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EstimationofPenetration Depth ofβ- Radiations inParaffin Wax andMica

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Abstract:*A precise method for determination of penetration depth of β-radiationin paraffin wax and mica is described in this paper.The measurements have carried out using Gamma-Scout with Tl-204 and Cs -137 sources. The Gamma Scout is very sensitive, portable and reliable instrument. We have used paraffin wax of density 0.9 g/cm^3 and mica of density 2.8g/cm^3.The penetration depth of β-particles strongly depends on energy of incident β-radiation and the density of the intervening material. The paraffin wax is low density material its density is nearly equal to density of flesh and hence determination of penetration depth of β-radiation in the paraffin wax is helpful in understanding the interaction of β-particles with low density materials. The mica is very important dielectric material and is used in capacitors and electric appliances. The determination of penetration depth of β-particles in mica is useful in understanding the interaction of β-particles with mica. This experimental technique can be used to estimate thickness, density, presence of impurity in sample.*
Key words:*β-radiation, Gamma scout, mica, Paraffin wax,penetration depth*

I. Introduction

β- particlehas lesser electric charge and mass than alpha particle. Due to this β- particle interactsweakly with matter;therefore β- particles have a longer range than alpha particles. The β- transmission method isused to carry out research in nuclear science, industries, defense and medicine. Interaction of beta radiation with materials can provide significant information about the nature of the sample. The β- radiations can penetrate materials. The extent of penetration depends upon several factors including density of material and the energy of beta radiation. Beta particles can be used as tracers. Beta particles are also used in quality control to test the thickness of sheet metal, paper, plastics, photographic film etc. The energy transfer from ionizing radiation to individual molecules causes the ejection of electrons from the molecules and initiates a variety of chemical and physical effects; the most important one is the damage of DNA molecules[1].The cancer risks associated with low-dose radiation are of societal importance[2].The μ/ρ values have been calculated for monoenergetic electron and positron using semi-empirical transmission equation[3]. Theoretically calculated values of μ/ρ of beta particles in elements were reported [4, 5]. The β transmission method itself can be used for quality assurance and selection of a uniform set of TLD tape dosemeters over thickness range 30–150 mg/cm^2[6]. Thedosimetry is required to calculate patient-based activity for patient safety and to optimize planning of administered activity and post-therapy verification of absorbed doses. The dosimetry is also essential for regulatory approval of new radiopharmaceuticals. Beta particles can be used as tracers. Beta particles are also used in quality control to test the thickness of sheet metal, paper, plastics, photographic film etc. It is very difficult to accurately predict thickness of material required to absorb a given fraction of incident radiation from theory. This present work is useful to estimate the penetration depth of beta radiation dose in paraffin wax and micaexperimentally.

II. Experimental Work

2.1. Theory:

β-particles interact with the matter and loss their kinetic energy through the collisions with atomic electrons. In addition the β- particle may lose its energy by radiative process called Bremsstrhlung. In macroscopic level beta particles suffer from absorption inside absorber material.

The change in beta intensity after traversing the thickness 'dx' in a material can be expressed in the form of an equation as:

$dI = - I(x).n.\sigma.dx$ ------------ (1)

dI = the change in beta radiation intensity
I = the initial beta radiation intensity of
n = the number of atoms/cm^3
σ = total microscopic cross section that reflects the total probability of a photon being scattered or absorbed
dx = the incremental thickness of material traversed.
On integration, the equation (1) becomes;

$I = I_0$ e-nσx --------- (2)
The number of atoms/cm^3 (n) and the microscopic cross section (σ) are usually combined to yield the linear attenuation coefficient (μ). Therefore the equation becomes:
$I = I_0 e^{-\mu x}$ ------------ (3)

From the above equation one can know that intensity of β- radiation decreases exponentially as it traverses through material. β- particles interact with the matter and loss their energy and eventually come to rest after traversing a certain distance in the material called range of the beta particles in that material. The range of beta particles in an absorber is the average penetration depth of the charged particle into the absorber before it loses all of its kinetic energy.

The depth Rmax of beta particles penetration in substance can be defined with the help of expression (1)

$$\text{Rmax} = \frac{E_\beta^{1.265 - 0.0954 \ln E_\beta}}{\rho} \text{ -------------------- (4)}$$

where E_β is the maximum energy of β- particles and ρ, the density of sample material.

2.2. Instrument:

In the present work the Gamma scout (GmbH & Co. KG) is used to carry out measurements. The Gamma scout is general purpose survey meter which measures alpha, beta and gamma radiations. Gamma Scout is a dose rate meter equipped with a Geiger-Müller counter. Geiger-Müller counter consists of a gas filled tube containing electrodes, between which there is an electrical voltage. When ionizing radiation passes through tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. It has the ability to shift from dose rate mode to pulse counting mode and reverse of pulses per second measures the intensity of the radiation field. The Gamma scout determines the dose rate in terms. Comparative study of the gamma radiation dose level in different industries in Jos Plateau State, Nigeria was carried out using Gamma Scout [7].

2.3 Pulse rate measurement:

The thickness of sample is determined using the relation:

$$\text{Thicknees (cm)} = \frac{\text{Mass in gram}}{\text{Length (cm)} \times \text{breadth (cm)} \times \text{densty} \left(\frac{\text{gm}}{\text{cm}^3}\right)}$$

The experimental setup for studying penetration depth is shown in the Fig. (1). The experiment was carried out by switching the Gamma Scout to the pulse count mode. In this mode it is possible to set desired measuring time. In the present work the measuring time is preset to two minutes. The Tl- 204 source in the source holder was kept at distance 3.5cm from the end window of the GM tube. Tl- 204 is pure β -emitter and it emits β- particles with maximum energy 0.763MeV. Without sample the number of pulses was recorded for two minutes. The Paraffin wax of thickness 0.033 cm was introduced in between the source and the GM tube end of the Gamma- Scout and the the number of pulses was recorded for two minutes. The sample thickness was increased and data acquisition was continued until the measured value was very close to the background level i.e the number of pulses in the absence of the Tl- 204. The same procedure was used for mica.The Cs- 137 emits both γ and β- radiations. Cs- 137 emits β - particles with maximum energy 0.510MeV.Inorder to find penetration depth of β radiations from Cs- 137 in paraffin wax and mica, the Gamma-Scout was switched at β + γ. In this casethe Gamma Scout records pulses of both gamma rays and beta rays. Without sample the number of pulses was recorded for two minutes. Then the Gamma Scout was switched at β. In this case the Gamma- Scout gives pulses of β- rays only. The subtraction of β pulses from β + γ pulses gives background due to γ rays. The paraffin wax of thickness 0.033 cm was introduced in between the source and the GM tube end of the Gamma-Scout and the the number of pulses was recorded for two minutes. The sample thickness was increased and data acquisition was continued until the measured value was very close to the background level i.e the number of pulses in the absence of the Cs- 137 and background due to γ- rays. The same procedure was repeated for mica.

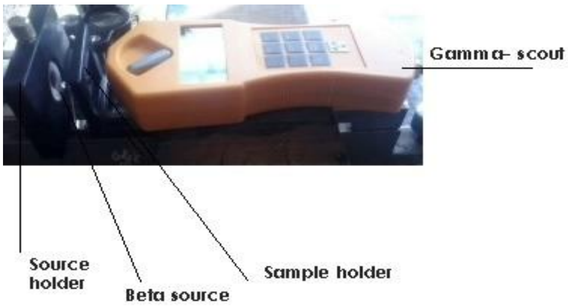


Figure1. Experimental setup.

Table (1): Count Rate versus thickness for paraffin wax with ^{204}Tl beta source.

Thickness (cm)	Count rate(Number of counts/sec)			
	Trail 1	Trail 2	Trail 3	Mean
0	12.3333	12.4167	12.5667	12.4389±0.1183
0.033	7.1167	7.1500	7.0917	7.1195±0.0292
0.048	5.9167	6.0417	6.2083	6.0556±0.1463
0.070	3.8667	3.9167	4.0000	3.9278±0.0673
0.088	3.1250	3.3083	3.1750	3.2028±0.0948
0.158	1.2083	1.1333	1.1417	1.1611±0.0411
0.206	0.7083	0.7000	0.7333	0.7139±0.0173
0.239	0.5250	0.5667	0.6167	0.5695±0.0459
0.246	0.4583	0.4750	0.5000	0.4778±0.0210
Background	0.4333	0.4750	0.5000	0.4694±0.0337

Table (2): Count Rate versusthickness for micawith ^{204}Tl beta source.

Thickness (cm)	Count Rate(counts/sec)			
	Trail 1	Trail 2	Trail 3	Mean
0	12.1417	12.1917	12.2250	12.1861±0.0419
0.0045	9.4417	9.5167	9.4250	9.4611±0.0488
0.0098	6.8750	6.7083	6.9833	6.8555±0.1385
0.0232	3.1250	3.0000	3.0833	3.0694±0.0636
0.0366	1.6000	1.7417	1.6500	1.6639±0.0719
0.0500	0.9917	1.0667	1.0167	1.0250±0.0382
0.0598	0.7750	0.7000	0.7250	0.7333±0.0382
0.0688	0.6250	0.6333	0.6500	0.6361±0.0127
0.0786	0.4750	0.4500	0.5000	0.4750±0.0250
Background	0.4667	0.4500	0.4917	0.4695±0.0210

Table (3): Count Rate versus thickness for paraffin waxwith ^{137}Cs beta source.

Thickness (cm)	Count Rate(counts/sec)			
	Trail 1	Trail 2	Trail 3	Mean
0	32.6250	31.9500	32.3167	32.2972±0.3380
0.033	22.9000	23.5083	23.1667	23.1917±0.3049
0.048	17.6917	18.0333	17.2917	17.6722±0.3712
0.070	11.9417	12.0417	12.4083	12.1306±0.2457
0.088	8.3000	8.4750	8.3667	8.3806±0.0883
0.158	7.0583	7.0500	7.0417	7.0500±0.0083
0.206	6.5083	6.4917	6.5167	6.5056±0.0127
Background	6.4833	6.4583	6.4917	6.4778±0.0173

Table (4): Count Rate versus thickness for micawith ^{137}Cs beta source.

Thickness (cm)	Count rate(counts/sec)			
	Trail 1	Trail 2	Trail 3	Mean
0	33.0333	31.9500	32.3167	32.4333±0.5510
0.0045	22.9000	23.5083	23.1667	23.1917±0.3050
0.013	17.6917	18.0333	17.2917	17.6722±0.3712
0.021	11.9417	12.0417	12.4083	12.1306±0.2457
0.034	8.3000	8.3000	8.3667	8.3222±0.0385
0.046	7.0583	7.0583	7.0417	7.0528±0.0096
0.054	6.5083	6.5083	6.5167	6.5111±0.0049
Background	6.4833	6.4833	6.4917	6.4861±0.0049

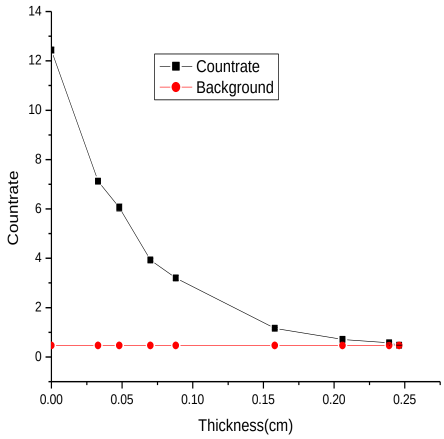
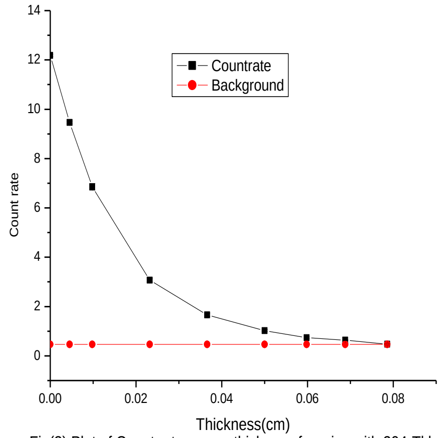


Fig.(2): Plot of count rate v/s Thickness for paraffin wax with Tl- 204 source.



Fig(3):Plot of Count rate versus thickness for mica with 204-Tl beta source

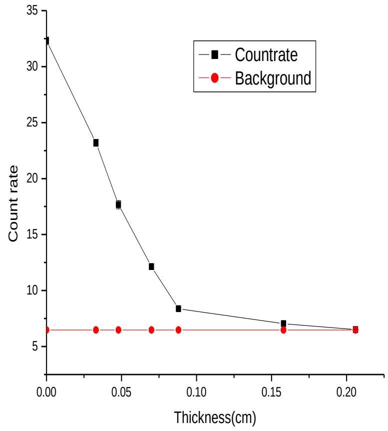


Fig.(4) Plot of count rate versus thickness for paraffin wax with 137Cs beta source.

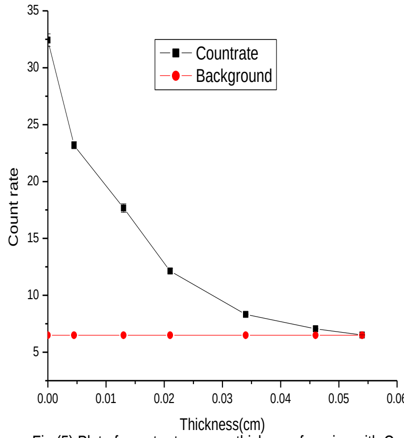


Fig.(5) Plot of count rate versus thickness for mica with Cs-137 beta source.

III. Results And Discussion

The Experimental setuptostudy penetration depth is shown in the Fig. (1). Table (1) and Table (2) show the dose rate versus thickness of material for paraffin wax and mica respectively for β- particles from Tl-204.Fig.(2) and Fig.(3) showthe plots of count rate versus thickness of material for paraffin wax and mica respectively using the data tabulated in the Table (1) and Table (2).Table (3) and Table (4) show the count rate versus thickness of material for paraffin wax and mica respectively for β- particles from Cs- 137. Fig.(4) and Fig.(5) show the plots of count rate versus thickness of material for paraffin wax and mica respectively using the data tabulated in the Table (3) and Table (4). From the Fig (2) and Fig (3) the penetration depth of Tl- 204 beta particles in paraffin wax and mica are found to be 0.246cm and 0.079cm respectively. From the Fig.(4) andFig.(5), the penetration depth of Cs- 137 beta particles in paraffin wax and micaare found to be 0.206cm and 0.054cm respectively.

IV. Conclusion

For given energy of β- particles, the penetration depth decreases with increasing density of intervening material.Due to this, penetration depth of β- particlesis lesser for mica because of its higher density relative to paraffin wax.The count rate measurement confirms that the radiation dose penetrates deeper in to the lower density materials such as paraffin wax for given incident β- radiation energy. The density of paraffin wax is 0.9g/cm^3 which isvery close to density of flesh. This experimental technique is useful for understanding the β- radiation dose absorption in low and medium density materials. This technique can be used in estimatingthickness and density of mica, paraffin wax, paper, plastics, etc. This technique can also be used to determine moisture content and porosity of samples.

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