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Research Article

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Measurement of attenuation coefficient and mean free path of some vitamins in the energy range 0.122-1.330 MeV

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ABSTRACT

Vitamins are essential nutrients to the body needs in small amount to work properly. The attenuation coefficient is an important parameter for characterizing the penetration and diffusion of x-rays and gamma rays in biological material. The measurement of mass, linear and mean free path of biological samples viz. thiamine, adenine, pyridoxine and ascorbic acid in the energies 0.122, 0.356, 0.511, 0.662, 0.840, 1.170, 1.275, 1.330 MeV by using NaI(Tl) scintillation detector. The measured values of mass, linear attenuation coefficient and mean free path showed good agreement with theoretical values.

Keywords: Mass attenuation coefficient, linear attenuation coefficient**,** mean free path and NaI(Tl) detector.

INTRODUCTION

Investigation of radiation effect on biologically important molecules (Hydrogen, Carbon, Nitrogen and Oxygen based compound) find important immense application in the field of medical physics and radiation biology. Depending quantity of radiation absorbed by the biological matter, the extent of low doses are sufficient to modify and inactive the biomolecules. The absorbed dose is an important radiation quantity is defined as the energy absorbed per unit mass of matter with which radiation interacts, and its accurate measurement is vital to many application of radiation [1]. The attenuation coefficient (μ) is a basic quantity used in calculation of the penetration of material by quantum particles or other energy beams. The attenuation coefficient is also called linear coefficient or absorption coefficient. It depends only on the photon energy (E) and atomic number (Z) of an element. The mass-attenuation coefficients of elements, molecules and materials are widely used in plasma physics, dosimetry, space physics and many other applications in radiation studies [2,3]. Photons of energy range from 0.1 to 1.5MeV are used in medical and biological application [4]. In recent year several researcher studies have been performed to understand the nature of interaction of attenuation coefficient of biological important molecule [5,6,7,8]. Theoretical values for the mass attenuation coefficients can be found in the tabulation [3]. A convenient alternative to manual calculations using tabulated data is to generate attenuation data as needed using a computer. For this purpose Win-Xcom software for calculating mass attenuation coefficients or photon interaction cross-sections for any element compound for a wide range of energies .In this work we measured the mass and linear attenuation coefficient and mean free path for H, C, N and O based vitamins in the energy range 122 keV to 1330 keV compared these experimentally evaluated parameters with theory using Win-Xcom program [9].

The theoretical and practical values of $\mu_{m,}$ μand mfp obtained are found to be in good agreement with theory.

Theory:

In this section we summarize the theoretical relations related to mass attenuation coefficients and other parameters dependent on it. If in the path of a beam of gamma radiations a matter is placed, then the intensity of the beam will be attenuated according to the Beer-Lambert law, the attenuation of gamma rays in a medium is expressed by

$$I = I_0 \, e^{-\mu t} \tag{1}$$

Where, I_0 and I are the initial and final intensities of interacting photons respectively. μ is linear attenuation coefficient of the sample decreases exponentially and t is the thickness of a material. From equation (1) the linear attenuation coefficient (μ) is given by

$$\mu = \frac{1}{t} \ln\left(\frac{Io}{I}\right) \tag{2}$$

Where, $\ln(I_0/I)$ is the absorbance depends on the concentration and length of the sample. By introducing density of the material in above Equation (2) the mass attenuation coefficients μ/ρ ($cm^2\ g^{-1}$) for a sample is given by

$$\mu_m = \frac{\mu}{\rho}\left(cm^2 gm^{-1}\right) = \frac{1}{\rho t} \ln\left(\frac{Io}{I}\right) \tag{3}$$

Where, the density, ρ is calculated for material and express in the form of (g/cm^3).

The mean free path is the average distance a gamma ray travels in the absorber before interacting. The reciprocal of the attenuation coefficient has units of length and is often called mean free path.

$$\text{mean free path} = \overline{X} = \frac{1}{\mu} cm \tag{4}$$

Experiment Setup:

In this experiment to measure the incident and transmitted photon energies were done with the help of vertical narrow beam geometry set up. Fig.1 gives the schematic view of the experimental set up. The author measured linear attenuation coefficient of vitamin samples like B_1, B_4, B_6 and C at different photon energies 122, 356, 511, 662, 840, 1170, 1275 and 1330 keV by using NaI(Tl) scintillation detector. The diameter of the collimator is 1.18cm.The vitamin samples of required thickness were prepared in the form of 1cm diameter cylindrical pellets by pressing the weighed quantity of the finely ground powder in a hand operated hydraulic press. Each sample pellet was weighed in a sensitive digital balance having accuracy 0.001 mg. The weighing was repeated several times to obtain consistent value of the mass. The mean of this set of values was taken to be the mass of the sample. By using the diameter of the pellet and mean value of the mass of the pellet, the mass per unit area was determined in each case. The sample thicknesses were selected in order to satisfy the following ideal condition as far as possible [11]. Thickness of absorber was increased by placing pellets one by one between the source and the detector. The diameters of the samples were determined with the help of a traveling microscope. The pellets of uniform thickness placed below the source at a distance of 12.3cm and 9.0cm above the detector. The sodium iodide detector connected to PC based 8k-MCA. We measured mass attenuation coefficient for vitamin samples at eight photon energies by using six standard gamma source Co^{57}, Ba^{133}, Na^{22}, Cs^{137}, Mn^{54} and Co^{60}. The measured mass and linear attenuation coefficients have been compared with the values calculated based data [10].

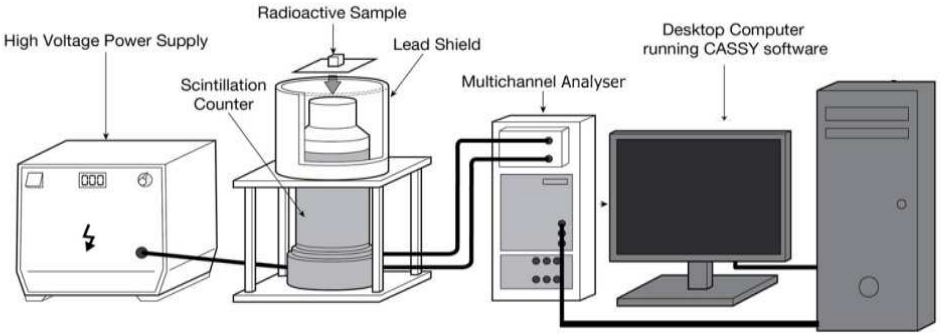

Fig. 1 The schematic view of the experimental set up

Table 1. Mass attenuation coefficient μ/ρ (cm^2 g^{-1}) of vitamins

Sr.No.	Source	Energy in keV	Thiamine		Adenine		Pyridoxine		Ascorbic acid	
			Expt.	Theo.	Expt.	Theo.	Expt.	Theo.	Expt.	Theo.
1	Co^{57}	122	0.161	0.160	0.152	0.150	0.155	0.154	0.154	0.152
2	Ba^{133}	356	0.104	0.105	0.102	0.103	0.108	0.106	0.105	0.104
3	Na^{22}	511	0.090	0.091	0.091	0.090	0.090	0.089	0.088	0.087
4	Cs^{137}	662	0.083	0.081	0.082	0.081	0.080	0.079	0.079	0.078
5	Mn^{54}	840	0.077	0.076	0.073	0.072	0.075	0.073	0.077	0.075
6	Co^{60}	1170	0.061	0.062	0.062	0.061	0.071	0.070	0.071	0.069
7	Na^{22}	1275	0.060	0.059	0.059	0.058	0.066	0.064	0.064	0.062
8	Co^{60}	1330	0.057	0.058	0.058	0.057	0.060	0.058	0.056	0.055

Table 2. Linear attenuation coefficient μ(cm^{-1}) of vitamins

Sr.No.	Source	Energy in keV	Thiamine		Adenine		Pyridoxine		Ascorbic acid	
			Expt.	Theo.	Expt.	Theo.	Expt.	Theo.	Expt.	Theo.
1	Co^{57}	122	0.230	0.229	0.243	0.240	0.210	0.208	0.301	0.297
2	Ba^{133}	356	0.149	0.150	0.163	0.165	0.146	0.143	0.205	0.203
3	Na^{22}	511	0.129	0.130	0.146	0.144	0.122	0.120	0.172	0.170
4	Cs^{137}	662	0.119	0.116	0.131	0.129	0.108	0.107	0.154	0.152
5	Mn^{54}	840	0.110	0.109	0.117	0.115	0.101	0.099	0.150	0.147
6	Co^{60}	1170	0.087	0.089	0.099	0.098	0.096	0.095	0.139	0.135
7	Na^{22}	1275	0.086	0.084	0.094	0.093	0.089	0.087	0.125	0.121
8	Co^{60}	1330	0.082	0.083	0.093	0.091	0.081	0.078	0.109	0.107

Table 3. Mean free path of 1/μ (cm) of vitamins

Sr.No.	Source	Energy in keV	Thiamine		Adenine		Pyridoxine		Ascorbic acid	
			Expt.	Theo.	Expt.	Theo.	Expt.	Theo.	Expt.	Theo.
1	Co^{57}	122	4.344	4.371	4.112	4.167	4.768	4.799	3.323	3.367
2	Ba^{133}	356	6.725	6.662	6.127	6.068	6.844	6.973	4.874	4.921
3	Na^{22}	511	7.770	7.686	6.868	6.944	8.212	8.304	5.816	5.882
4	Cs^{137}	662	8.432	8.636	7.622	7.758	9.239	9.356	6.478	6.561
5	Mn^{54}	840	9.083	9.208	8.562	8.711	9.855	10.125	6.646	6.824
6	Co^{60}	1170	11.468	11.287	10.081	10.204	10.410	10.559	7.208	7.417
7	Na^{22}	1275	11.655	11.862	10.593	10.776	11.198	11.548	7.996	8.254
8	Co^{60}	1330	12.270	12.063	10.776	10.965	12.318	12.743	9.139	9.305

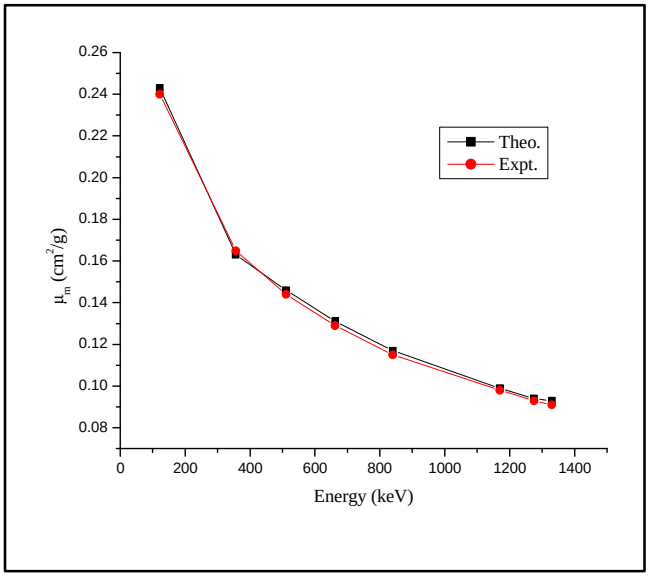

Fig. 2 Plot of mass attenuation coefficient (μ_m) verses photon energy for Adenine

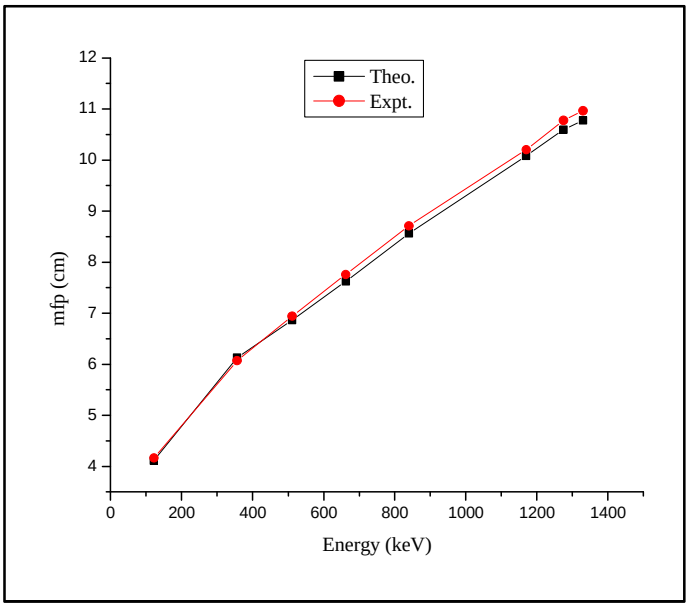

Fig. 3 Plot of mean free path (cm) verses photon energy for Adenine

RESULTS AND DISCUSSION

In the interaction of photons with matter μ_m values are dependent on the physical and chemical environments of the samples. The mass attenuation coefficient μ_m (cm^2/g) for the vitamins like thiamine, adenine, pyridoxine and ascorbic acid at 122, 356, 511, 662, 840, 1170, 1275 and 1330keV photon energies have been calculated.The mass attenuation coefficient (μ_m) values were found to decrease with increasing photon energy given in table 1 and variation given in fig. 2. The mean free path increases with increases in the energy of photons and decreases with increasing the atomic number given in table 3 and variation given in fig 3. Theoretical and experimental values of μ_m, $\mu$and 1/μrespectively and are found to be in good agreement with theory.

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