

Mass Attenuation Coefficients of Lead Nitrate Dilute Solutions for 13.5 cm Thickness at 1173 and 1333 keV

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ABSTRACT: The total mass attenuation coefficients determined in deionized water and different concentration lead nitrate dilute solutions at photon energies 1173 and 1333 keV by using good geometry setup. Gamma ray photons are emitted from source of ⁶⁰Co. The measurements has been performed using a gamma spectrometer which contain 2"×2" NaI (TI) detector connected to 8K Multi-Channel Analyser(MCA). The results are in good agreement with the theoretical calculations of X.COM.

KEYWORDS: Mass attenuation coefficients, deionized water, Lead nitrate dilute solutions, photon energies, Good-Geometry setup, gamma ray spectrometer.

I. INTRODUCTION

Increasing usage of radioactive sources in several fields such as medicine, industry and agriculture etc., the study of gamma ray attenuation measurements in elements, compounds has become important. Accurate data on narrow beam attenuation coefficients for gamma rays are required in many fields, such as tomography, X-ray fluorescence studies and radiation biophysics. Most of the previous measurements of attenuation coefficients have been performed on the materials in their solid and crystalline forms using various techniques. These observations have been compared with the theoretical values calculated from the mixture rule and various tables [1].

II. BACK GROUND OF RELATED WORK

Many measurements of mass attenuation coefficients have been reported for instance Bradley et. al., [2]; Cunningham and John [3]; Hubbell [1 and 4]; Hubbell and Seltzer [5]; Singh et.al.,[6]; Teliet, et al.,[7 - 13] have used the mixture rule for multi elemental media in order to provide gamma ray attenuation for materials which are generally in liquid form or soluble in solvent, such as water. The observations were compared with the values; those are derived from application of mixture rule by using tabulated values for each element [4]. Gerward [14] has developed the theory of X-ray and gamma ray attenuation in solutions and has elaborated the rule of mixtures of linear and mass attenuation coefficients in the general case, as well as, in the limit of extreme dilution. Kulwant Singh et.al., [15] have measured attenuation coefficients of some dilute solutions at 662 keV. So it is important to study attenuation measurements of deionized water and different dilute solutions.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

III. PRESENTATION OF THE MAIN CONTRIBUTION OF THE PAPER

In the present work, mass attenuation measurements of different concentration lead nitrate dilute solutions (mixed in deionized water) and deionized water have been measured in the energies 1173 and 1333keV for 13.5 cm thickness.

IV. PROPOSED METHODOLOGY AND DISCUSSION

The mass attenuation coefficients were determined by performing transmission experiments in narrow beam geometry as shown in Fig.1. A reasonable amount of lead shielding was used around the source and detector to prevent detection of scattered radiation from surrounding objects. For the low energy measurements the probability of coherent scattering interactions is relatively high and so very good collimation is required to reduce the contribution of Rayleigh scattered photons reaching the detector. Tight collimation reduces the absolute detection efficiency so that high activity sources must be employed that is around 10 mCi strength. At higher energies the probability of elastic scattering becomes much smaller and so scattered radiation is less important which reduces the need for such close collimation. Therefore, source strengths in the range 10-20 μ Ci were found to be adequate for the higher energy measurements. The radioactive sources of strength around 10 μ Ci were procured from BRIT, Mumbai, India and details of the source are given in Table.1.

Table.1: Table showing the source, energy and half-life period of the radioactive isotope used in the present work.

Source	Energy [keV]	Half-Life [Years]
^{60}Co	1173 & 1333	5.3

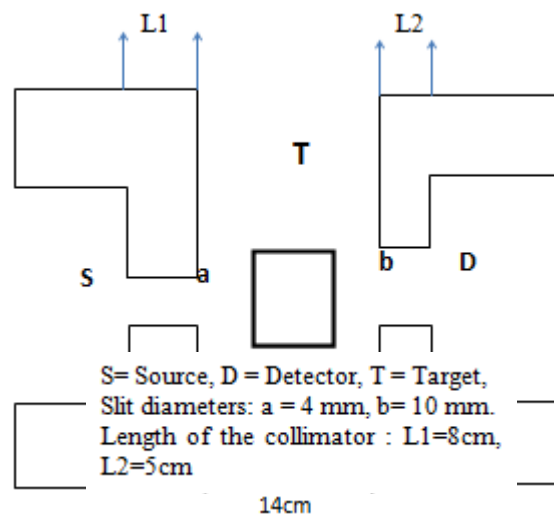


Fig. 1 Schematic diagram of the experimental setup.

A 2"×2"NaI(Tl) crystal detector with the energy resolution 8% at 662 keV and 8K Multi-Channel Analyzer(MCA) plug-in-card were used with associated electronics to record the pulse-height spectra's of γ -radiations emitted by radioactive sources. h_1, h_2 and h_3 concentration solutions are prepared.

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Where h_1 concentration : 210 g of lead nitrate diluted in 300ml of water.
 h_2 concentration : 105 g of lead nitrate diluted in 300ml of water.
 h_3 concentration : 52.5 g of lead nitrate diluted in 300ml of water.

13.5cm thickness glass container is prepared with general method which is used in aquarium shops. This container is used for taking readings with water and dilute solutions. Thickness of the glass container is measured with vernier calipers. The sample thickness measured in such a way the internal distance of the glass container. Thickness (t) is measured for different areas of thickness of the each container, then the average “t” value was taken and that is 13.5cm. The Table.2 shows the average density and thickness of the different concentration of lead nitrate dilute solutions. Interpolations from tabulated theoretical values of the mass attenuation coefficients for deionized water and different dilute solutions were obtained using X.COM [16]. For this we calculated the percentage of lead nitrate and water.

Example

For h_1 concentration : 210 g of lead nitrate diluted in 300ml of water.

Weight of the compound (W_c) = 210g.

Weight of the solution (W_s) = 508.9g.

Percentage of lead nitrate (W_c / W_s) = 0.413

Percentage of water = 0.587

Simultaneously h_2 and h_3 concentrations:

For h_2 concentration

Percentage of lead nitrate = 0.254

Percentage of water = 0.746

For h_3 concentrations

Percentage of lead nitrate = 0.149

Percentage of water = 0.851

Density of the sample is measured by using common principle, that is

Density (ρ) = Mass (M) / Volume (V)

$V = M / \rho$

$V_{\text{water}} = V_{\text{mixture}}$

$\rho_{\text{mixture}} = M_{\text{mixture}} \times [\rho_{\text{water}} / M_{\text{water}}]$

M_{water} = weight of the volumetric flask with water – weight of the empty volumetric flask.

M_{mixture} = weight of the volumetric flask with mixture – weight of the empty volumetric flask.

Table.2 Average density and thickness of lead nitrate dilute solutions and deionized water

Type of sample	Thickness [cm]	Density [g/cm ³]
Deionized Water	13.5	13.5±0.27
h_1 concentration of lead nitrate solution	13.5	20.032±0.401
h_2 concentration of lead nitrate solution	13.5	16.606±0.332
h_3 concentration of lead nitrate solution	13.5	15.529±0.311

For each sample, counts were taken in the following sequence, back ground, no sample, sample, sample, no sample, and so on [17]. Different parts of the sample are exposed to the beam. The counting sequence was continued in most cases until counting statistics contributed less than 0.5% error.

The mass attenuation coefficients [cm²/g] are obtained from the Beer-Lambert Law:

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$$\frac{\mu}{\rho} = \frac{1}{t\rho} \ln\left(\frac{I_0}{I}\right)$$

Where 't' is the thickness of the sample (cm), and 'ρ' is material density (g/cm³), I₀ and I are the net counts under the photo peak, without sample and with sample, respectively. I₀ and I were obtained for same counting time and experimental conditions. The errors in the present investigations are due to [i] counting statistics, [ii] non uniformity of the sample, [iii] density measurements and [iv] scattered radiation reaching the detector within the accepted maximum angle of scattering. In the present investigation this angle was around 3° and the error due to this factor was about 0.3%. The counting statistics were such that the error was less than 0.5%. The fractional error arising due to non-uniformity of the sample was estimated to be in the order of 0.2%. The error in the density measurement is less than 1%. Therefore, the overall error was estimated to be less than 2.25%.

V. RESULTS AND DISCUSSION

The experimentally measured and calculated values [16] for the mass attenuation coefficients for different concentration of lead nitrate solutions and deionized water sample in the energies 1173 and 1333keV as shown in Table.3. Comparing the experimental and calculated(theoretical) values for the mass attenuation coefficient of deionized water and h₁, h₂ and h₃concentration lead nitrate dilute solutions for 13.5cm, at energies 1173 and 1333keV. There is no deference between theoretical and measured mass attenuation coefficients of deionized water and different concentration of lead nitrate dilute solutions as shown in Fig.2 and Fig.3 and from these Figures mass attenuation coefficients of deionized water and differentconcentraton dilute solutions nearly equal.

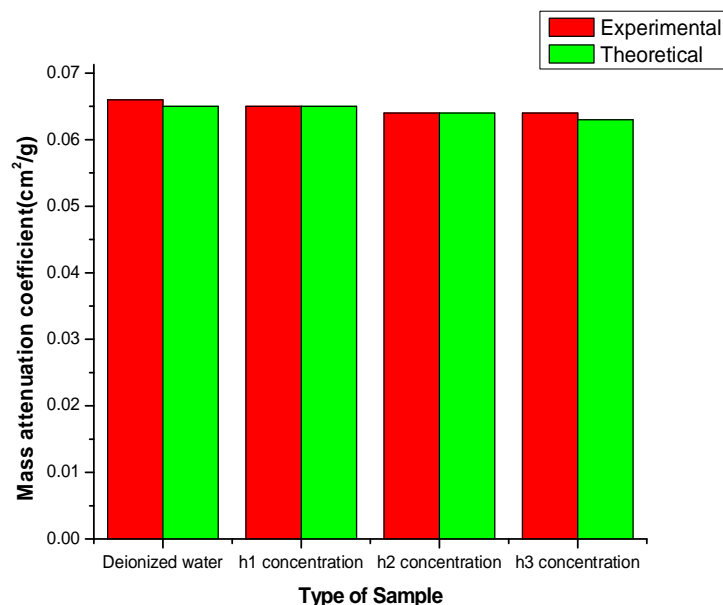


Fig. 2 Variation in Mass attenuation coefficients of lead nitrate different concentration dilute solutions and deionized water at 1173 keV for 13.5 cm thickness in cm²/g.

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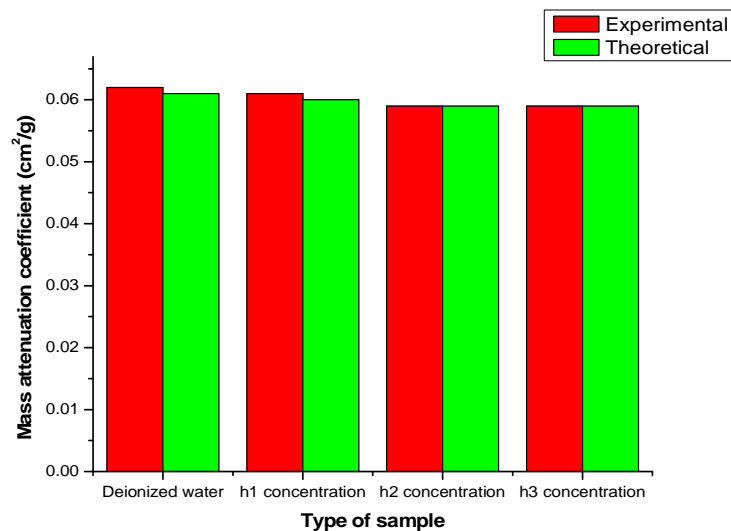


Fig. 3 Variation in Mass attenuation coefficients of lead nitrate different concentration dilute solutions and deionized water at 1333 keV for 13.5 cm thickness in cm²/g.

S. No.	Type of Sample/Energy	1173keV	1333keV
1	Deionized water	^a 0.066 ^b 0.065	0.062 0.061
2	210g of Lead nitrate in 300ml water h ₁ Concentration	0.065 0.065	0.061 0.060
3	105g of Lead nitrate in 300ml water h ₂ Concentration	0.064 0.064	0.059 0.059
4	52.5g of Lead nitrate in 300ml water h ₃ Concentration	0.064 0.063	0.059 0.059

Table.3 Mass attenuation coefficients of different concentration dilute solutions of lead nitrate for 13.5cm thickness in cm²/g [error≈2.25%]

a = Experimental mass attenuation coefficient b= Theoretical mass attenuation coefficient [16]

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 5, May 2016

VI. CONCLUSIONS

The change in mass attenuation coefficients is negligible as concentrations of lead nitrate dilute solution increasing for energies 1173 and 1333keV. Mass attenuation coefficients of deionized water is nearly equal to the mass attenuation coefficients of different dilute solutions of lead nitrate that means there is no deviation between deionized water and different dilute solutions of lead nitrate.

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