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Measurement of Linear Attenuation Coefficients of Gamma Rays For Ammonium Sulfate Salt by Aqueous Solution Method.

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Abstract

The linear attenuation Coefficients of dilute aqueous solutions of ammonium sulfate salt with varying concentrations are measured for different Gamma energies (0.36 MeV to 1.33 MeV). From these measurements linear attenuation coefficients for pure salts are obtained by using improved method. The comparison with theoretical values shows excellent agreement. Half values thickness of the salts and total atomic cross sections are also evaluated.

Introduction

Linear and mass attenuation coefficients and half value thickness are the important factors in the study of gamma rays. There is a large amount of data of studies of these properties Bhandal G.S. et al[10] , Dongarge[1,2] , Gerward[6,7] , Hubbell[12,9,] , Nathuram et al[11], Teli et al[3,4,5,8,] for elements and materials. Hubbell[13] used mixture rule for multidimensional media for calculating mass attenuation coefficient for gamma rays and has given tables of these values for various elements and mixtures .

Teli[4] has revised mixture rule for solutions which does not require separate determination of partial volumes of salts as was pointed out by Gerward. we use this method and give here our measurements of the linear attenuation coefficient of the salt ammonium sulfate for different Gamma energies.

Experimental Arrangement.

The experimental arrangement is as shown in the figure 1. The gamma rays from the source are narrowed by using the lead slits of thickness 3.6 cm. A cylindrical container of internal diameter 2.38 cm is placed below the source at a distance of 4.8 cm. The NaI (Tl) crystal is used as the detector which is connected to PC-based 4k-multichannel analyzer (MCA). The stand of appropriate size for holding the container and the source is made of perfex. The source and absorber are placed along the axis of the stand. The whole system is enclosed in lead castle.

Method of Observations

First gamma rays are passed through empty container reaching the detector and the MCA spectrum is obtained for 1800 sec. We select the interested peak and smoothen it for reducing the errors due to random nature of gamma radiations. The peak gross area A_0 which gives the sum of the spread counts coming under the peak is measured on MCA. Then water solution of salt of selected concentration is kept in the container and the gamma rays are passed through it . The interested peak gross area is measured as A_1 . The solution concentration is further varied by diluting the solution by adding water to it (one ml every time). The gamma rays are passed through such solutions and interested peak gross areas are measured as A_2, A_3, A_4……..A_{10}. The other quantities measured in the experiment are volume of the salt (V_s) and of water(V_w) added. The actual volume V of the solution is calculated by measuring its height in the container and by multiplying it by the cross sectional inner area of the container (πr^2). The set of measurements are taken for different gamma energies $E\gamma$ = 0.36 MeV to 1.33 MeV for the ammonium sulfate.

Solution technique For calculation of linear attenuation coefficients of pure salts.

The experimental linear attenuation coefficient of the salt solution (μ_{exp}) is obtained from the above data

$$\mu_{exp} = \frac{1}{h} \ln\left(\frac{A_0}{A}\right) \quad (1)$$

Where h is the height of the solution.

The mixture rule for aqueous solutions of salts is given as

$$\mu' = \mu_w + (\mu_s - \mu_w)\frac{V_s}{V'} \quad \text{where } v' = v_s + v_w \quad (2)$$

where μ' is scaled linear attenuation coefficient defined as

$$\mu' = \frac{V}{V'}\mu. \quad (2a)$$

Hence the experimental scaled (μ'_{exp}) is given by

$$\mu'_{exp} = \frac{V}{V'}\mu_{exp} = \frac{V}{V'} h * \ln\left(\frac{A_0}{A}\right) \quad (3)$$

The % deviation of experimental μ' from theoretical μ' equation (2) is calculated as

$$\% \text{ deviation} = \frac{\mu'_{th} - \mu'_{exp}}{\mu'_{th}} * 100 \qquad (4)$$

Theoretical μ' for solutions is obtained from equation (2) by obtaining μ_w and μ_s from Hubbell[13] tables. The results calculated are given in the table 1 for ammonium sulfate solution only for one gamma ray energy. Equation 2 is the equation of straight line between μ' and concentration ($\frac{V_s}{V'}$). Our observations exhibits the behavior as is illustrated in figure 2 for ammonium sulfate solution given by equation 3. We thus observe very good agreement between μ'_{exp} and μ'_{th} for solutions.

From the graph of μ'_{exp} verses ($\frac{V_s}{V'}$) straight line fitted by least square methods whose intercepts give μ_w and slope give μ_s-μ_w. We estimate experimental linear attenuation coefficient for pure ammonium sulfate (μ_s) for different gamma energies . The results are tabulated in the table - 2 along with the (μ_s) theoretical values . We find excellent agreement (within 1%) between the experimental values and the theoretical values for pure salts . The variation of linear absorption coefficient of ammonium sulfate salt with gamma energy is displayed in the fig. 3 . The experimental points are very close to (though spread around) the theoretical curves.

Atomic cross section and half Value Thickness:

The total atomic cross sections for different gamma ray energies for ammonium sulfate calculated by using the relation

$$\alpha = \frac{M}{N} * \left(\frac{\mu_s}{\rho}\right)$$

Where M is the molecular weight of the salt, N is Avogadro's number and $\left(\frac{\mu_s}{\rho}\right)$ is obtained by dividing μ_s with the density of the ammonium sulfate. Linear attenuation coefficient for ammonium sulfate (μ_s) is given in table 2. These experimental and theoretical values are tabulated in the table 3. The atomic cross section is seen to decrease with increase of gamma energy as is seen from the figure 4.

The half value thickness is calculated as

$$R_{1/2} = \frac{0.693}{\mu_s}$$

These values are tabulated in table 4. The plot of $R_{1/2}$ versus gamma energy is given in figure 5 and it shows linear increase of $R_{1/2}$ with gamma energy in the range which we have considered.

Table 1 : Experimental and theoretical values of scaled linear absorption coefficient μ' in cm^{-1} of ammonium sulfate solution for concentration in terms of $\frac{V_s}{V^f}$ at E_γ=0.36 MeV gamma ray energy.

Concentration $\frac{V_s}{V^f}$	**μ'_{Exp} cm^{-1}**	**μ'_{th} cm^{-1}**	**% Error**
0.1238	0.1173	0.1191	1.511
0.1115	0.1149	0.1182	2.7918
0.101522	0.118204	0.117521	0.5811
0.093153	0.117241	0.116943	0.2548
0.086058	0.116411	0.116452	0.03520
0.079968	0.113573	0.116031	2.1183
0.074682	0.114636	0.115665	0.8896
0.070052	0.113864	0.115345	1.2839
0.065963	0.113043	0.115062	1.7547

Table 2 : Linear absorption coefficient μ_s in cm^{-1} (expt. and Theo) of ammonium sulfate salt for various gamma ray energies (E_γ =0.36 MeV to 1.33MeV).

Gamma ray energy E_γ (MeV)	**$\mu_{s\ Exp}$ cm^{-1}**	**$\mu_{s\ th}$ cm^{-1}**	**% Error**
0.36	0.177341	0.179665	1.2935
0.511	0.164204	0.162967	0.759
0.662	0.141931	0.143837	1.325
0.84	0.130931	0.129953	0.7525
1.17	0.112133	0.110393	1.5272
1.28	0.104730	0.105499	0.7289
1.33	0.101820	0.103620	1.737

Table 3 : Total atomic cross section of ammonium sulfate salt for different gamma ray energies in units of 10^{-18} cm^{-1}.

Gamma ray energy E_γ (MeV)	**Total atomic cross section Expt.**	**Total atomic cross section Theo.**
0.36	7.3	7.4
0.511	6.7	6.7
0.662	5.9	5.9
0.84	5.3	5.4
1.17	4.5	4.6
1.28	4.3	4.3
1.33	4.2	4.2

Table 4 : Half value thickness ($R_{1/2}$) cm of ammonium sulfate salt for different gamma ray energies.

Gamma ray energy E_γ (MeV)	($R_{1/2}$) Expt.	($R_{1/2}$) Theo.
0.36	3.907705	3.857165
0.511	4.220339	4.252383
0.662	4.882627	4.817944
0.84	5.292837	5.332680
1.17	6.180143	6.277564
1.28	6.616992	6.568777
1.33	6.805472	6.688054

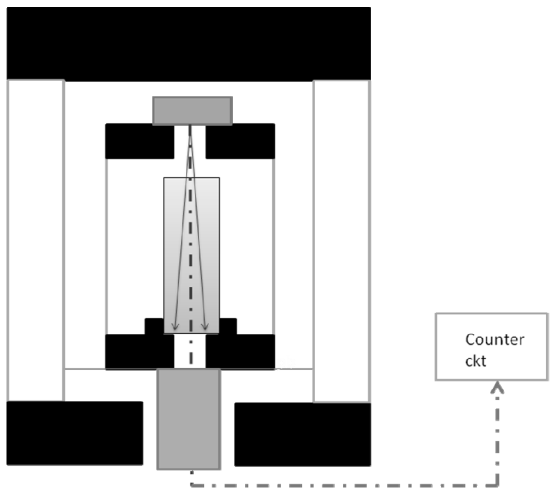

Figure 1: Experimental set up for measurement of gamma absorption coefficient for solution.

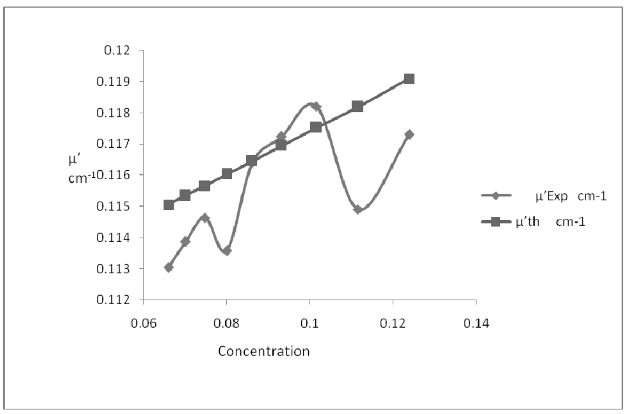

Figure 2: The plot of experimental and theoretical scaled linear attenuation coefficient for Ammonium Sulphate solution (μ'_{exp} and μ'_{th}) cm^{-1} with concentration of solution (V_s/V')

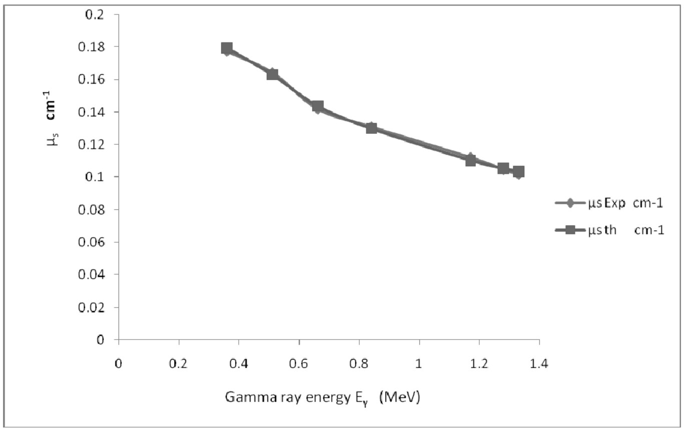

Figure 3: Linear attenuation coefficient of ammonium sulfate for different gamma ray energies.

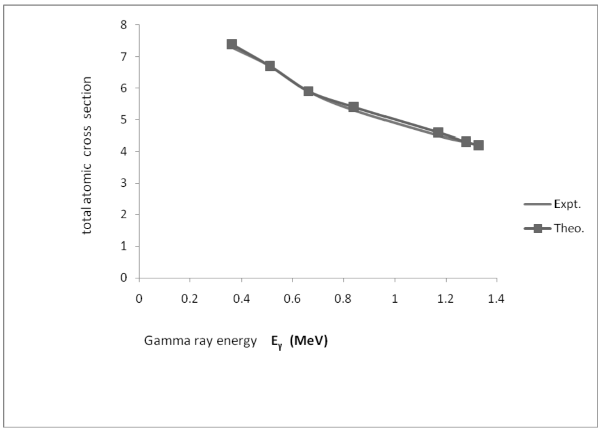

Figure 4: Total atomic cross section of ammonium sulfate salt for different gamma ray energies in units of 10^{-18} cm^{-1}.

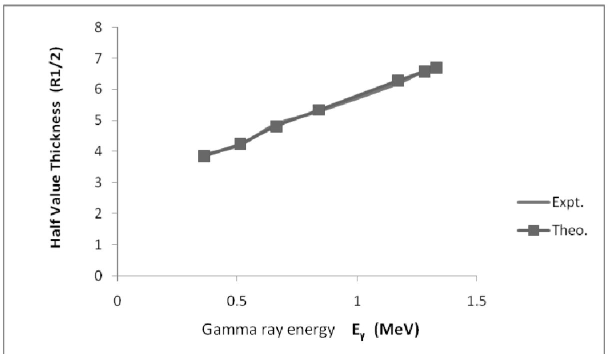

Fig 5: . **Half Value Thickness (R1/2) cm of** Ammonium Sulfate salt for different gamma ray energies.

Figure 5 : Half Value Thickness (R1/2) cm of Ammonium Sulfate salt for different gamma ray energies.

Conclusions

Our experimental measurement of linear attenuation coefficients of aqueous solutions of salts for different concentrations and estimation from them the attenuation coefficients for pure salts by using the formula establishes the validity and utility of the solution technique . This method is simple and avoids the need of preparation of pure single crystalline salts for experiment thereby saving time and expenditure. The use of multichannel analyzer has also improved the results as we could replace the counts at the photo peak by the area under it. Further the variation of concentration of solution is made easy by adding water to the solution without changing the salt amount in it. This saves the salt quantity and thus further economizes the experiment.

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