Absorption Coefficient of Polymers (Polyvinyl Alcohol) by Using Gamma Energy of 0.39 MeV

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Abstract. The gamma absorption coefficents are very important parameters widely used in Medicine, agriculture, science and technology, basic sciences and in research area. The mixture rule is developed by Chaudhari and Teli for determination of absorption coefficients of various salts by using various gamma ray energies and compared theoretical and experimental results with Hubbell's tables. By using this method, the gamma absorption coefficients of Polymers Poly(vinyl alcohol) studied at various concentrations by using various source at 0.39MeV. The results are in good agreement.

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1 Introduction

The study of interaction of radiations with materials of common and industrial use, as well as of biological and commercial importance, has become a major area of interest in the field of radiation science. A scientific study of interaction of radiation with matter demands a proper characterization and assessment of penetration and diffusion of rays in the external medium. The mass attenuation co-efficient usually depends upon the energy of radiation and the nature of material. The study of mass attenuation coefficient of various materials has been an important part of research in Radiation Chemistry and Physics.

There are various literature reported by scientists [1-20], Hubbell [8] has compiled an extensive data on mass attenuation coefficients of gamma rays in some compounds and mixtures of dosimetric interest in the energy range 1 keV to 20 MeV. Hubbell *et al.* [8] have compiled an updated version of attenuation coefficients for elements having atomic number 1–92 and for 48 additional substances. Carlsson, Cunningham, Jahagirdar, Singh *et al.* [2-10] have conducted systematic studies of attenuation coefficients from time to time. The method of measurement of linear and mass attenuation coefficients of gamma rays for salts

by using their aqueous solutions has already been developed by Teli *et al.* [19] and they have measured linear and mass attenuation coefficients of salts. The method is further improved by Teli *et al.* by considering the fact that the volume of the solution must be equal to the sum of the volume of salt(solute) and of water solvent. The mathematical expression of mixture rule is

$$[\mu/\rho]_{\text{solution}} = [\mu/\rho]_{\text{solvent}} + [(\mu/\rho)_{\text{solute}} - (\mu/\rho)_{\text{solvent}}](m_{\text{solute}}/m). \quad (1)$$

The linear dependence of μ as concentration c given by the above equation and provides a useful method for the direct determination of μ and μ_s/ρ_s. The experimental graph of μ against c demonstrates accord with a linear linear ship. Experimental measurements provide an estimate slope, enabling us to calculate μ and μ_s/ρ_s.

The mixture rule for the mass attenuation coefficient of a compound is given by

$$(\mu/\rho)_i = \sum W_i[\mu/\rho]_i, \quad (2)$$

where $(\mu/\rho)_i$ and W_i are the total mass attenuation and the weighing factors, respectively, of the constituent elements of the compound mixture.

2 Experimental Set-Up

The schematic experimental set-up is shown in Figure 1.
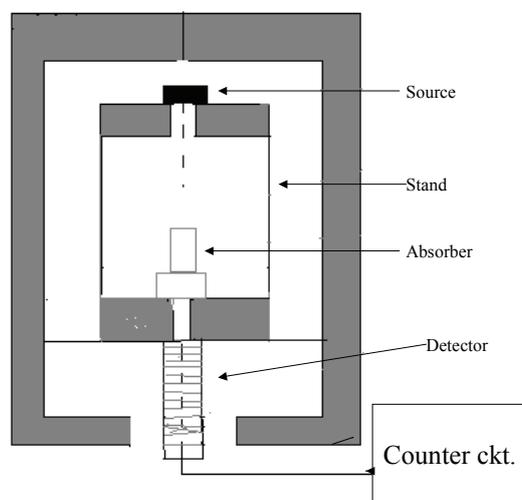

Figure 1. Experimental block diagram.

3 Experimental Method and Observations

A cylindrical beaker of internal diameter of 3.2 cm was placed just below the shielded gamma source Sn^{113} of energy 0.39 MeV. The apparatus is kept in a stand. The assembly was placed directly over the detector. The detector is connected to MCA plug in card coupled to a personal computer.

While taking the readings a sufficient number of counts were collected under photo peak to limit the static error to less than 1%. First the beaker was kept empty and reading for zero path length was obtained for gamma rays of a particular energy and noted as N_0. Thereafter the path length was increased by filling the desired solution in the beaker up to levels marked at 1 cm, 2 cm, 3 cm, 4 cm successively.

The absorption of radiation is characterized by the equation

$$N = N_0 \exp\left(-\mu x\right), \tag{3}$$

where N_0 is the number of particles of radiation counted during a certain time duration without any absorber, N is the number counted during the same time with a thickness x of absorber between the source of radiation and the detector, and μ is the absorption coefficient. This equation may be cast into the linear form

$$\ln N = -\mu x + \ln N_0. \tag{4}$$

The mass absorption coefficient μ_m is defined as

$$\mu_m = \frac{\mu}{\rho}, \tag{5}$$

where ρ is the mass density of the absorber. The attenuation coefficient is represented by the symbol μ, and measured in cm^{-1}.

4 Preparation of Solution of PVA

Dissolving of polymers is a slow process that occurs in two stages. First solvent molecules slowly diffuse into the polymer to produce a swollen gel. If the polymer–polymer intermolecular forces due to hydrogen bonding, crystallinity or cross linking are overcome by introduction of strong polymer–solvent interactions, the second stage of solution takes place. Here the gel gradually disintegrates into a true solution. Only this stage can be materially speeded up by agitation. The solution of polymer depends upon the number of factors such as topology of the polymer, the degree of crystalline, the nature of solvents and conditions maintained [23].

Polyvinyl alcohol unlike many other polymers is water soluble. It dissolves slowly in cold water but more rapidly at evaluated temperatures. It can be dissolved completely at 90°C.

Preparation of stock solution 95% PVA : 25 g of PVA in the form of solid crystal was first taken in a beaker and then stirred with 300–400 ml of water at temperature of 60–70°C for one hour. After overcoming the first stage of gel stage formation, a true solution is formed. This solution is diluted to exactly 500 ml using volumetric flask. The solution thus obtained has concentration 5 g/100cc, *i.e.*, 5%. Other more dilute solutions of polyvinyl alcohol were prepared by using this 5% solution. The amount of 5% solution to be added to prepare 100 ml of each solution was calculated using equation

$$N_1 V_1 = N_2 V_2. \tag{6}$$

The dilutions of 5% solution used for preparing other solution.

	Solution concentration			
	1%	2%	3%	4%
Dilution of 5% solution	$20 \rightarrow 100$ ml	$40 \rightarrow 100$ ml	$60 \rightarrow 100$ ml	$80 \rightarrow 100$ ml

5 Observation Tables

Counts recorded for various thickness (cm) and concentration of PVA at 0.39 MeV as shown in Table 1. Counts for zero path length $N_0 = 5436$.

Table 1. Counts per 30 min

Thickness	Concentration				
	1%	2%	3%	4%	5%
1 cm	4871	4860	4851	4847	4774
2 cm	4481	4428	4452	4380	4282
3 cm	4275	4204	4053	3837	3696
4 cm	3591	3534	3501	3473	3353

Table 2. $\ln N_0/N$ for various thickness (cm) and concentration of PVA at 0.39 MeV

Thickness	Concentration				
	1%	2%	3%	4%	5%
1 cm	0.109744	0.112005	0.113859	0.114684	0.129859
2 cm	0.193197	0.205095	0.19969	0.215995	0.238623
3 cm	0.240259	0.257007	0.293586	0.348353	0.385792
4 cm	0.414613	0.430613	0.439995	0.448025	0.483188

Table 3. Values of μ/ρ versus mass fraction of PVA at 0.39 MeV

PVA concentration	μ (cm^{-1})	Density ρ (g/cc)	μ/ρ (cm^2/g)	m_2/m
1%	0.0960	1.0038	0.095607	0.0100
2%	0.1006	1.0057	0.10005	0.0199
3%	0.1060	1.0073	0.105202	0.0298
4%	0.1130	1.0096	0.111896	0.0396
5%	0.1222	1.0115	0.120811	0.0494

From the above observations the graphs of path length (*i.e.* thickness in cm) *vs.* counts /sec. are plotted for the concentrations 1%, 2%, 3%, 4%, 5%. The experimental data are fitted by the least square method. The results show a linear straight line and indicate the relation

$$\mu = (\mu_s - \mu_w)/\rho_s + \mu_w. \tag{7}$$

The linear dependence of μ as concentration c given by the above equation and provides a useful method for the direct determination of μ and μ_s/ρ_s. The experimental graph of μ against c demonstrates accord with a linear linear ship. The experimental measurements provide an estimate slope, enabling us to calculate μ and μ_s/ρ_s.
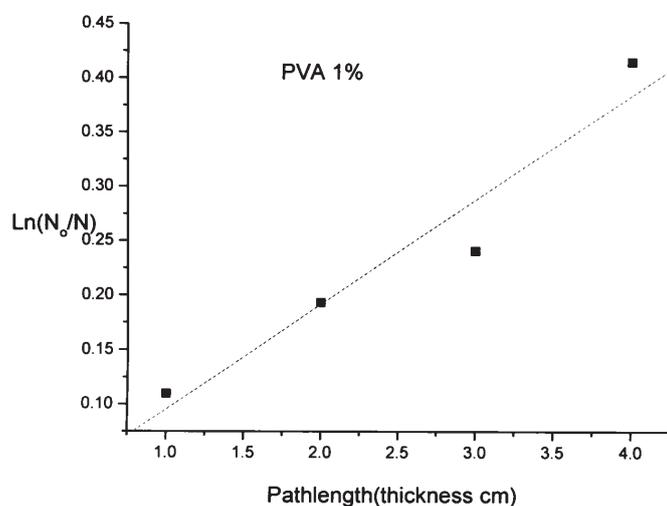

Figure 2. Path length (thickness in cm) *vs.* $\ln N_0/N$ for concentration PVA 1% at energy 0.39 MeV.

6 Results

From Table 2, the graphs of path length (thickness cm) *vs.* $\ln N_0/N$ are plotted for the concentrations 1%, 2%, 3%, 4%, 5%, respectively, as shown in Figures 2–6. Also from Table 3, the graph of m_2/m *vs.* mass absorption coefficients is plotted in Figure 7.
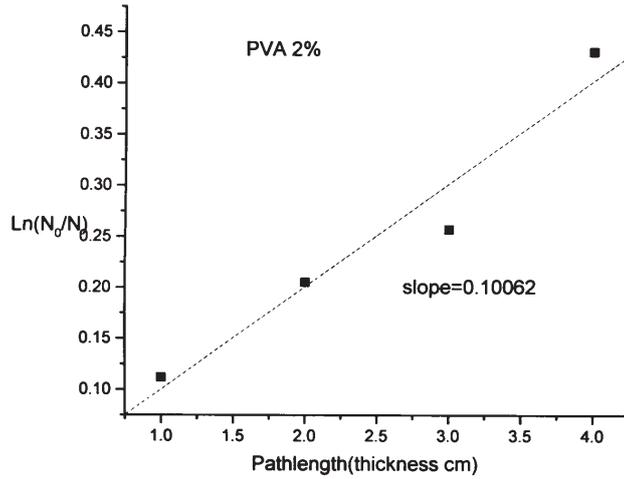

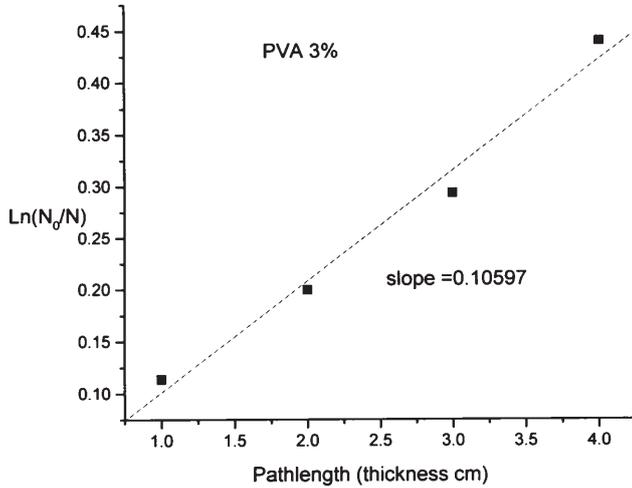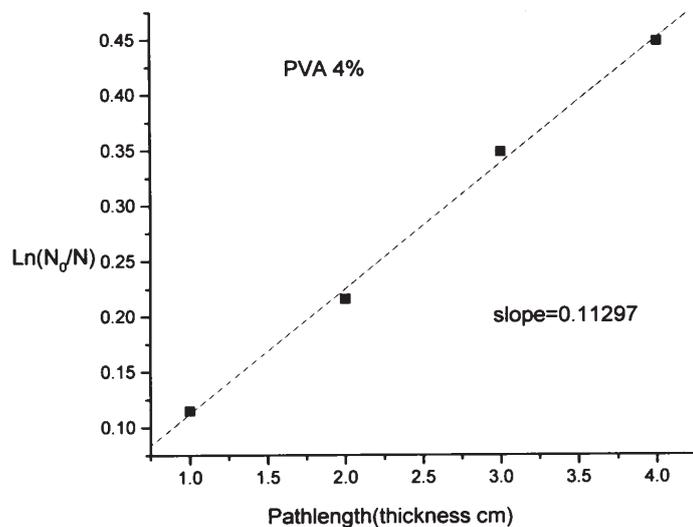Figure 3. Path length (thickness in cm) *vs.* $\ln N_0/N$ for concentration PVA 2% at energy 0.39 MeV.

Figure 4. Path length (thickness in cm) *vs.* $\ln N_0/N$ for concentration PVA 3% at energy 0.39 MeV.

Figure 5. Path length (thickness in cm) *vs.* $\ln N_0/N$ for concentration PVA 2% at energy 0.39 MeV.
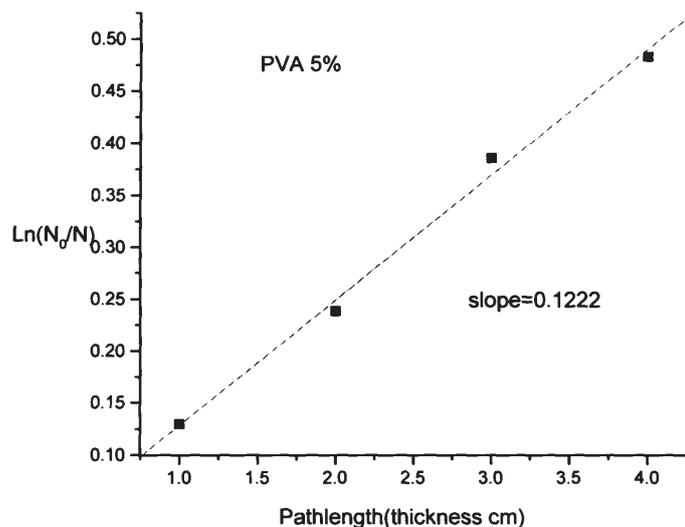

Figure 6. Path length (thickness in cm) *vs.* $\ln N_0/N$ for concentration PVA 3% at energy 0.39 MeV.

7   Conclusions

The study of absorption coefficients at 0.39 MeV of polyvinyl alcohol solution explores the validity of the exponential absorption law for gamma radiation in
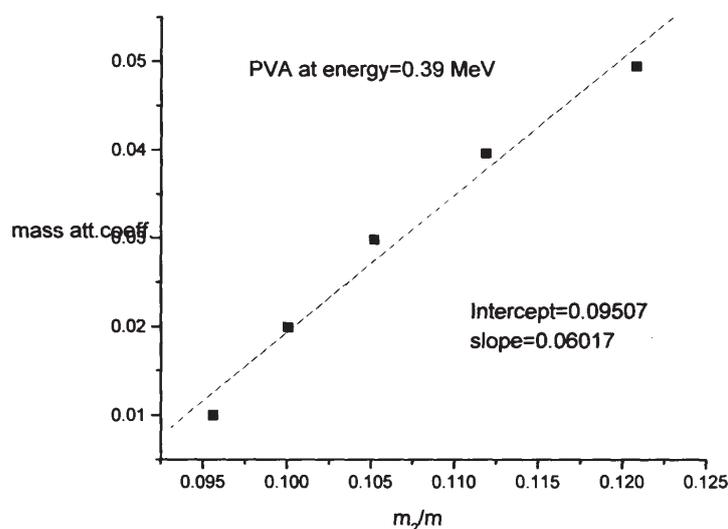
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Figure 7. m_2/m *vs.* mass absrorption coefficient at energy 0.39 MeV.

solutions. Also this is an alternative method for the determination of linear and mass attenuation coefficients for soluble substances in solid form without preparing their pure crystals. This method is also used to determine the density. The theoretical value of mass attenuation coefficient is 0.1603 cm^{-1} and the experimental value is 0.1559 cm^{-1}. The results are in good agreement with theoretical results. The other work is in progress.

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