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A Study of Linear and Mass Attenuation Coefficient of Some Salt Sample for Gamma-Rays at Different Energies

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Abstract: *The linear attenuation coefficient (LAC) and mass attenuation coefficient (MAC) are most important while studying of radiation, radio-isotopes in dosimentry and irradiation of materials. In the present work to calculate linear attenuation coefficient (LAC) and mass attenuation coefficient (MAC) values of different salts samples by using Gamma-ray spectrometry with Photo-Multiplier Tube (PMT) and Multi-Channel Analyzer (MCA). The 0.123, 0.511, 0.662, 1.17, 1.28 and 1.33MeV gamma energy rays used for the experiment in the interaction of some salt samples and compared the Mass attenuation coefficient (MAC) values of salt samples.*

Key Words:-*Gamma-ray attenuation parameters, Slat samples, Gamma-ray spectrometry.*

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I. Introduction

The linear attenuation and mass attenuation coefficient of elements, molecules and materials are widely used in space physics, dosimetry, and plasma physics and in the field of radiation physics. The study of absorption of gamma radiations in the material and these are used for study of biological importance. Gamma ray spectrometry is used to determine activity concentration of natural and artificial radionuclides material in environment. There are different measurement techniques to measure them. As the technology developed now a day, the gamma rays are used in many areas such as food preservation and medicine and with their measurement techniques are developed. This method is developed from single element mass attenuation coefficient of gamma rays to a mixture that is solute and solvent. In 1977 Hubbel *et al.,* has reported the mass attenuation coefficient for hydrogen, carbon, nitrogen and oxygen at low gamma energy, according to his μ/ρ of these elements using butanol, pentanol, N-N dimethyl acetate and acetone and the other elements i.e. Na, Mg are measured from $MgSO_4$ and $NaSO_4$ using aqueous solution method. Teli *et al.,* 1994 have measured the attenuation coefficient of 123Kev gamma radiations by dilute solution of sodium chloride. Dongarge et al., 2010 proposed the linear attenuation coefficient for gamma a rays for ammonium sulfate salt by aqueous solution method 1.28 MeV gamma ray energy. Hubbel has calculated mass attenuation coefficient for 92 elements for hydrogen to Uranium and some compounds from photon energies 1 KeV to 20 MeV.

II. Method and Material

In this study to calculate gamma ray attenuation parameters, some salt samples were by using gamma-ray spectrometry with Photo-Multiplier Tube (PMT) and Multi-Channel Analyzer (MCA). The interaction of these with matter has various effect like light pulses or chemical changes in materials which is to be detected by detector. The block diagram of gamma-ray spectrometry with Multi-Channel Analyzer (MCA) is as shown in the fig.1. The spectrometer comprises scintillator material coupled with photomultiplier tube (PMT) and preamplifier housed in scintillation head. The signal collected from PMT are amplified and digitalized for further processing in Multi-Channel Analyzer (MCA). For gamma ray spectrometry, inorganic crystal of thallium doped Sodium iodide [NaI(Tl)] was used in scintillation detector. The NaI(Tl) was the most extensively used as it has very scintillation efficiency and available in single crystal polycrystalline forms a wide variety of size and geometries. It has maximum light yield is in the range 20^oC to 60^oC which normal ambient temperature.

The experiment for the measurement of mass attenuation coefficient and linear attenuation coefficient carried out of aqueous solution of Magnesium Carbonate compound by a gamma transmission in narrow beam geometry. The measurement of mass attenuation coefficient and linear attenuation coefficient of Magnesium Carbonate at different gamma energies range as 0.123 to 1.33MeV at different amount of concentrations of salt ranges 6.9774gm to 15.9391gm. The experimental arrangement for measuring mass attenuation coefficient and linear attenuation coefficient of the compound is as shown in the fig.2. The total linear attenuation coefficient μ/p (cm^{-1}) and mass attenuation coefficient μ/p (cm^2/gm) of the absorber are related by the standard exponential law.

$$I = Io\, e^{-\mu h} \quad \text{and}$$
$$I = Io \exp\left[\mu / \rho^{\,(ph)}\right]$$

Since Io, I are proportional to the gross area under the photo-peak of interest. A cylindrical container of internal radius r cm, the density of the solution of mass m and height h cm in the container is given by $p = m / \pi r^2$ therefore the equation as-

$$I = Io \exp\left[\frac{\mu}{\rho} + \frac{m}{\pi r2}\right]$$

From above equation (μ / ρ)' as-

$$\left(\frac{\pi}{\rho}\right)' = \frac{\pi r^2}{m} In[\frac{Io}{I})$$

By using this graphical equation calculate the value $\frac{\pi}{\rho}$ from slope.

The gross area of selected region of interest in accumulated spectrum for 1800 sec was used for calculations. The data of measured linear attenuation coefficient of Magnesium Carbonate at different gamma energies range as 0.123, 0.511, 0.662, 1.17, 1.28 and 1.33MeV at different concentration range 6.9774 gm to 15.9391gm as shown in table 1, 2, 3,4,5 and 6.

The block diagram of gamma-ray spectrometry with Multi-Channel Analyzer (MCA) is as shown in the fig.1.

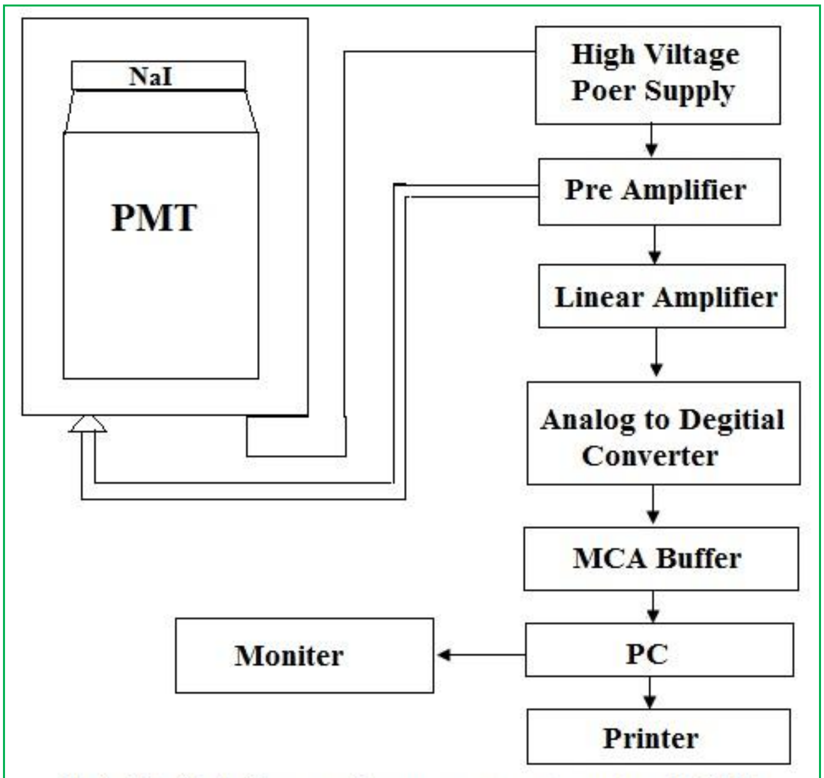

Fig.1- The block diagram of gamma-ray spectrometry with MCA

The experimental arrangement for measuring mass attenuation coefficient and linear attenuation coefficient of the compound is as shown in the fig.2.

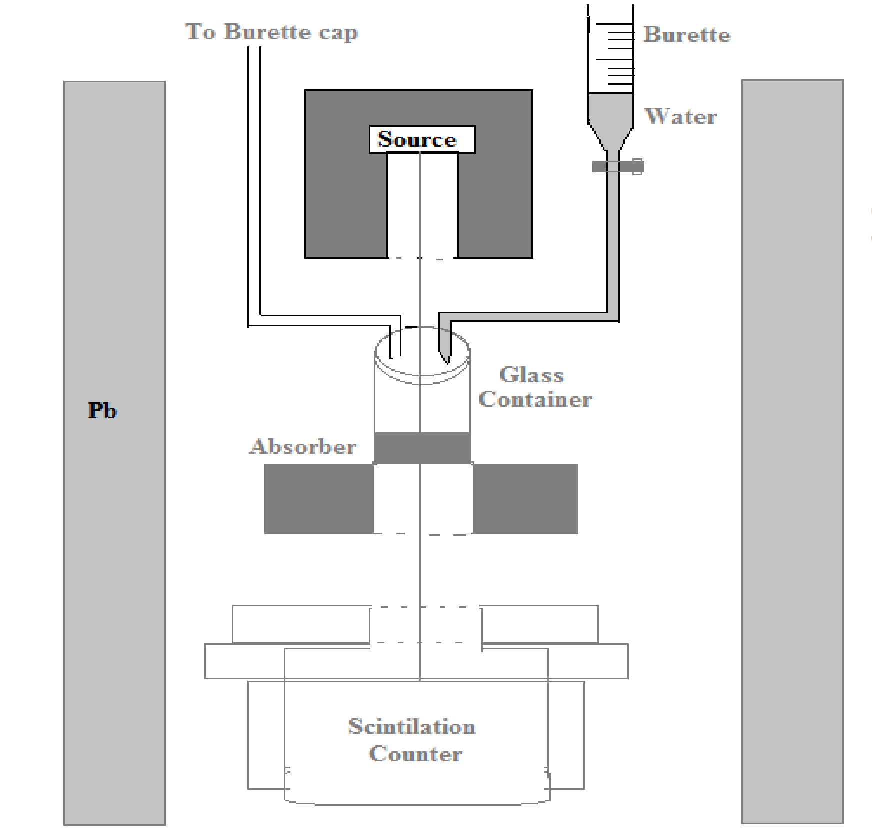

Fig. 2- Experimental narrow beam geometry setup for measuring gamma absorption coefficient for liquids and salts

III. Results and Discussion

The experimental observations were made for the measurement of measured linear attenuation coefficient and mass attenuation coefficient of Magnesium Carbonate. The gross area of selected region of interest in accumulated spectrum for 1800 sec was used for calculations. The mass attenuation coefficient $(\frac{\mu}{\rho})$was estimated from the linear attenuation coefficient of Magnesium Carbonate. The data of measured linear attenuation coefficient of Magnesium Carbonate at different gamma energies range as 0.123, 0.511, 0.662, 1.17, 1.28 and 1.33MeV at different concentration range 6.9774 gm to 15.9391gm as shown in table 1, 2, 3,4,5 and 6. The percent deviations between experimental and theoretical values of mass attenuation coefficient $(\frac{\mu}{\rho})$ are showing good agreement, as shown in table7.

The measured values of linear attenuation coefficient μc (cm^{-1}) at different gamma energies.

Table-1- Gamma ray energy 0.123 MeV

m(gm) $m=m_c+m_w$	Io, I 1800 Sec	Ln(Io/I)	m_c / m x-axis	$(\frac{\mu}{\rho})$ y-axis
0.0000	10056			
6.9774	7723	0.26397	0.28661	0.15761
7.9710	7373	0.31034	0.25081	0.16215
8.9693	7128	0.34414	0.22297	0.15985
9.9652	6928	0.37260	0.20068	0.15577
10.9611	6529	0.43238	0.18242	0.16431
11.9572	6287	0.46969	0.16728	0.16367
12.9521	6018	0.51341	0.15441	0.16515
13.9430	5819	0.54704	0.14339	0.16341
14.9447	5689	0.56963	0.13380	0.15877
15.9391	5487	0.60579	0.12547	0.15835

Table-2- Gamma ray energy 0.511 MeV

m(gm) $m=m_c+m_w$	Io, I 1800 Sec	Ln(Io/I)	m_c / m x-axis	$(\frac{\mu}{\rho})$ y-axis
0.0000	17398			
6.9774	14803	0.16153	0.28660	0.06944
7.9710	17636	0.17287	0.25079	0.09032
8.9693	14287	0.19701	0.22299	0.91151
9.9652	14026	0.21544	0.20070	0.09008
10.9611	13539	0.25078	0.18240	0.09529
11.9572	13278	0.27025	0.16728	0.09418
12.9521	13034	0.28879	0.15440	0.09289
13.9430	12826	0.30488	0.14339	0.09107
14.9447	12328	0.34448	0.13380	0.09602
15.9391	12037	0.36837	0.12548	0.09629

Table-3- Gamma ray energy 0.662 MeV

m(gm) $m=m_c+m_w$	Io, I 1800 Sec	Ln(Io/I)	m_c / m x-axis	$(\frac{\mu}{\rho})$ y-axis
0.0000	13278			
6.9774	11649	0.13089	0.28663	0.07815
7.9710	11288	0.16237	0.25078	0.08482
8.9693	11028	0.18567	0.22297	0.08624
9.9652	10826	0.20416	0.20069	0.08535
10.9611	10725	0.21353	0.18240	0.08113
11.9572	10528	0.23207	0.16729	0.08088
12.9521	10289	0.25503	0.15441	0.08503
13.9430	10098	0.27377	0.14339	0.08178
14.9447	9802	0.30352	0.13379	0.08460
15.9391	9648	0.31936	0.12548	0.08348

Table-4- Gamma ray energy 1.17 MeV

m(gm) $m=m_c+m_w$	Io, I 1800 Sec	Ln(Io/I)	m_c / m x-axis	$(\frac{\mu}{\rho})$ y-axis
0.0000	12087			
6.9774	10814	0.11129	0.28661	0.06945
7.9710	10727	0.11937	0.25076	0.06235
8.9693	10527	0.13819	0.22299	0.06414
9.9652	10384	0.15196	0.20070	0.06349
10.9611	10198	0.16994	0.18240	0.06457
11.9572	9982	0.19135	0.16728	0.06668
12.9521	9898	0.19980	0.15440	0.06426
13.9430	9754	0.21445	0.14339	0.06406
14.9447	9532	0.23748	0.13379	0.06619
15.9391	9367	0.25494	0.12548	0.06664

Table-5- Gamma ray energy 1.28 MeV

m(gm) $m=m_c+m_w$	Io, I 1800 Sec	Ln(Io/I)	m_c / m x-axis	$(\frac{\mu}{\rho})$ y-axis
0.0000	9825			
6.9774	8902	0.09865	0.28657	0.05889
7.9710	8726	0.11862	0.25074	0.06196
8.9693	8658	0.12992	0.22301	0.06036
9.9652	8525	0.14193	0.20702	0.05934
10.9611	8409	0.15563	0.18241	0.05914
11.9572	8208	0.17982	0.16727	0.06266
12.9521	8197	0.18116	0.15439	0.05827
13.9430	8027	0.20212	0.14340	0.06038
14.9447	7925	0.21491	0.13379	0.05990
15.9391	7768	0.23492	0.12547	0.06140

Table-6- Gamma ray energy 1.33 MeV

m(gm) $m=m_c+m_w$	Io, I 1800 Sec	Ln(Io/I)	m_c / m x-axis	$(\frac{\mu}{\rho})$ y-axis
0.0000	9956			
6.9774	9063	0.09398	0.28657	0.05610
7.9710	8849	0.11787	0.25072	0.06156
8.9693	8730	0.13141	0.22300	0.06105
9.9652	8668	0.13854	0.20068	0.05792
10.9611	8539	0.15353	0.18242	0.05834
11.9572	8423	0.16721	0.16728	0.05827
12.9521	8352	0.18772	0.15438	0.06037
13.9430	8193	0.19490	0.14340	0.05822
14.9447	8037	0.21412	0.13380	0.05968
15.9391	7926	0.22803	0.12548	0.05960

The percent deviations between experimental and theoretical values of mass attenuation coefficient $(\frac{\mu}{\rho})$ are follows

Table-7- Mass attenuation coefficient for Magnesium Carbonate.

Energy (MeV)	Experimental values	Theoretical Values	% Deviation
0.1230	0.14780	0.15632	5.32693
0.5110	0.08604	0.08640	0.41205
0.6620	0.07655	0.07700	0.58442
1.1700	0.05835	0.05870	0.59284
1.2800	0.05799	0.05607	-3.42530
1.3300	0.05488	0.05503	0.27260

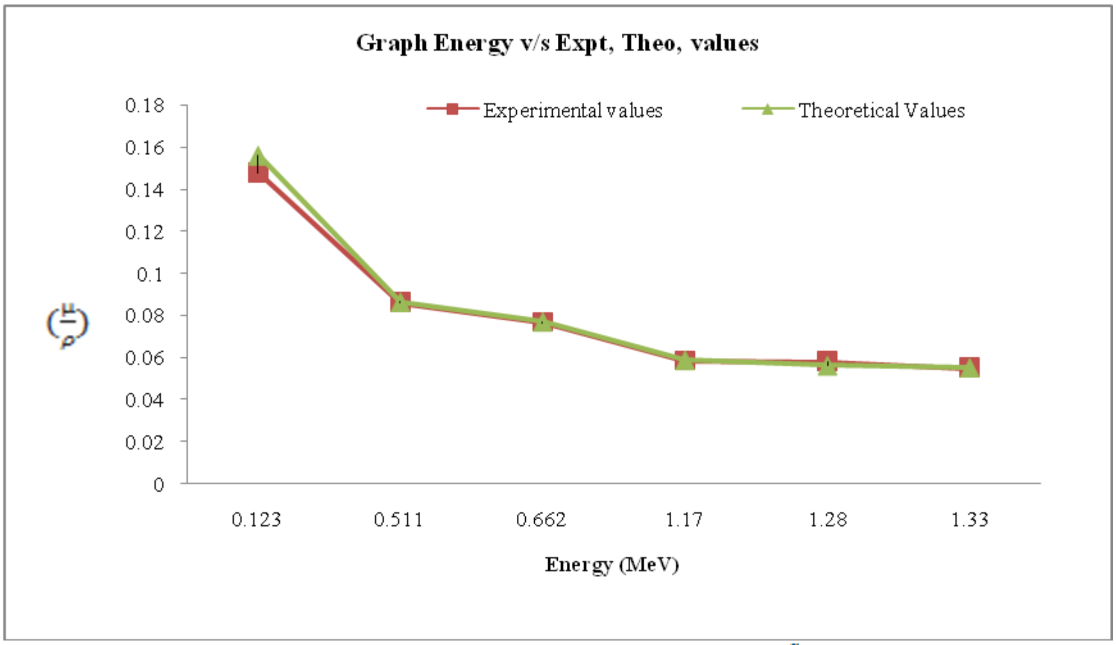

Fig.3- Graph of Energy V/S experimental and Theoretical values of $(\frac{\mu}{\rho})$ forMagnesium Carbonate

IV. Conclusion

In the present research work experimental measurement of linear and mass attenuation coefficient of Magnesium Carbonate at different gamma energies range as 0.123, 0.511, 0.662, 1.17, 1.28 and 1.33MeV. The validity of the exponential absorption law for gamma radiation in solution, also as in solids and provide a new method for the determination of linear attenuation coefficient μc (cm^{-1}) and mass attenuation coefficient $(\frac{\mu}{\rho})$ for soluble substance. The method used is simple and avoids the need of preparation of pure crystalline compound for experiment thereby saving time and expenditure. The obtained results are in good agreement.

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