JCBPS; Section C; February 2018 – April - 2018, Vol. 8, No. 2; 068-074, E- ISSN: 2249 –1929
[DOI: 10.24214/jcbps.C.8.2.06874.]

Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

*Available online at*www.jcbsc.org

Section C: Physical Sciences

CODEN (USA): JCBPAT Research Article

Absorption studies in dilute solutions of few amino acids at 662 keV gamma energy

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Received: 23 March 2018; **Revised:** 07 April 2018; **Accepted:** 14 April 2018

Abstract: The gamma absorption studies in dilute solutions of amino acids has been carried out using NaI(Tl) scintillation detector coupled with single channel analyzer at 662 keV gamma energy. The mass absorption coefficients of gamma radiation by dilute amino acid solutions are studied for 10 % concentration. The present study explored the validated exponential absorption law for gamma radiation in solutions. A comparison of experimental results with theoretical values revealed the validity of mixture rule. This study proved to be a base study for extension of applications towards investigating the purity of liquid samples and quality control of the liquid materials.

Keywords: Attenuation coefficient, Gamma absorption, Mixture rule, Single Channel Analyzer

INTRODUCTION

Radiations and various radionuclides have been adopted in many fields of science such as agriculture, medicine, academics and industry. Radiopharmaceutical drugs containing radioactive materials have become important in diagnosis and treatment of many diseases. For instance, X-rays have been successfully employed in image formations and gamma rays are being used in biological studies, radiation sterilization and industries. This increasing use of radionuclides in various fields has made researchers to precisely understand the interaction of photons with biologically important substances. The study of absorption of gamma radiation in various shielding materials is important subject in the field of radiation physics[1]. The linear and mass attenuation coefficient are important parameters and

widely used in industry, agriculture, science and technology etc. and have been measured by researchers in various materials[2-4]. Linear and mass absorption coefficients have been measured for various types of mixtures using the popular mixture rule. In 1982, Hubbell published tables of mass attenuation coefficients for more than 40 elements, compounds and mixtures[5]. Later a detailed tabulation of cross sections and mass attenuation coefficients has been published by Hubbell and Seltzer[6] and Chantler[7]. The theoretical calculations of mass attenuation coefficients of various elements, compounds and mixtures have been programmed and available in a web version. This well known and much used program has been transformed to the Windows platform by Gerward *et al.*[8] The windows version of XCOM is called WinXCom. The measurement of mass absorption/attenuation coefficients have been carried out in both solid and aqueous form of samples. People around the world have worked over the measurement of attenuation parameters in many amino acid samples.

In the present work an attempt has been made to determine the mass absorption coefficients in few amino acids viz. L-Lysine, L-glutamic acid, L-arginine, Phenylalanine and L-Glutamine in aqueous form. The mass absorption coefficients have been measured using NaI(Tl) scintillation detector coupled with single channel analyzer. The work would reveal the knowledge of gamma interaction with matter providing the mass attenuation coefficients of amino acids. This investigation would also throw light on the utility of scintillation detector coupled with single channel analyzer for students and researchers.

THEORY

The mass attenuation coefficient (μ/ρ) can be defined as a measure of the average number of interactions between incident photons and matter that occur in a given mass per unit area thickness of the substance. The mass attenuation coefficient usually depends upon the energy of radiation and nature of the material. For characterization, the penetration and diffusion of gamma radiation in any medium, the roll of attenuation coefficient is very important[4].

Lambert developed the equation for attenuation of a photon beam as a function of the thickness of a homogeneous medium. Beer developed the equation for the effect of concentration[3]. According to Beer Lambert law the probability that a photon will be absorbed in a medium is directly proportional to the concentration of the absorbing molecule and to the thickness of the sample.

The linear attenuation coefficient can be obtained from the rearrangement of Beer Lambert's law.

$$\mu = \frac{1}{t} \ln \frac{I_o}{I} \qquad (1)$$

where, t is the path length or thickness of the absorber in cm.

The mass attenuation coefficient μ/ρ (cm^2/g) for the absorber sample can be obtained as

$$\frac{\mu}{\rho}\left(cm^2 / g\right) = \frac{1}{\rho t} \ln\left(\frac{I_0}{I}\right) \qquad (2)$$

Where ρ (g/cm^3) is a measured density.

For a given gamma-ray energy, the mass attenuation doesn't change with the physical state of a given absorber. The mass attenuation coefficient for a compound or mixture is given by the mixture rule[9]

$$\left(\frac{\mu}{\rho}\right)_C = \sum_i w_i \left(\frac{\mu}{\rho}\right)_i \quad (3)$$

Where w_i and $(\mu/\rho)_i$ is the weight fraction and mass attenuation coefficient of the constituent element in a mixture.

Theoretically the values of (μ/ρ) for binary solutions of different concentration can be obtained by mixture rule. The mathematical expression are given as[3]

$$\left(\frac{\mu}{\rho}\right) = \left(\frac{\mu}{\rho}\right)_s w_s + \left(\frac{\mu}{\rho}\right)_w (1 - w_s)$$

$$\left(\frac{\mu}{\rho}\right) = \left(\frac{\mu}{\rho}\right)_w + \left[\left(\frac{\mu}{\rho}\right)_s - \left(\frac{\mu}{\rho}\right)_w\right] w_s \quad (4)$$

Where $(\mu/\rho)_s$ is the mass attenuation coefficient of the solute, $(\mu/\rho)_w$ is the mass attenuation coefficient of water and w_s is the weight fraction of the solute.

Experimentally linear attenuation coefficient for solution can be obtained by

$$\mu_{\exp} = \frac{1}{h} \ln \frac{I_O}{I} \quad (5)$$

Where h is the path length or thickness of the sample in cm. And the mass attenuation coefficient can be measured using linear attenuation coefficient and density of the sample.

$$\left(\frac{\mu}{\rho}\right)_{\exp} = \frac{\mu_{\exp}}{\rho} \quad (6)$$

MATERIALS AND METHOD

The Cs-137 gamma source has been used for emission of 662 keV gamma energy. Amino acid samples viz. L-lysine, L-glutamic acid, L-arginine, Phenylalanine and L-Glutamine purchased from the chemical shops has been analyzed in the study. The aqueous solutions of the samples of 10% concentration for all samples were prepared by dissolving measured quantity of amino acid in 100 ml of distilled water.

In the present work, Thallium activated sodium iodide detector coupled with single channel analyzer (model GRS 612), procured from Nucleonix system, Hyderabad, was adopted. Cs-137 source was used for producing gamma rays of energy 662 keV. A beaker with graduation marks for sample solution is placed vertically between the source and detector. The path length of solution for gamma ray transmission is x = 6 cm. The operating voltage and resolution of the detector were measured. A schematic diagram of the experimental arrangement is shown in Fig 1. Resolution of a scintillation spectrometer is specified in percentage and defined as the full width at half maximum of the photopeak spectrum. Aqueous solution of amino acid of varying heights (h = 0 cm to 6 cm) was taken in the sample container and counted for 900 s. The source detector distance and sample detector distance was maintained throughout the experiment.

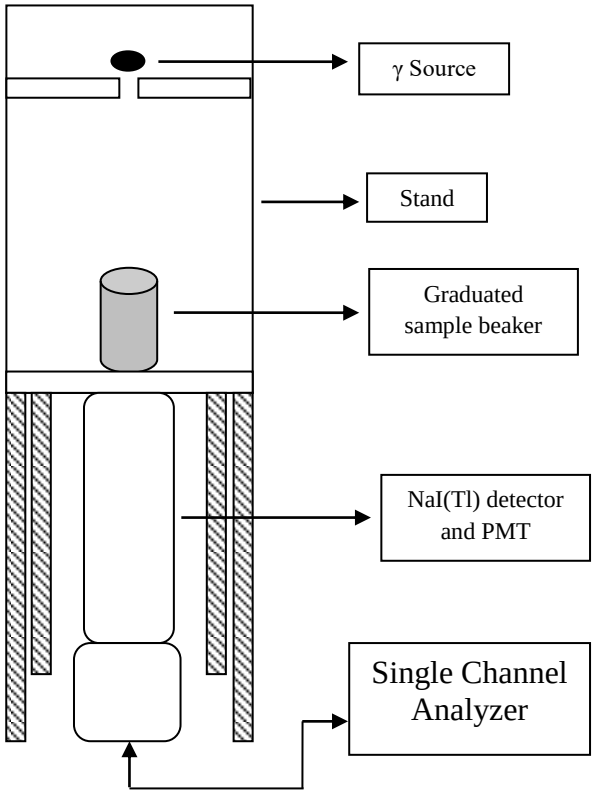

Fig. 1. : Schematic diagram of Experimental arrangement.

RESULTS AND DISCUSSION

The resolution of the detector was measured to be 7.4 % which is in agreement with the standard range for the resolution of scintillation detector, i.e.,7-10 %. Fig 2 shows the plot of unattenuated transmitted radiation and attenuated transmitted gamma radiation. The relative gamma transmission i.e. the ratio of gamma transmitted counts (I_0) without absorber to gamma transmitted counted with absorber (I) were observed to be linearly increasing with increasing path length of absorber in cm. The linear and mass attenuation coefficient values were measured from the slope of plots of ln (I_0/I) against the path length, h in cm as shown in Fig 3. The results are tabulated in table 1 for all the study samples. The mass attenuation coefficient values for amino acid samples were found to vary from 0.07843 to 0.0953 cm^2/g. The theoretical values of mass absorption coefficient for all the samples also were calculated using WinXCOM program[5,8]. A good to moderate agreement of the experimental and theoretical values were observed in all the samples with slight deviation. The deviation is quite possible as it is known that the values are affected by the chemical, molecular and thermal environments. Also, since the calculation of the theoretical values has been done by considering the cross section for an isolated atom[10]. This difference also might be from experimental setup, counting and efficiency errors[11]. Few researchers have worked with the measurement of mass absorption coefficient for amino acid samples[1,12,13]. It can be observed that mass attenuation coefficient depends on the chemical content and form of the sample. Also the linear and mass absorption coefficient and

related parameters are useful parameters for low and medium atomic number materials encountered in biological and medical applications[11].

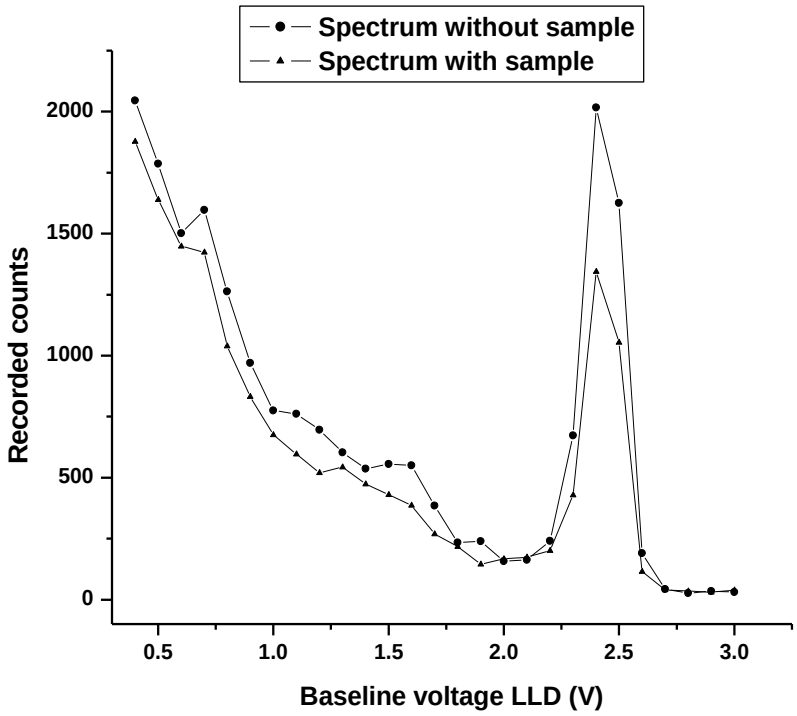

Fig. 2. : Gamma Photopeak intensity of unattenuated and attenuated transmitted radiation.

Table 1: Linear and Mass attenuation coefficients of amino acid samples in aqueous form

Sample	Chemical formula	Linear attenuation coefficient μ (cm^{-1})		Mass attenuation coefficient μ/ρ (cm^2/g)		
		Theoretical	Experimental	Theoretical	Experimental	% error
L-lysine	$C_6H_{14}N_2O_2$	0.08665	0.08655	0.08562	0.08551	0.12
L-glutamic acid	$C_5H_9NO_4$	0.08482	0.07794	0.08536	0.07843	8.11
L-arginine	$C_6H_{15}N_4O^+_2$	0.08419	0.08331	0.08550	0.08460	1.05
Phenylalanine	$C_9H_{11}NO_2$	0.08557	0.09555	0.08540	0.09530	11.6
L-Glutamine	$C_5H_{10}N_2O_3$	0.08487	0.0946	0.08541	0.09520	11.5

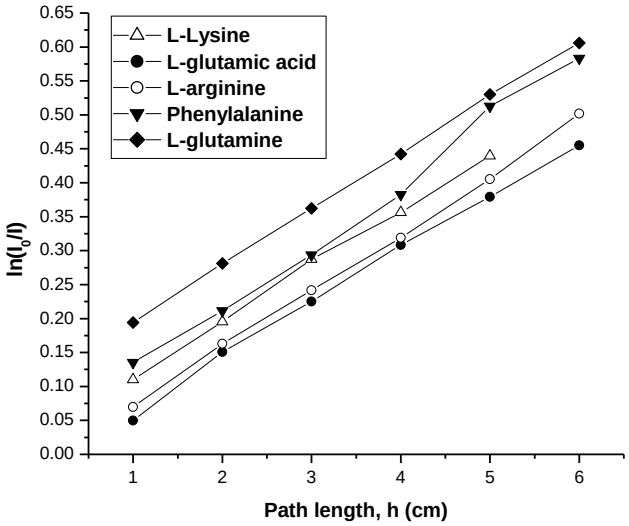

Fig. 3: Variation of $\ln(I_0/I)$ with path length h (cm) of amino acid solution.

These observations verified the gamma absorption law and famous mixture rule applicable to mixtures for the determination of mass absorption coefficients. So, the present experimental work proves the suitability of the WinXCom to that estimated values by using the mixture rule[9]. Also this technique of technique of measuring mass attenuation coefficient proves to be simple, quick, non-destructive and a successful tool to analyze the quality control of the materials involving amino acids through the relative intensity measurements[14]. The results obtained also justifies the utility of NaI(TI) detector for the mass attenuation studies in biologically important compounds and the method can be easily adopted by students for academic purposes.

CONCLUSION

The linear and mass attenuation coefficients depend on gamma energy and chemical content of the materials. The work revealed the validation of gamma absorption law and mixture rule for dilute solutions of amino acids. The study also proved the successful utility of NaI(Tl) detector for attenuation studies for biologically important compounds was performed and found to be satisfactory. Also this type of work can be applied to check the adulteration in processed liquids and is a simple non destructive method for analysing quality control of materials.

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Online publication Date.14.04.2018