Dependence Of Gamma Ray Attenuation On Concentration Of Manganese (II) Chloride Solution

Chikkappa Udagani

Abstract: This paper presents the precise method to estimate the dependence of linear and mass attenuation coefficients of gamma rays on concentration of Manganese (II) chloride ($MnCl_2$). The experiment was done using GSpec gamma spectroscopy system. The GSpec consists 2”x 2” NaI (Tl) detector with Multichannel analyzer (MCA). The GSpec has built in 14 Pin PMT base.The GSPEC is pc based Gamma Ray Spectroscopy system, which communicates with PC through USB port. In this experimental work ^{137}Cs radioactive source emitting 0.662 MeV gamma rays has been used for analyzing the dependence of linear and mass attenuation coefficients of gamma rays on concentration of $MnCl_2$. The spectral analysis was made using Spectrum Analysis and Analyzing Software (SAAS). Inorder to minimize the effect of multiple scattering on the linear attenuation and mass attenuation coefficients, a good geometry experimental arrangement was setup. The experimental results shown that the linear attenuation coefficient varies linearly with concentration of $MnCl_2$ solution. The experimental values of the linear attenuation and mass attenuation coefficients are in close agreement with the theoretical values.

Index words: ^{137}Cs radioactive source, concentration, Gamma ray, attenuation, GSpec, MnCl2 SAAS.

1 INTRODUCTION

The study of attenuation of Gamma radiations through different materials is of wide interest in industrial, medical and agricultural fields. The X-rays and gamma rays are highly energetic radiations. The gamma radiations can penetrate solid, liquid and gaseous materials. The extent of penetration depends upon several factors including energy of incident radiation and nature of intervening material. The study of absorption of gamma radiations in shielding materials is important subject in the field of radiation physics. The study of Gamma photon attenuation coefficients is an important parameter for characterizing the penetration and attenuation properties of Gamma rays in materials. Accurate data on photon attenuation coefficients are required in a verity of applications in nuclear science, technology and medicine. The values of mass attenuation coefficients are available for a wide range of elements and composite materials from the National Institute for Standards and Technology NIST -XCOM database. The linear attenuation and mass attenuation coefficients by dilute solutions of Ferrous Sulfate, potassium chloride and Ammonium chloride for varying concentrations at various gamma energies have been studied [1], [2], [3]. Linear and mass attenuation coefficients of 0.511 MeV gamma radiations from alcohol ethanol by dilute solution of Phenol (C6H6O) studied for different concentrations [4]. Linear and mass attenuation coefficients of 662 KeV gamma radiations from alcohol ethanol by dilute solution of para-nitroaniline (C6H6O2N2) have been studied for different concentrations [5].

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The linear attenuation and mass attenuation coefficients of 662 and 1170 keV gamma radiations, from ^{137}Cs and ^{60}Co, respectively, for varying concentrations of solutions of $CoSO_4$-$7H_20$ were studied [6]. The linear attenuation coefficients in aqueous solutions of three carbohydrates, glucose ($C_6H_{12}O_6$), maltose monohydrate ($C_{12}H_{22}O_{11} \cdot H_2O$), and sucrose ($C_{12}H_{22}O_{11}$), were determined at different energies by the gamma-ray transmission method in a good geometry setup [7]. The aim of the present work is to test the linear variation of attenuation coefficients on concentration of $MnCl_2$ solution

2. EXPERIMENTAL WORK

2.1 Theory of transmission of gamma rays

The intensity of gamma ray after transmitting through the material of thickness x is: $I = I_0 e^{-\mu x}$, where I_0 and I are initial and final intensity of gamma radiation and μ is linear attenuation coefficient of material for the gamma ray. In analogy with the above equation the intensity of gamma radiation after traversing the height h of chemical solution is given by: $I = I_0 e^{-hx}$ Using the values of density (ρ) and linear attenuation coefficient (μ), the values of mass attenuation coefficient (μ/ρ) for different energies can be calculated. For chemical mixtures, the total mass attenuation coefficient (μ/ρ) is related to the (μ/ρ) values of each constituent component. The total mass attenuation coefficient (μ/ρ) of chemical solution can be calculated by the following mixture rule;

$$\mu/\rho = w_i (\mu/\rho)i$$

where w_i is the fraction by weight of the i^{th} constituent.

The theoretical linear and mass attenuation coefficients can be estimated using the NIST- XCOM. The XCOM program can generate cross sections on a standard energy grid, selected by the user, or for a mix of both grids. The XCOM program can generate cross sections and attenuation coefficients for compounds and mixtures at energies between 1 keV and 100 GeV. This program depends on applying the mixture rule to calculate the partial and total mass attenuation coefficients for all elements, compounds and mixtures at standard as well as selected energies

2.2 Gamma spectrometry

The gamma ray spectrometry system used in this present work consists of a high efficiency GSpec. The GSpec consists NaI (Tl) crystal detector of size 2"x2" and Multichannel analyzer (MCA). GSpec has built in 14 Pin PMT base.The GSpec is pc based Gamma Ray Spectroscopy system, which communicates with PC through USB port. The voltage divider and pulse processing circuitry is housed as front end electronics in GSpec. This plug-in PMT on GSpec makes it compatible with any NaI (Tl) detector with standard 14 Pin PMT. GSpec is powered through USB port. NaI (Tl) detector PMT requires around 1000V DC. These voltages are generated by DC-DC convertors operating on 5V DC supply from USB port. Power supply for the instrument consists of +5V for digital circuits and +9 and -9V, for analog circuits. High Voltage supply is generated by programmable HV module. It can generate HV upto 1200V DC. Data Acquisition and Control is through PC based application software, Spectrum Acquisition and Analysis Software (SAAS). Calibration of multi-channel analyzer converts the channel number, which is proportional to the pulse amplitude into incident gamma energy. In the present work calibration was done using Co-60 (1.17 MeV, 1.333 MeV), and Cs-137 (0.662 MeV). Due to internal heating, external temperature variations and due to the internal drifts in detector, pulse processing electronics and HV supply circuit, there could be a small shift in the output of spectroscopy amplifier. In order to get the stability in the spectrum i.e. minimum variation in the channel number for given energy of incident gamma rays, it is necessary to get back to the originals setting of channel for a particular energy pulse input. This is normally done by either adjusting the HV applied to the detector or by adjusting the gain of the spectroscopy amplifier. This stabilization can also be achieved by storing the energy calibration and applying the conversion factors at a fixed time interval. This is done automatically as the spectrum is being acquired. The Spectrum Stabilization Menu prompts user to enter the value of energy and also to enter the value of time interval. It is necessary to have the energy calibration prior to Spectrum Stabilization.

2.3 Method of preparation of $MnCl_2$ solutions

The concentration of a chemical solution can be defined as amount of solute that is dissolved in solvent. Concentration can be expressed in several ways; using percent composition by mass, volume percent, normality, molarity, or molality. In this experimental work concentration is expressed in terms of Percent Composition by Mass (%). The Percent Composition by Mass (%) is the mass of the solute divided by total mass of the solution (mass of solute plus mass of solvent), multiplied by 100. In this experimental work electronic balance was used to precisely measure the weight of $MnCl_2$. First 15.733 g $MnCl_2$ was taken in glass cylinder. The 100mL distilled water was added carefully to the glass cylinder. In order to prevent the leak out of the solution, top of the cylinder was gently sealed by stretching and tightly wrapping a piece of Para film around it. The glass cylinder was hold securely and gently invert several times until the $MnCl_2$ was completely dissolved in the distilled water. Concentration of the prepared solution was found to be 14% w/w. The same procedure was used to prepare 16%, 18%, 20%, 22%, and 24% w/w solutions of $MnCl_2$. The table (1) shows the concentration of prepared solutions and amount of $MnCl_2$ dissolved in 100mL distilled water.

2.4 Acquisition and analysis of gamma spectrum

The gamma spectrometry system was initially tested for resolution, linearity and stability characteristics to fix the best operating conditions by performing preliminary experiments. The resolution of the detector was nearly found to be 6 % for 0.662 MeV gamma rays at operating voltage 750V. In order to minimize the unwanted noise, walls and floors of the room and other scattering materials are kept as far as away from the spectrometer and a good stabilizer must be used to minimize electronic noise. The schematic of experimental arrangement is as shown in the Fig. (1). This arrangement provides good geometry setup. The ^{137}Cs radioactive source was kept in line with the Gamma spectrometer assembly at a distance of 5cm. First the spectrum of gamma rays from ^{137}Cs radioactive source without sample was recorded. The schematic of recorded spectrum is as shown in the Figure (2). Spectrum analysis is the most important function of the SAAS. However, before the analysis is done, it is necessary to select the peak regions. This is done by selecting the Region of Interest or ROI. ROI will be selected between the start and stop channels as desired. From the recorded spectrum the photopeak has been identified and Region of Interest (ROI) was fixed for experimental work. The SAAS gives integral counts, background counts and background subtracted counts under ROI. For fixed experimental geometry the photopeak appears at 0.662MeV when using ^{137}Cs radioactive source. With the same experimental geometry the empty beaker marked 10 mL, 20 mL, 30 mL and 40mL was mounted directly in line with the ^{137}Cs radioactive source and detector at opening end of the safety wooden box and the count rate under ROI was recorded. The 14%w/w $MnCl_2$ solution was gently poured to the beaker at a height of 1cm and count rate under ROI was recorded. The height of $MnCl_2$ solution was increased by gently pouring the solution into the beaker. With the different heights of the solution for given concentration, the count rates under the ROI were recorded. The experiment was repeated with 16%, 18%, 20%, 22%, and 24% w/w of $MnCl_2$ solutions.

Concentration (%w/w)	Amount of $MnCl_2$ dissolved in 100mL distilled water
14	16.30g
16	19.10g
18	21.95g
20	25.00g
22	28.25g
24	31.60g

Table.1 Concentration and amount of $MnCl_2$ dissolved in 100mL water.

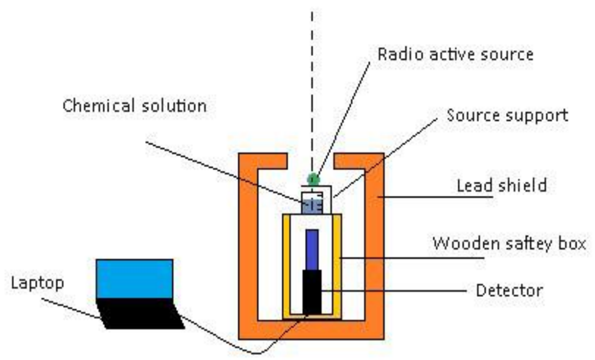

Fig.1. Experimental arrangement.

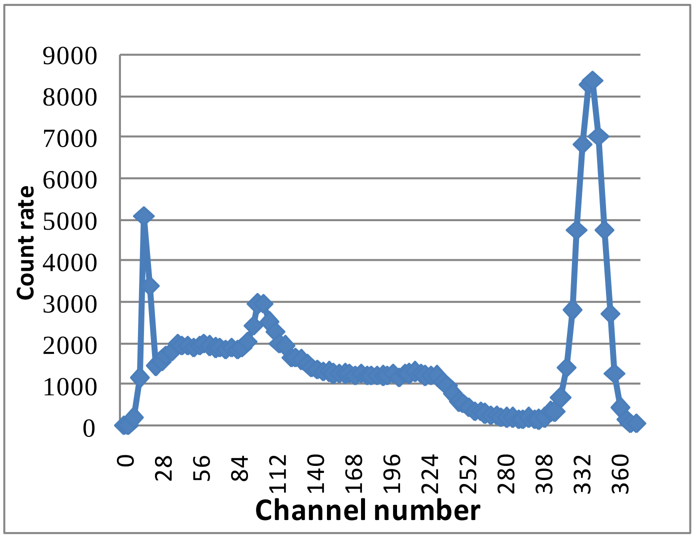

Fig.2. Schematic of gamma ray spectrum from Cs source.

3 RESULTS AND DISCUSSION

The Table (2) shows the variation of transmission factor for 0.662 MeV gamma rays with varying height of MnCl2 solution of given concentration and it also shows variation of transmission factor for different concentrations of MnCl2 solution. The transmission factor decreases with height of the solution at given concentration decreases with height of the solution. This is due to absorption of gamma rays while passing through the solution. Due to this fact intensity of gamma rays decreases. This results in increasing of linear attenuation coefficient and mass attenuation coefficients of $MnCl_2$ solution for the Gamma rays. The Table (3) shows the experimental and theoretical values of linear and mass attenuation coefficients of $MnCl_2$ solution with varying concentration. The linear attenuatiuon coefficient varies with concentration of the solution. The linear attenuation coefficient increases with increasing concentration. The linear attenuation coefficient is found to be maximum for 24%w/w solution and minimum for 14%w/w solution. The Mass attenuation coefficient also increases with increasing concentration of the solution. The Figure (3) shows the variation of linear attenuation coefficient versus concentration of $MnCl_2$ solution.

4 CONCLUSION

From this experimental work it was found that the Cs -137 radioactive source is useful in the study of gamma attenuation

Concentration% w/w	Density (g/cm^3)	Height of column of solution(cm)	Transmission factor(I/I_0)	$-\ln(I/I_0)$
14	1.124	1	0.9044	0.1005
		2	0.8179	0.2010
		3	0.7408	0.3000
		4	0.6698	0.4008
16	1.143	1	0.9018	0.1034
		2	0.8132	0.2068
		3	0.7342	0.3090
		4	0.6628	0.4113
18	1.164	1	0.8998	0.1056
		2	0.8096	0.2112
		3	0.7293	0.3157
		4	0.6565	0.4208
20	1.185	1	0.8985	0.1070
		2	0.8049	0.2170
		3	0.7235	0.3237
		4	0.6490	0.4323
22	1.206	1	0.8943	0.1117
		2	0.8006	0.2224
		3	0.7176	0.3318
		4	0.6358	0.4529
24	1.228	1	0.8928	0.1134
		2	0.7964	0.2277
		3	0.7120	0.3397
		4	0.6358	0.4529

Table (2) Height of column of solution of $MnCl_2$ and transmission factor.

Concentration of $MnCl_2$ solution %w/w	Density(g/cm^3)	Experimental value of Linear attenuation coefficient, μ(cm^{-1})	Experimental value of mass attenuation coefficient,μ/ρ (cm^2/g)	Theoretical value of Linear attenuation coefficient, μ(cm^{-1})	Theoretical value of mass attenuation coefficient, μ/ρ (cm^2/g)
14	1.124	0.1003	0.0892	0.1004	0.0893
16	1.143	0.1032	0.0903	0.1031	0.0902
18	1.164	0.1054	0.0905	0.1056	0.0907
20	1.185	0.1079	0.0911	0.1083	0.0914
20	1.206	0.1117	0.0926	0.1109	0.0920
24	1.228	0.1134	0.0923	0.1136	0.0925

Table (3) Height of column of $MnCl_2$ and transmission factor.

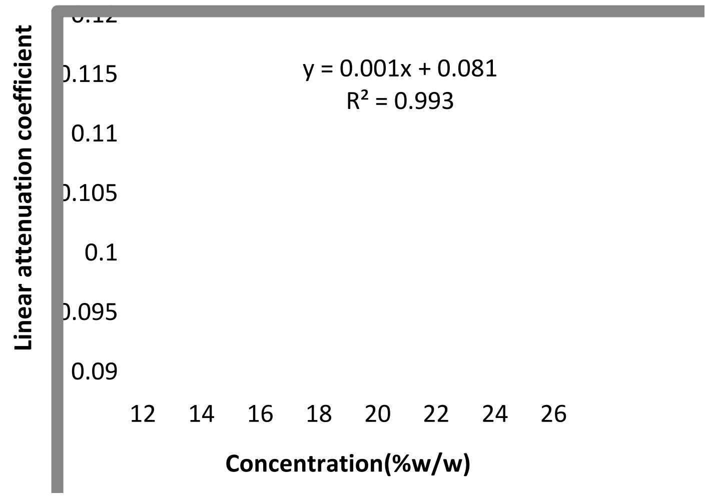

Fig.3. Plot of linear attenuation coefficient versus concentration of $MnCl_2$ solution.

by chemical solutions such as MnCl2. The linear attenuation coefficient varies linearly with concentration of the MnCl2 solution. Theoretical values of linear and mass attenuation coefficients have been calculated using NIST- XCOM online data base. The experimental values of linear and mass attenuation coefficients are in close agreement with the theoretical values within the experimental errors. The linear variation of attenuation coefficient with concentration of chemical solution will be useful phenomenon to estimate the concentration of chemical solution. This type of experimental work is useful in plotting calibration curves for estimating the unknown concentration of chemical solution. The precise estimation of concentration of chemical solutions is useful to determine concentration of chemical solutions in pharmaceutical industries and forensic laboratories

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