Applications of Geiger-Muller Counter

Swaroop Ramakant Avarsekar*
School of Physical Sciences, National Institute of Science Education and Research, HBNI, Jatni -752050, India
(Dated: March 18, 2023)

We study the range and back scattering of beta particles, production and attenuation of Bremsstrahlung as part of application of GM counter. Tl-204 and Sr-90 is used as beta sources. The range of beta particles for Sr-90 was found to be $0.711 g/cm^2$ and end point energy as 1.54 MeV. In back scattering, the saturation thickness could not be estimated. In Bremsstrahlung, the count rate of perspex was lower than metals and the rate was comparable between Al and Cu. Also short half life of radioactive sample is also calculated. Mixture of 0.9% NaCl in 0.04 M HCl as used as a solvent which is mixed with Cs-137 isotope generator. Half life of the same was found to be 385.726± 3.434 s.

Keywords: Bremsstrahlung, End point energy, Back-scattering

I. THEORY

A. Range of Beta Particles

A widely used empirical formula for the range of beta particles related to its end point energy in the Aluminum absorber is given by,

$$R = (0.52E - 0.09) g/cm^2 \tag{1}$$

where E is end point energy of beta source.

To calculate range by half thickness method, we have,

$$\frac{t_1^{1/2}}{t_2^{1/2}} = R_1/R_2 \tag{2}$$

where $t_1^{1/2}$ and $t_2^{1/2}$ are thickness of Al at half count rate for two sources and R_1 and R_2 are range of β particles from two sources.

We use Tl-204 and Sr-90 as source for experiment.

B. Back-Scattering of Beta Particles

Absorption occur when collision of beta particles with matter, scattering may also occur due to collision with increasing atomic no. Back scattering occurs when angle of deflection is greater than 90°, which is dependent on material. Higher atomic no. scattering occurs at large angle with little loss of energy. Back scattering is proportional to $\sqrt{Z}$. Thickness of material influence Back scattering upto a saturation point with maximum value attaining thickness less than range of beta particles.

C. Bremsstrahlung

Bremsstrahlung is electromagnetic radiation produced by deceleration of charged particles like electron. It looses kinetic energy and converted to a photon. Bremsstrahlung has continuous spectrum becomes intense as intensity shifts towards higher frequencies. the intensity increases with the atomic no./density goes up. If the mass per unit area of plates used as absorbers such that beta particles are completely absorbed, then materials with higher atomic density, higher Bremsstrahlung count rate is obtained.

II. EXPERIMENT AND ANALYSIS

A. Range of Beta Particles

Table I: Background count

Sl no.	Count
1	62
2	51
3	54
4	58
5	55
Average	56

* swaroop.avarsekar@niser.ac.in

Table II: Source:Tl-204, Absorber: Al

Absorber Thickness (mm)	Absorber Thickness (mg/cm^2)	Counts	Net Counts
0	0	12653	12597
0.06	16.26	9120	9064
0.12	32.52	6776	6720
0.18	48.78	5262	5206
0.24	65.04	3834	3778
0.3	81.3	2206	2150
0.36	97.56	2015	1959
0.42	113.82	1188	1132
0.48	130.08	1206	1150
0.54	146.34	864	808

Table III: Source:Sr-90, Absorber: Al

Absorber Thickness (mm)	Absorber Thickness (mg/cm^2)	Counts	Net Counts
0	0	10088	10033
0.06	16.26	8074	8019
0.12	32.52	7315	7260
0.18	48.78	6247	6192
0.24	65.04	5684	5629
0.3	81.3	5273	5218
0.36	97.56	4814	4759
0.42	113.82	4440	4385
0.48	130.08	4173	4118
0.54	146.34	4119	4064

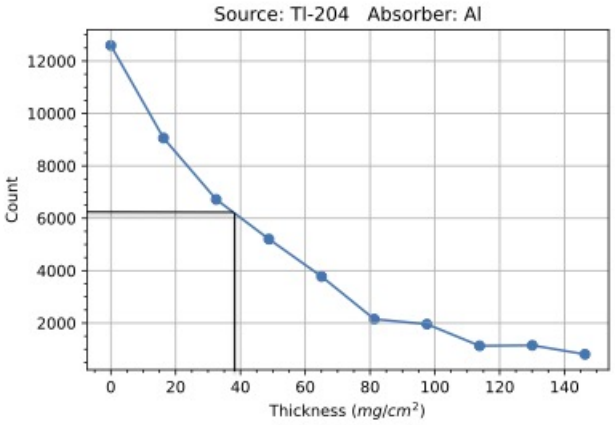

Figure 1: Net Count vs Thickness curve for Tl-204

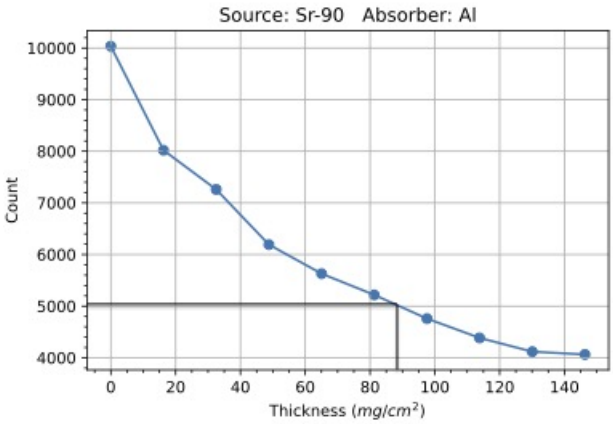

Figure 2: Net Count vs Thickness curve for Sr-90

We obtain thickness of Al required to reduce the count rate by half is $t_1^{1/2} \approx 38\ gm/cm^2$ and $t_2^{1/2} \approx 88 gm/cm^2$ where $t_1^{1/2}$ is thickness of Al for Tl-204 and Sr-90, respectively.

The end point energy of Tl-204 is 0.764 MeV. Therefore, Range of beta particles from Tl-204 is

$$R_1 = (0.52E_o - 0.09) \tag{3}$$

$$R_1 = (0.52 \times 0.764 - 0.09) = 0.30728 g/cm^2 \tag{4}$$

Therefore,

$$\frac{t_1^{1/2}}{t_2^{1/2}} = \frac{R_1}{R_2} \tag{5}$$

$$\frac{t_2^{1/2}}{t_1^{1/2}} \times R_1 = R_2 \tag{6}$$

$$R_2 = \frac{88}{38} \times 0.30728\ g/cm^2 = 0.711\ g/cm^2 \tag{7}$$

End-point energy of Sr-90 is

$$E_2 = \frac{R_2 + 0.09}{0.52} \tag{8}$$

$$E_2 = \frac{0.711 + 0.09}{0.52} = 1.54 MeV \tag{9}$$

B. Back-Scattering of Beta Particles

Table IV: Material-Al, Preset time-200 s

Thickness (mm)	Counts			Net Counts
	I	II	Avg	
0	208	182	195	-
0.05	217	194	205.5	10.5
0.1	205	222	213.5	18.5
0.15	208	202	205	10
0.2	197	213	205	10
0.25	233	221	227	32
0.3	226	225	225.5	30.5
0.35	208	210	209	14
0.4	215	241	228	33
0.45	196	180	188	-7
0.5	162	192	177	-18
0.55	210	184	197	2
0.6	198	202	200	5
0.65	200	181	190.5	-4.5

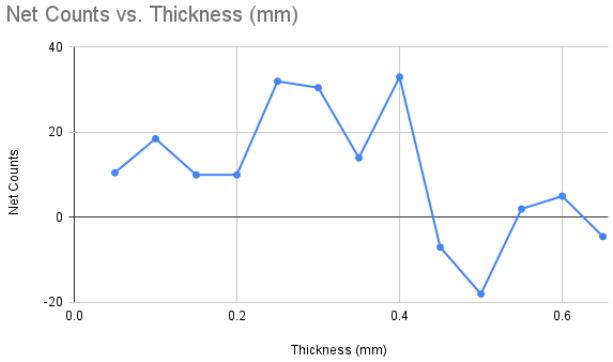

Figure 3: Net Count vs Thickness curve for Back scattering

The angle between source and detector was set to 100°. It was expected to be saturated but counts was not read as expected. It may happened due to usage of source on two different days may have resulted in unexpected count as experiment was done on two different days. Therefore, this experiment failed to determine saturation thickness of the material.

C. Bremsstrahlung

Sr-90 source was used with preset time of 300s and distance between source and detector as 6 cm and activity of 0.1 mCi. The Background count is 307. The observation of Bremsstrahlung is shown in tables V, VI and VII.

Table V: For Al(0.7 mm) and Perspex (1.8 mm) combination

S. No.	Absorber Position	Counts	Net Counts
1	-	6812	6505
2	Perspex facing source	395	88
3	Al. facing Source	495	188

Table VI: For Perspex (1.8 mm) and Cu(0.3mm) combination

S. No.	Absorber Position	Counts	Net Counts
1	-	7554	7247
2	Perspex facing source	434	127
3	Cu facing Source	445	138

Table VII: For Al (1.8 mm) and Cu(0.3mm) combination

S. No.	Absorber Position	Counts	Net Counts
1	-	7562	7255
2	Cu facing source	414	107
3	Al facing Source	410	103

The count rate of Bremsstrahlung depends on order of arrangement of the materials. We can see from table V that the count rate for the perspex is low with that of aluminium, since Bremsstrahlung generated is not absorbed in metals. Even for perspex-Cu combination, shown in table VI, we see count rate of Cu is higher than perspex. With the combination of Al-Cu, as shown in table VII, the count rate is almost similar in both the materials.

D. Short half life

A mixture of 0.9% NaCl in 0.04 M HCl is used as a solvent which is mixed with Cs-137 isotope generator. The mixture is used to take the count reading. The background count was found to be 294.

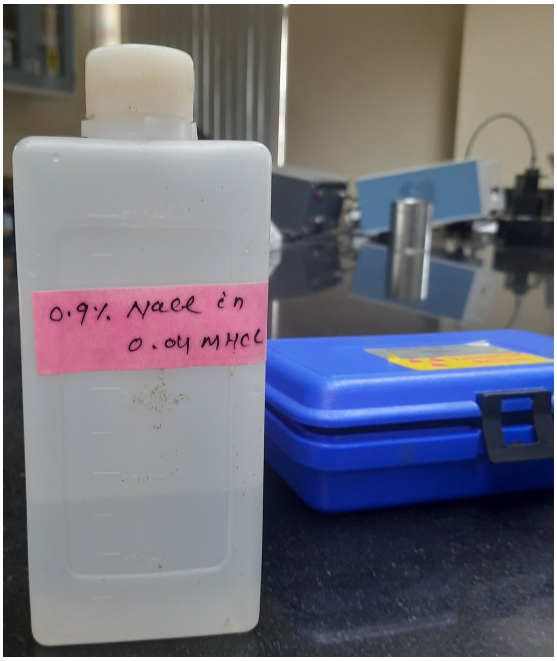

Figure 4: Solvent used for generator

Figure 5: Cs-137 Isotope generator.

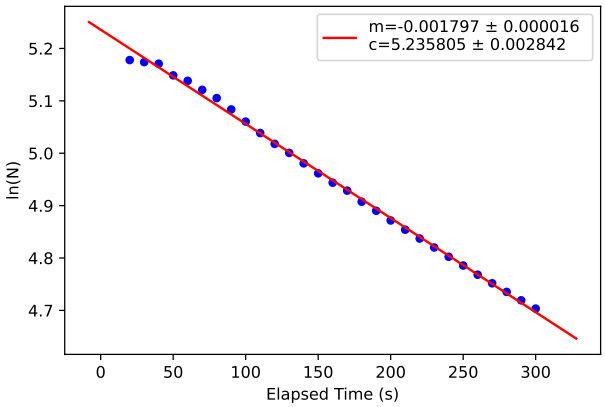

Figure 6: Plot of ln(N) versus time

Table VIII: Determination of short half life

S. No.	Elapsed Time (s)	Counts	Corrected count/s	ln(N)
1	20	3840	177.30	5.177843213
2	30	5592	176.60	5.173887288
3	40	7337	176.08	5.170910041
4	50	8904	172.20	5.148656592
5	60	10519	170.42	5.138246419
6	70	12019	167.50	5.120983351
7	80	13485	164.89	5.105263423
8	90	14815	161.34	5.083541486
9	100	16059	157.65	5.060377386
10	110	17262	154.25	5.03860413
11	120	18425	151.09	5.017886717
12	130	19600	148.51	5.000636757
13	140	20674	145.57	4.980666884
14	150	21718	142.83	4.961631774
15	160	22742	140.30	4.943782987
16	170	23786	138.19	4.92861678
17	180	24648	135.30	4.907494535
18	190	25559	132.97	4.890151246
19	200	26401	130.54	4.87164139
20	210	27229	128.26	4.854074304
21	220	28040	126.12	4.837219418
22	230	28808	123.97	4.820071165
23	240	29526	121.80	4.802380355
24	250	30240	119.78	4.785690121
25	260	30896	117.70	4.768139014
26	270	31557	115.79	4.75176861
27	280	32185	113.90	4.735289514
28	290	32799	112.09	4.71926828
29	300	33392	110.33	4.703445662

We have slope as -0.001797 ± 0.000016 s^{-1} with intercept as 5.238± 0.002. The intercept gives as initial count, ln(N)=5.238 implying 188.29 count/s. Therefore, decay constant is the slope, $\lambda = -0.001797 s^{-1}$. Hence,

$$t_{1/2} = 0.693/\lambda = 385.726s \tag{10}$$

Error in $t_{1/2}$ is given by:

$$\delta t_{1/2} = t_{1/2} \times \delta\lambda/\lambda \tag{11}$$

$$\delta t_{1/2} = 385.726 \times 0.000016/0.001797 = 3.434s \quad (12)$$

The short half life of the mixture is 385.726± 3.434 s, with initial count as 188.29 count/s.

III. CONCLUSION

We studied the range of beta particles and calculated the end point energy of Sr-90. The other source was Tl-204 used as reference. We determined the range as $0.711 g/cm^2$ by half thickness method and end point energy as 1.54 MeV. Backscattering with Al as absorber was also studied. In this part of experiment, we were unable to determine the saturation thickness as experiment have been performed in two different days. The Bremsstrahlung was studied and the count rate was expected based on the order of the materials. Combination of Al, Cu and Perspex was used. It was seen that count rate is low for perspex as 188.29 count/s. Bremsstrahlung generated is not absorbed for Al and Cu. The count rate of Al and Cu was comparable. We also determined the half life of mixture of 0.9% NaCl in 0.04 M HCl as used as a solvent which is mixed with Cs-137 isotope generator. It was found to be 385.726± 3.434 s with initial count as

One of the ways to improve the back scattering experiment to get thickness saturation is by setting angle between the source and detector to optimal obtuse angle based on several trials and marking the positions of the source and detector. Good aluminium sheets must be used for this experiment. Torn sheets may give inaccurate count readings. It is to be noted that they should be blocked by lead block. Also the count rate is not continuous and exact in the GM counter as it can only count upto a limited number. One must take precautionary measure while handling radioactive sources.

IV. REFERENCES

1. NISERlabmanual