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Finding Mass Attenuation Coefficient of Behenic Acid by Using Gamma-Ray Sources.

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Abstract: *This measurement aims to determine the mass attenuation coefficient (μ/ρ) of the sample. This paper used ($C_{22}H_{44}O_2$) Behenic fatty acid, exposed to gamma rays (γ), emitted from various sources ^{57}Co, ^{133}Ba, ^{22}Na, ^{137}Cs, ^{54}Mn, and^{60}Cowith energies from 0.122 to 1.330 MeV. It exposes the compound to gamma rays and discloses the radiation force that passes through the sample, the rest of the gamma radiation attenuated. A (NaI) fluorescence detector (Tl) with an accuracy of 8.2% (at 662 kV) was used for the gamma-ray detector beam. An advantage of using (μ/ρ) coefficient data can be obtained effective atomic numbers, atomic cross-section, and effective electron densities.All the obtained practical values were compared with the theoretical values available online "XCOM Program", and a good agreement was reached between experiment and theory.*

Keywords*: mass attenuation coefficient, emitted of gamma rays, radioactive sources, NaI (Tl) scintillation detector.*

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I. Introduction

The term gamma-rays used to include all electromagnetic radiations emitted by radioactive substances. The spectral region, which gamma rays occupy, ranges from the soft x-ray region to a very short wavelength of the order of a few x-units ($1x^0=10^{-11}$ cm)[1]. The gamma rays are characterized by their frequency υ the energy $h\upsilon$ which may be expressed in ergs, eV, or in the unit of m_0c^2 . The gamma rays do not bend in electric and magnetic fields. They travel with the velocity of light and are made to diffract and interfere, just like x-rays. The gamma rays are very penetrating and being uncharged; they produce less ionization per unit length of the path. The ionization produced per unit length of a path is only 1 to 10 percent of beta particles (β) of the same energy Gamma rays (γ) when traverse through the matter is stopped only in one or two encounters. At the same time, alpha (α) and beta particles require several encounters to stop. Further, since gamma-radiations are removed only in the first few angstroms of it, or they may travel a long distance before being encountered, the range concept in gamma-ray is very much vaguer[2].

This quantitative examination can establish specific parameters, including the substance's mass attenuation coefficient[3]. This makes it important to investigate the (μ/ρ) in various materials in physics research. The (μ/ρ) has been used in evaluating the effective cross-sectional number of atoms and the density electron, usually according to radiation energy and substance nature.

The (μ/ρ) is a measurement of the future relationship between absorbed radiation and unit mass matter per area. Manufacturing, chemical, agriculture, and medicinal applications are of significant importance in the awareness of radiation and other related products gamma photons [4]. Data on the (μ/ρ) of Fatty acid by using sources of $Co^{57}, Ba^{133}, Na^{22}, Cs^{137}$ and $Co^{60}$are$0.122, 0.356, 0.511, 0.662, 1.170, 1.275$ and $1.330\ MeV$are very helpful. The incident ray's energy is the basis to control the interaction between the incident ray and substance [5]. The absorber attenuation gamma (photons) differs from either alpha or beta radiation in equalization. Although these two corpuscular radiations are distinct and can thus be avoided completely, only increasingly thicker absorbers will mitigate gamma radiation. [6]The study was performed to gain knowledge about the (μ/ρ) coefficient of mass attenuation by using Behenic acid sample, due to most of the research presented recently to calculate the mass effect coefficient, samples of the type of amino acids and fats in addition to sugars have been approved because they are rather complex compounds consisting mainly of carbon, hydrogen and oxygen molecules[7][8]. Thus, fatty acid was adopted within this work.

II. Theory

The study of parameters such as atomic cross-section, electron density, active atomic number, etc., is directly dependent on the measurement of mass attenuation coefficient.Several researchers have suggested that the mass attenuation coefficient,"which write as (μ/ρ)" is determined when estimating such coefficients, was relied on in completing the calculations[9], [10]. The attenuation parameter that gives the fraction of the energy consumed or distributed to evaluate radiation and matter reaction is one of the activity parameters[11].

It has been experimentally observed that a mono-energetic and homogeneous beam of gamma radiations, when passes through a thin absorber, is attenuated in such a fashion that change in intensity of the beam is proportional to the thickness of the absorber and intensity of incident radiation; mathematically[2]

$$\Delta I = -\mu I \Delta x \qquad (1)$$

where
ΔI = change in intensity
I = Incident intensity
Δx =thickness of the absorber
μ= proportionality constant and is called the absorption coefficient. The integration of Eq. (1) yields to exponential absorption,

$$I = I_0 e^{-\mu x} (2)$$

The eq. (2) determines the intensity of radiation of initial intensity I after traversing the absorber's thickness x. Changes in the power of gamma-radiations in passing through the matter measureabsorption and deflection's combined effects. This is why absorption is used synonymously with attenuation.
Sometimes it is desirable to express the attenuation of gamma radiations in terms of a quantity called the half-thickness and is defined as the absorber's thickness to reduce the intensity to one half of its incident value. eq. (2) can recastas[2][12]

$$\log_e \frac{I}{I_0} = -\mu x$$
$$\log_e \frac{1}{2} = -\mu x_{1/2}$$
$$\mu = \frac{\log_e 2}{x_{1/2}} = \frac{0{\cdot}693}{x_{1/2}} (3)$$
$$\frac{\mu}{\rho} = \frac{0{\cdot}693}{x_{1/2}\text{P}}$$

where
ρ the density of matter, μ linear attenuationcoefficients,$x_{1/2}$half-value thickness.
Using the related samples' density, we are extracted mass attenuation coefficients for the pieces from the following equation.

$$\mu_m = \frac{\mu}{\rho}(\text{cm}^2\text{gm}^{-1}) = \frac{1}{\rho t}\ln\left(\frac{I_0}{I}\right)(4)$$

Experimentally the mass attenuation coefficient μ/ρ calculatedby the chartln (I_0/I)as a function of the thickness x of the material traversed. The graph should be a straight line of slope ($-\mu/\rho$). In our work have been the study the mass attenuation coefficient so has taken the thickness multiplied by the density of a sample which was Behenic Acid$T$*ρ (gm/cm^2)[13]

III. Experimental and measurement operation

Used in the current inquiryγ-rays with energy (0.122, 0.360, 0.511, 0.662, 1.170, 1.275and1.330) MeV which emitted from radioactive sources$Co^{57}, Ba^{133}, Na^{22}, Cs^{137}andCo^{60}$. The NaI (Tl) detector was collimated and detected, which can see in figure 1. An 8 K multi-channel analyzer has amplified the detector signals. TheBehenic acid sample ($C_{22}H_{44}O_2$), during the experiment, the sample was put in a plastic tube cylindrical. With a traveling microscope, the diameters of the pieces were determined. Photons of empty containers have been marginal attenuation was detected. The sensitive digital balance of a sample pellet is 0.001 mg precision. Multiple weights were replicated to maintain a stable weight. The mean value of this collection was called the sample mass. The density per unit area was estimated in each case using the pellet diameter and the medium value of the pellet density. Sample thickness was chosen 2<ln(I_0/I) < 4 to conform as closely as possible with the following optimal conditions[14].

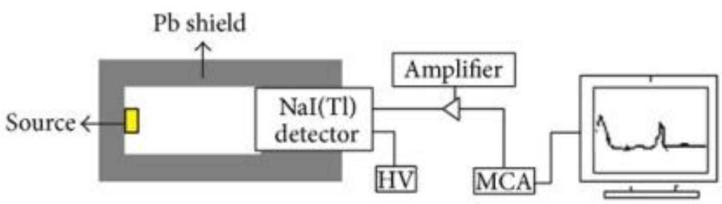

Figure 1. Scintillation counter as a spectrometer

A narrow beam with a strong geometry may be used to calculate the photons' events and transmitted energy.Thepractical(μ/ρ) for Behenic acid sample was obtained from the graph that was placed between the ln(I_0/I) and the mass thickness as shown in following figures (section 4), were (I) was calculated before placing the sample, after that, I_0 was calculated with the presence of the sample, and this process was repeated for each radioactive source. The*(μ/ρ)*values using Online XCOMto achieved it[15], on all current photon energies expressing theoretical data. Other potential sources of error due to the small-angle dispersion contribution, sample impurity, sample irregularity, photographic effects integrated, the dead time of the measuring instrument, and pulse pile effect were analyzed and taken into consideration in addition to multiple dispersion and counting data. The overall dispersion angle was less than 30 minutes by changing the distance between the sensor and the source (30<d<50) cm. According to Hubbell and Berger (1968), in measured cross-sections at intermediate energies, the contributions of both incoherent and coherent scattering at those angles are insignificant. Therefore, the measured data were not corrected by small-angle scattering. The sample used in the present analysis was of high purity (99, 9%), and no high (Z) impurities content was present; the measured data did not obtain sample impurity corrections. The loss of the sample material results in a fraction of an error of approximately half the root means square weight variance per unit area. The mass variance per unit area and the error due to sample non-uniformity are below 4% of all energies in the present work. By determining the optimal count rate and counting time, the built-up photon effect was kept low. The built-up photon depends on the atomic number and thickness of the sample as well as the photon energy incident. This is also a function of the multiple dispersion within the sample. A dead time correction clause was used in the multi-channel analyzer used in the present analysis. The pulse stacks of effects have been kept low by choosing the optimal number and duration[16].

IV. Results

Have been examining (μ/ρ) of Behenic acid sample ($C_{22}H_{44}O_2$), by using gamma rays with different energy sources,0.122, 0.360, 0.511, 0.662, 0.840 1.170, 1.275, and 1.330 MeV, and the sample density was (ρ = 0.8821 g/cm^3).

The results are proven among the following tables and figures. The values of (μ/ρ) thus obtained are considered to be in substantial accordance with the theory,as shown in figure (10). In these eight following figures, we found the mass attenuation coefficient as a slope, and it should be noted that all the following tables represent the calculation of the mass attenuation coefficient of the different sources and their energies; in addition to that, the chart represents the relationship between the mass thickness and I_0/I.Calculate the variation as a comparison of theories and test values, as seen in Table 9.

Table 1.Source ^{57}Co for energy 0.122 MeV, I_0=18820(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I (count/50minut)	I0/I	ln(I_0/I)
0.2	0.17642	18277	1.029725	0.029292
0.4	0.35284	17851	1.054307	0.052884
0.6	0.52926	17168	1.096229	0.091876
0.8	0.70568	16739	1.124309	0.117168
1	0.8821	16175	1.163532	0.151460
1.2	1.05852	15787	1.192143	0.175752
1.4	1.23494	15485	1.215365	0.195044
1.6	1.41136	14865	1.266094	0.235937
1.8	1.58778	14411	1.305947	0.266929
2	1.7642	14069	1.337659	0.290921

Table 2. Source ^{133}Ba for energy 0.356 MeV, I_0=19500(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I **(count/50minut)**	I_0/I	ln(I_0/I)
0.2	0.17642	19129	1.019392	0.019207
0.4	0.35284	18752	1.039888	0.039113
0.6	0.52926	18575	1.049821	0.048620
0.8	0.70568	18149	1.074468	0.071826
1	0.8821	17679	1.102999	0.098033
1.2	1.05852	17377	1.122142	0.115239
1.4	1.23494	17201	1.133654	0.125446
1.6	1.41136	16723	1.166085	0.153652
1.8	1.58778	16454	1.185137	0.169859
2	1.7642	16100	1.211144	0.191565

Table3. Source ^{133}Ba for energy 0.511 MeV, I_0=22562(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I(count/50minut)	I_0/I	$\ln(I_0/I)$
0.2	0.17642	22165	1.017932	0.017773
0.4	0.35284	21723	1.038675	0.037946
0.6	0.52926	21477	1.050555	0.049319
0.8	0.70568	20996	1.074647	0.071992
1	0.8821	20541	1.098412	0.093865
1.2	1.05852	20079	1.123713	0.116638
1.4	1.23494	20003	1.127960	0.120411
1.6	1.41136	19494	1.157409	0.146184
1.8	1.58778	19250	1.172124	0.158817
2	1.7642	18901	1.193763	0.177110

Table 4. Source ^{137}Cs for energy 0.662 MeV, I_0=23225(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I (count/50minut)	I_0/I	$\ln(I_0/I)$
0.2	0.17642	22842	1.016806	0.016666
0.4	0.35284	22437	1.035136	0.034533
0.6	0.52926	22159	1.048121	0.046999
0.8	0.70568	21881	1.061481	0.059665
1	0.8821	21476	1.081481	0.078332
1.2	1.05852	21115	1.099986	0.095298
1.4	1.23494	20648	1.124841	0.117642
1.6	1.41136	20572	1.128998	0.121330
1.8	1.58778	20171	1.151421	0.140997
2	1.7642	19818	1.171943	0.158663

Table5. Source ^{54}Mn for energy 0.840 MeV, I_0=23231(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I (count/50minut)	I_0/I	$\ln(I_0/I)$
0.2	0.17642	22920	1.013582	0.013491
0.4	0.35284	22613	1.027349	0.026981
0.6	0.52926	22399	1.037145	0.036472
0.8	0.70568	22011	1.055445	0.053963
1	0.8821	21679	1.071601	0.069154
1.2	1.05852	21425	1.084311	0.080944
1.4	1.23494	21244	1.093556	0.089435
1.6	1.41136	20854	1.113965	0.107926
1.8	1.58778	20579	1.128869	0.121217
2	1.7642	20299	1.144431	0.134907

Table 6. Source ^{60}Co for energy 1.170 MeV, I_0=23260(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I (count/50minut)	I_0/I	$\ln(I_0/I)$
0.2	0.17642	22935	1.014216	0.014116
0.4	0.35284	22693	1.025041	0.024732
0.6	0.52926	22319	1.042215	0.041349
0.8	0.70568	22160	1.049659	0.048465
1	0.8821	21937	1.060331	0.058581
1.2	1.05852	21652	1.074330	0.071697
1.4	1.23494	21327	1.090693	0.086814
1.6	1.41136	21112	1.101783	0.096930
1.8	1.58778	20775	1.119683	0.113046
2	1.7642	20582	1.130163	0.122362

Table7.source ^{22}Na for energy 2.275 MeV, I_0=23271(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I (count/50minut)	I_0/I	$\ln(I_0/I)$
0.2	0.17642	23008	1.011461	0.011395
0.4	0.35284	22706	1.024875	0.024571
0.6	0.52926	22553	1.031853	0.031356
0.8	0.70568	22378	1.039918	0.039142
1	0.8821	22025	1.056569	0.055027
1.2	1.05852	21726	1.071128	0.068713
1.4	1.23494	21526	1.081077	0.077958
1.6	1.41136	21433	1.085764	0.082284
1.8	1.58778	21097	1.103039	0.098069
2	1.7642	20868	1.115146	0.108985

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Table 8. Source^{60}Co for energy1.330 MeV, I_0=23413(count/50minut)

T (cm)	T*ρ (gm/cm^2)	I (count/50minut)	I_0/I	$\ln(I_0/I)$
0.2	0.17642	23166	1.010653	0.010597
0.4	0.35284	22922	1.021420	0.021194
0.6	0.52926	22671	1.032714	0.032190
0.8	0.70568	22307	1.049577	0.048387
1	0.8821	22205	1.054413	0.052984
1.2	1.05852	22001	1.064155	0.062181
1.4	1.23494	21759	1.076029	0.073278
1.6	1.41136	21403	1.093928	0.089775
1.8	1.58778	21262	1.101168	0.096371
2	1.7642	21072	1.111075	0.105328

Table 9. Mass attenuation coefficient & values deviation

sample	source	Energy MeV	Theo. (μ/ρ)	Exp. (μ/ρ)	deviation
$C_{22}H_{44}O_2$	Co	0.122	0.16120	0.1660	-3%
	Ba	0.356	0.11270	0.1089	3%
	Na	0.511	0.09743	0.1007	-3%
	Cs	0.662	0.08706	0.0888	-2%
	Mn	0.840	0.07803	0.0765	2%
	Co	1.170	0.06642	0.0687	-3%
	Na	1.275	0.06355	0.0611	4%
	CO	1.330	0.06218	0.0601	3%

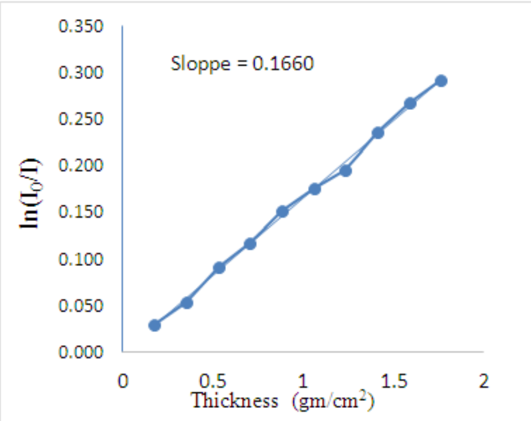

Figure 2. Chart between thickness and ln I_0/I for energy 0.122 MeV

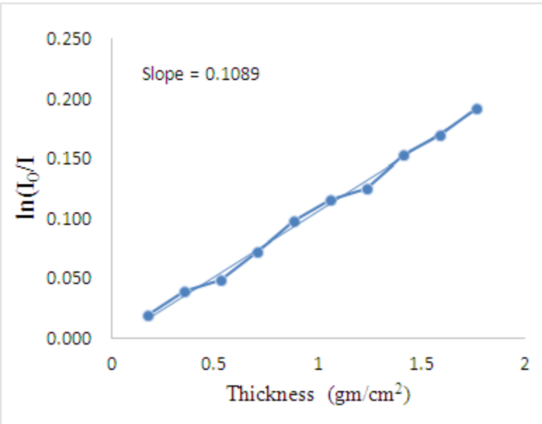

Figure 3. Chart between thickness and ln I_0/I for energy 0.356 MeV

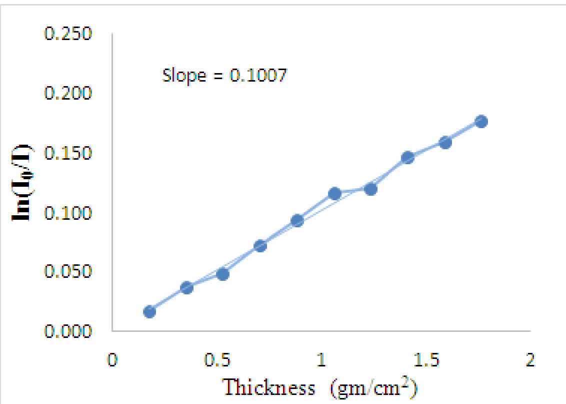

Figure 4. Chart between thickness and ln I_0/I for energy 0.511 MeV

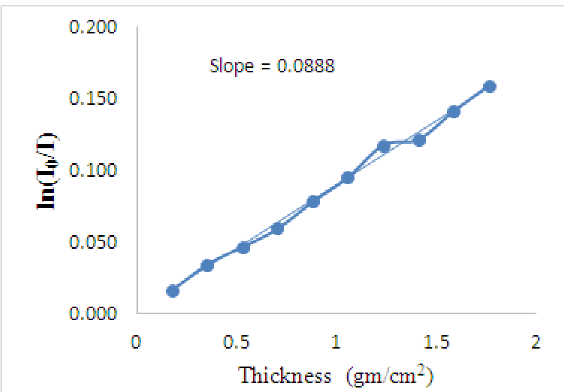

Figure 5. Chart between thickness and ln I_0/I for energy 0.662 MeV

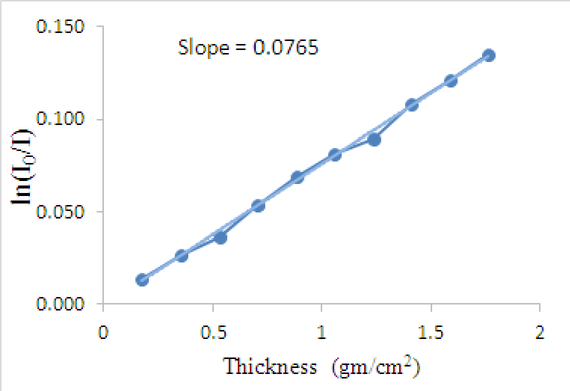

Figure 6. The chart between thickness and ln I_0/I for energy 0.840 MeV

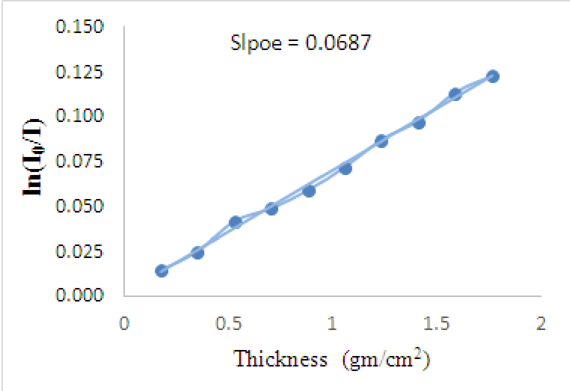

Figure 7. The chart between thickness and ln I_0/I for energy 1.170 MeV

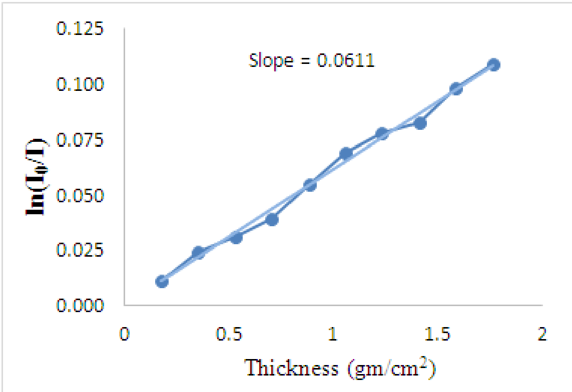

Figure 8. The chart between thickness and ln I_0/I for energy 1.275 MeV

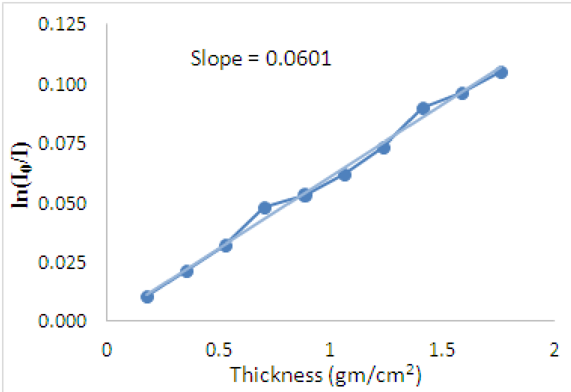

Figure 9. The chart between thickness and ln I_0/I for energy 1.330 MeV

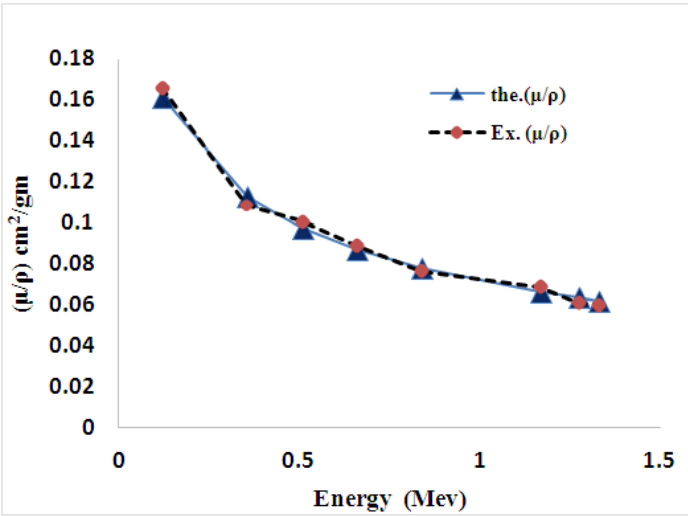

Figure 10. The chart between *μ/ρ* and energy at MeV shows a deviation in theoretical and experiment values

V. Conclusion

We studied the mass attenuation coefficient values that were measured for the behenic acid by using Gamma-ray radiation (γ), emitted from different sources ^{57}Co, ^{133}Ba, ^{22}Na, ^{137}Cs, ^{54}Mn, and ^{60}Co with energies from 0.122 to1.330 MeV. The measured values were found to be in well good agreement with the mixture rule. This research method is very useful for systematic study in basic sciences and also in the research area. The results valid the gamma attenuation law. The values obtained (μ/ρ) can be used to study the effective atomic numbers, atomic cross-section, and effective electron densities. We expect the effective coefficient of the atomic number and effective electron density to decrease at the beginning and is almost constant as a consequence of gamma radiation energy via the attenuation coefficient computed in this article.

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