I_t decreases exponentially as

$$I_t / I_0 = e^{-\mu t} = e^{-\mu/\rho(\rho t)} = e^{-N\sigma} , \qquad (1)$$

where μ (cm^{-1}) is the linear attenuation coefficient , μ/ρ(cm^2 g^{-1}) is the mass attenuation coefficient, t (cm) is the thickness of the target, ρt (g cm^{-2}) is the mass thickness , σ(cm^2) is the atomic cross section and N is the number of atoms per cm^2 of the target. The linear attenuation coefficient μ is the probability per unit length that an incident gamma photon interacts with the target material, the mass attenuation coefficient μ/ρ is the probability per unit areal density that an incident gamma photon interacts with the target material, and σ is the cross section offered by an atom for interaction with the incident gamma photon. By determining experimentally I_t and I_0 for a given target thickness t, one can determine μ/ρ using relation :

$$\mu / \rho = \frac{\ln (I_t / I_0)}{t}. \qquad (2)$$

The total atomic cross section σ_{tot} is related to μ/ρ by

$$\sigma_{tot} (cm^2/g) = \mu/\rho \ (cm^2/g) \ \ x \ \ u\ (g) \ \ x \ \ A \ , \qquad (3)$$

where u (g) is the atomic mass unit which is (1/12) th of the mass of the carbon atom (1.6605402 x 10^{-24} g) and A is the atomic mass number of the target element. The total atomic cross section

σ_{tot} is the sum over the cross sections for the photoelectric effect, the Compton scattering and pair production processes.

In this work an attempt has been made to study the effect of H, C, N, and O weight fractions on the total attenuation coefficients,σ_{tot} ,of biological materials such as amino acids which are listed in table 1.

Table 1. Weight fraction of H,C,N and O of biological materials such as amino acids.

Material	% H weight fraction	Material	% C weight fraction	Material	% N weight fraction	Material	% O weight fraction
Aspartic acid	43.75	Glycine	20	Glutamic acid	5.26	Histidine	10
Histidine	45	Alanine	23.08	Aspartic acid	6.25	Alanine	15.39
Glutamic acid	47.37	Aspartic acid	25	Alanine	7.69	Glycine	20
Glycine	50	Glutamic acid	26.32	Glycine	10	Glutamic acid	21.05
Alanine	53.85	Histidine	30	Histidine	15	Aspartic acid	25

Computation of Photon cross section

The total attenuation coefficients,σ_{tot} ,of biological materials such as amino acids have been computed with the help of computer program (XCOM), Berger and Hubbell [25]:,in the energy range 10 KeV to 1500KeV.

There are two ways to use XCOM database. The text-based version outputs a basic text table of data. The other version gives the user more options and features (e.g., file-uploadind, graphing and graphical tables).The rest of the information in this document is appropriate for both avenues of output.

There are two forms to be completed to retrieve data. The first form produces the appropriate second form .The first form is concerned with general information (type of material: element, compound or mixture) ($Z \leq 100$).The second is more specific (energy values and graphing options). The specific input fields are described below.

The material for which cross sections are to be computed can be designated as an element, compound or mixture. The program will compute values for standard energies, but the user may also input additional energies.

In this database, by selecting the compound it is possible to obtain photon cross section data for a compound by filling the following information:

Identify material by: Compound

Method of entering additional energies (optional) Enter additional energies by hand.

Then submit the information .After this enter the formula for a compound and optional output title after this enter the energy range. Then submit the information. Finally we have obtained the data table containing required photon energy, Scattering coherent and incoherent, photoelectric absorption, Pair production and Total Attenuation with Coherent scattering and Without Coherent Scattering.

RESULTS AND DISCUSSION

The variation of the computed values of σ_{tot} due to weight fractions of different constituent elements is shown graphically (figures 1-4).

Figure 1 depicts the plot of σ_{tot} (cm^2/g) vs. hydrogen weight fraction at different energies. From this graph, it is seen that at low energies there is a large value of σ_{tot} and as energy increases there is a decrease in the value of σ_{tot} nearly about half. For photons with energy 0.279 MeV the σ_{tot} is 0.1165 where as for 1.33 MeV photons the σ_{tot} value is 0.0570. The variation of σ_{tot} with weight fraction is observed for low energy region (0.279 to 0.834); the σ_{tot} values increase up to 45 % hydrogen weight fraction, after this it remains constant up to 50% hydrogen weight fraction, and after that it again increases. For high energies 1.17 and 1.33 MeV the variation of σ_{tot} with weight fraction is remains nearly constant.

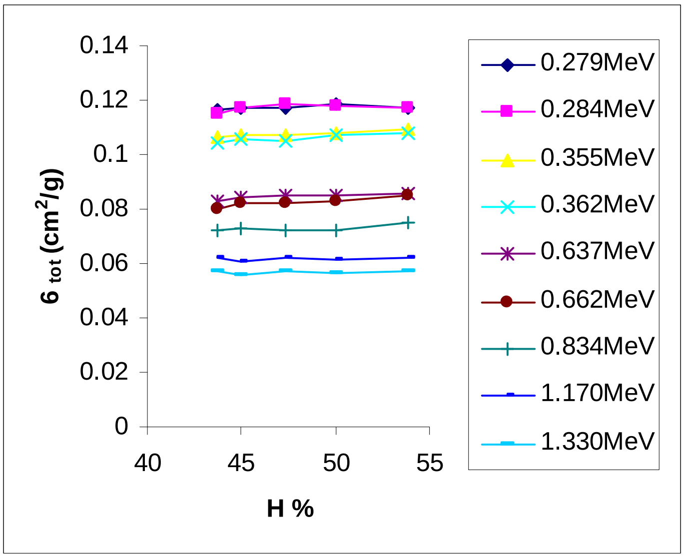

Fig. 1 Plot of σ_{tot} (cm^2/g) vs. hydrogen weight fraction at some energies.

Figure 2 depicts the plot of σ_{tot} (cm^2/g) vs. carbon weight fraction at different energies. From this graph, it is seen that at low energies there is a large value of σ_{tot} and as energy increases there is a decrease in the value of σ_{tot} nearly about half. For photons with energy 0.279 MeV the σ_{tot} is 0.11825 where as for 1.33 MeV photons the σ_{tot} value is 0.0558. The variation of σ_{tot} with weight fraction is observed for low energy region (0.279 to 0.834); the σ_{tot} values increase up to 23 % carbon weight fraction, after that it decreases up to 25% carbon weight fraction, and after that it again increases up to 27% carbon weight fraction and remain constant. And for higher energies 1.17 and 1.33 MeV the variation of σ_{tot} with weight fraction is nearly constant.

Figure 3 depicts the plot of σ_{tot} (cm^2/g) vs. nitrogen weight fraction at different energies. From this graph, it is seen that at low energies there is a large value of σ_{tot} and as energy increases there is a decrease in the value of σ_{tot} nearly about half. For photons with energy 0.279 MeV the σ_{tot} is 0.1175 where as for 1.33 MeV photons the σ_{tot} value is 0.0558. The variation of σ_{tot} with weight fraction is observed for low energy region(0.279 to 0.834)σ_{tot} values decreases up to 6 % nitrogen weight fraction, after that it increases up to 8 % carbon weight fraction, and after that it again decreases up to 10% nitrogen weight fraction and remain constant. And for higher energies 1.17 and 1.33 MeV the variation of σ_{tot} with weight fraction is nearly constant.

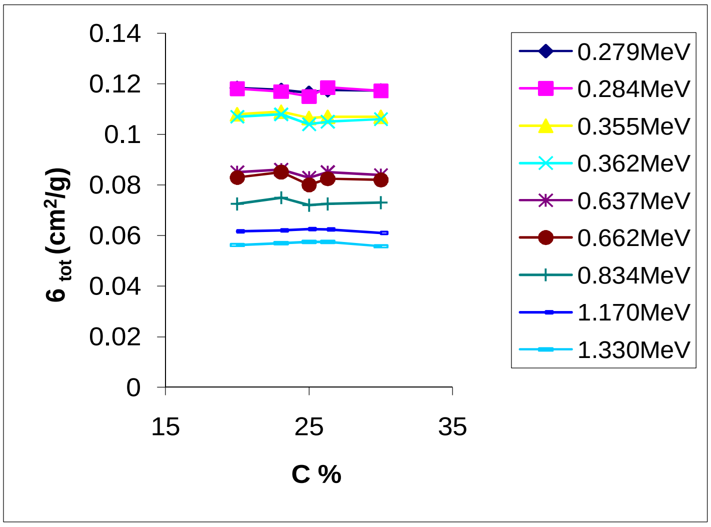

Fig. 2 Plot of σ_{tot} (cm^2/g) vs. carbon weight fraction at some energies.

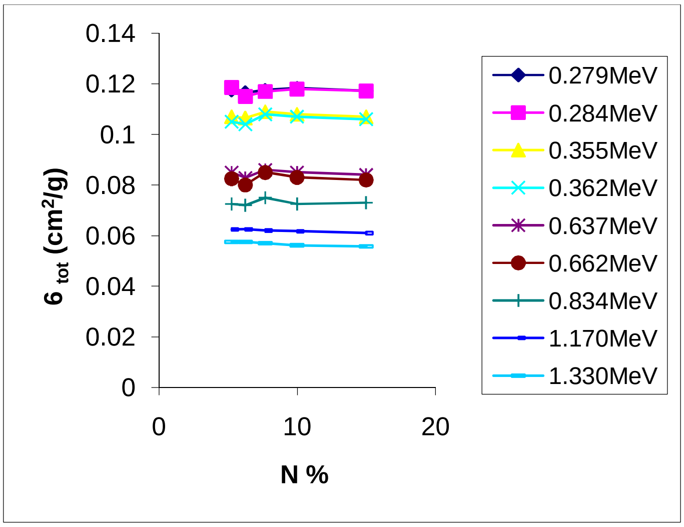

Fig. 3 Plot of σ_{tot} (cm^2/g) vs. nitrogen weight fraction at some energies.

Figure 4 is a plot of σ_{tot} (cm^2/g) vs. oxygen weight fraction at some energies which shows a different trend from those of H, C, and N weight fractions. There is no change in σ_{tot} value with increasing weight fraction; σ_{tot} remains nearly constant but as energy increases there is a decrease in σ_{tot} values for eg lowest energy is having σ_{tot} value 0.11725 and for highest energy it is 0.0575. The result predicts that considerable change in the σ_{tot} is seen only in the low energy region.

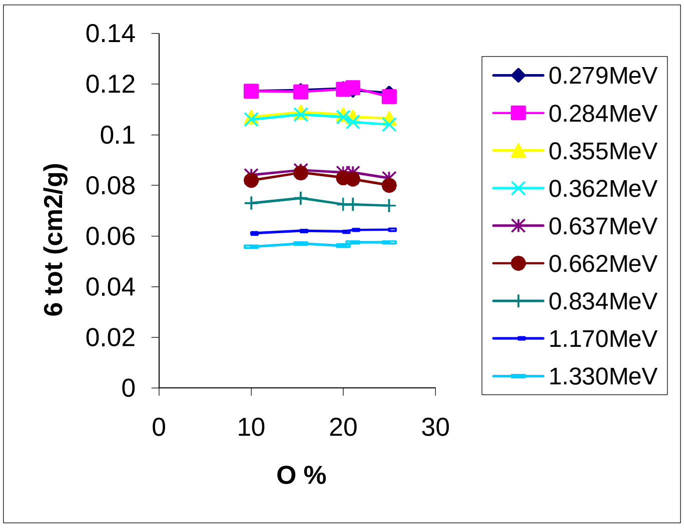

Fig. 4 Plot of σ_{tot} (cm^2/g) vs. Oxygen weight fraction at some energies

CONCLUSION

It is observed that in low energy region, the total attenuation coefficients,σ_{tot} is having higher value and as energy increases σ_{tot} values goes on decreasing. Also initially as weight fraction increases σ_{tot} values increase and then remain constant.

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