EXPERIMENTS WITH G. M. COUNTER

Centre for Medical and Radiation Physics

CONTENTS

Title Page

GENERAL INFORMATION ON GEIGER - MULLER TUBES

Geiger-Muller radiation counter tubes (G.M. tubes) are intended to detect alpha particles, beta particles, gamma, or X-radiation. A G.M. tube is a gas-filled device that reacts to individual ionizing events, thus enabling them to be counted. A G.M. Tube consists of an electrode at a positive potential (anode) surrounded by a metal cylinder at a negative potential (cathode). The cathode forms part of the envelope or is enclosed in a glass envelope. Ionizing events are initiated by quanta or particles entering the tube through the window or the cathode and colliding with the gas molecules. The gas filling consists of a mixture of one or more rare gasses and a quenching agent. Quenching is the termination of the ionization current pulse in a G.M. tube. Effective quenching in the G.M. tube is determined by the combination of the quenching gas properties and the value of the anode resistor.

DESCRIPTION OF G.M COUNTING SYSTEM GC602A

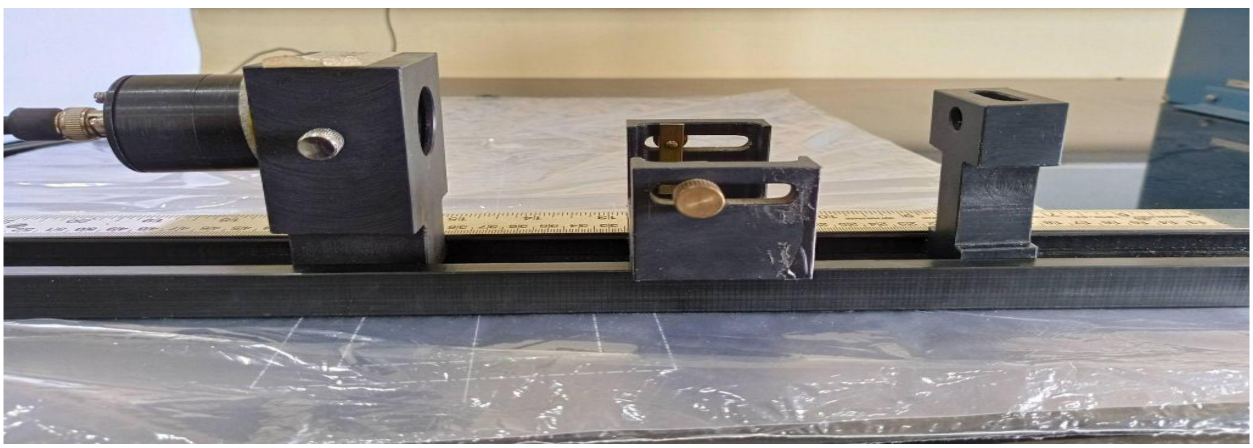
Geiger Counting system type GC602A is an Advanced Technology based versatile integral counting system designed around an eight-bit microcontroller chip. This system is highly recommended for research work, apart from its usefulness in the academic field of teaching. This system, along with wide-end window G.M. Tube Type GM125 and Lead Castle, will be an excellent Beta Counting System useful for swipe sample counting by Health Physics Labs. This counting system is useful for carrying out a number of Nuclear Physics experiments.

G.M Counting System GC602A Front & Rear panel

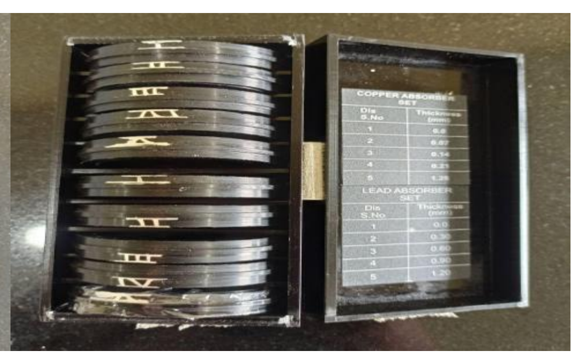
ACCESSORIES FOR GEIGER COUNTING SYSTEM:



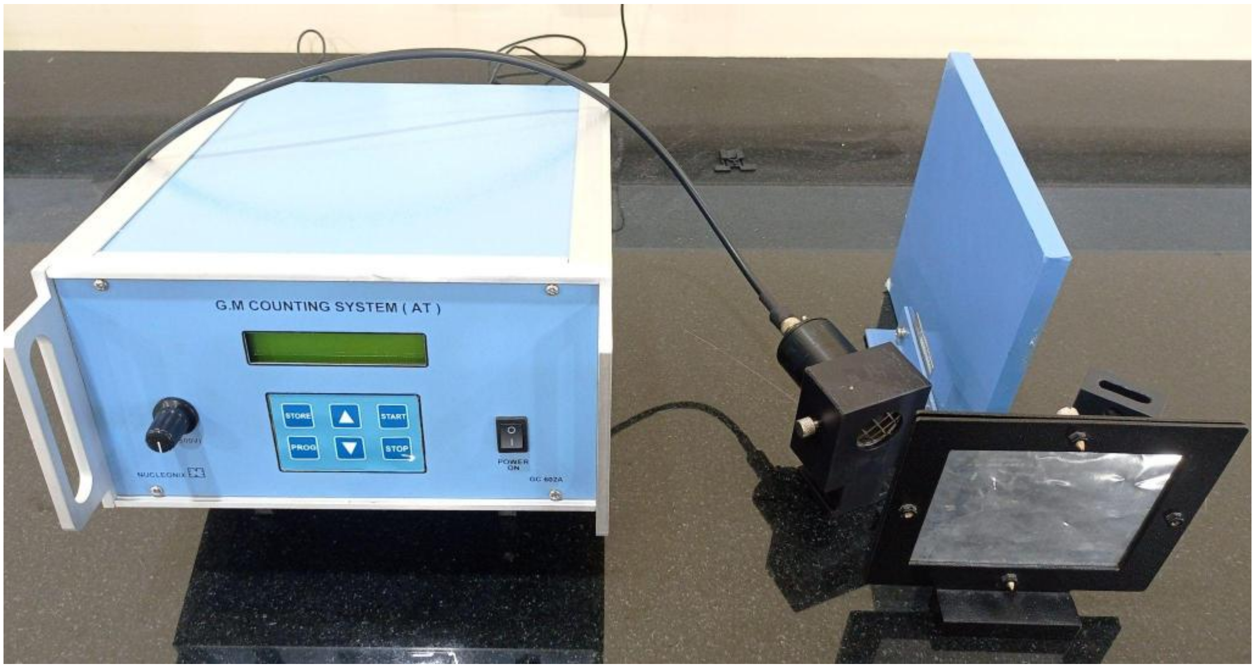
G.M Detector | Stand for G.M Detector | Source kit



Sliding bench for G.M Experiments

Aluminium Absorber Set | Copper & Lead Absorber Set



Scatterer Set (For Scattering of Beta Particles Experiment)

Geiger Mueller Counter - GC602A

The G.M. Detector, also known as the Geiger-Mueller counter, is a Gas-filled tube that detects various types of ionizing radiation. This device is named after the two physicists who invented the counter in 1928, and Mueller was a student of Hans Geiger. G.M. Detector is widely used in applications such as radiation dosimetry, radiological protection, experimental physics, and the nuclear industry. A Geiger counter (GM Counting system) consists of a Geiger-Mueller tube (the sensing element that detects the radiation) and the processing electronics display the result.

Geiger counter can detect ionizing radiation such as alpha particles, beta particles, and gamma rays using the ionization effect produced in a Geiger-Muller tube, which gives its name to the instrument. The voltage of the detector is adjusted so that the conditions correspond to the Geiger-Mueller region.

Applications - Detection of Alpha, Beta, and Gamma Radiation.

G.M. Detectors are mainly used in portable and installed radiation measuring instruments due to their sensitivity, simple counting circuit, and ability to primarily detect low-level to high-level gamma radiations. Although the major use of Geiger counters is probably in individual particle detection, they are also used in gamma Survey Meters, Contamination Monitors, Area Gamma Monitors, and a host of Health Physics instruments.

They can detect almost all the basic types of radiation, but there are slight differences in the construction of the Geiger-Mueller tube. Depending on the application to detect low or high gamma radiation, the construction of the wall material size of the detector varies, and for Beta-Gamma detection thin-walled G.M. Detector is employed. Whereas thin-end window detectors are used for Beta detection, G.M. Detectors are rarely used for Alpha detection. Also, the Geiger-Mueller tube cannot distinguish between different types of radiation, such as Alpha, Beta, and Gamma Radiation. However, detection efficiency varies depending on the type of radiation.

There are two main types of Geiger tube construction:

End-Window type: For alpha and beta particles to be detected by Geiger counters, they must be given a thin window. This "end-window" must be thin enough for the alpha and beta particles to penetrate. However, a window of almost any thickness will prevent an alpha particle from entering the chamber. The window is usually made of mica with a density of about 1.5 -2.0 mg/$cm^2$to allow low-energy beta particles (eg, from carbon-14) to enter the detector. The efficiency reduction for alpha is due to the attention, though the distance from the surface being checked also has a significant effect. Ideally, a source of alpha radiation should be less than 10mm from the detector due to attenuation in the air. Tubular Windowless type: Gamma rays have very little trouble penetrating the metal walls of the chamber. Therefore, Geiger counters may be used to detect gamma radiation and X-rays (thin-walled tubes) collectively known as photons, and for this, the windowless tube is used.

A thick-walled tube is used for gamma radiation detection above energies of about 25 keV, and this type generally has an overall wall thickness of about 1-2 mm of chrome steel.

A thin-walled tube is used for low-energy photons (X-rays or gamma rays) and high-energy beta particles. The transition from thin-walled to thick-walled design occurs at 300-400 KeV energy levels. Above these levels, thick-walled designs are used, and beneath these levels, the direct gas ionization effect is predominant.

Sometimes, a **"pancake" design** of the Geiger-Mueller tube is preferred. This detector is a flat Geiger tube with a thin mica window of a larger area. Flat Geiger tubes like this are known as "pancake" tubes. Such tubes are fitted with a wire screen to protect them. This design provides a larger detection area and, thus, higher efficiency to make checking quicker. However, the pressure of the atmosphere against the low pressure of the fill gas limits the window size due to the limited strength of the window membrane.

Exp: 1. INVERSE SQUARE LAW: GAMMA RAYS

1. PROCEDURE

- Make detector-source arrangement and power up the unit.
- Without a source, make a few (about 5 readings) background measurements and take an average of them for a preset time of, say, 60 sec.
- Compute Average background counts in 60 sec $Ba = (b_1+b_2+b_3+b_4+b_5)/5$. Compute Background rate = Ba/t (t =60 sec).
- Place a gamma source in the source holder, and adjust the distance (d) from the detector end window to be 2 cm away from the centre of the source holder.
- If you have an End window detector stand, keep the source holder in the 1st slot & raise the end window detector enclosed in a cylindrical shell by unscrewing the captive screw such that you get 2 cm distance from the end window to the 1st slot as shown in Figure 2.1.

Experiment Setup for Inverse Square Law (Figure 2.1)

- Set the HV to Operating Voltage (say 500 V), program 'preset time' to 60 sec, and record the data counts by pressing 'START' button.

- Increase the Distance (d) in steps of 0.5 cm (5 mm) and for each step record the observations, and tabulate the data as shown in Table (2.1), till you reach a distance of 8 to 10 cm from the detector face.
- Subtract the background counts from the recorded counts, resulting in "corrected counts" (N) in 60 sec. From this, obtain Net Count Rate (R) per sec.

2. COMPUTATION & ANALYSIS

1. Compute and tabulate 'Net count rate' (R), 'Distance', transformation ($1/d^2$), etc., as shown in Table (2.1). Plot a graph of Net count rate (R) Vs. distance (d) in cm. (Figure 2.2). It can be seen from the figure that the product, $R.d^2$ is a constant.

2. An alternative analysis method involves transforming the data so that the results lie in a straight line. For this purpose, "Net Count Rate" vs. "Reciprocal of the distance square" ($1/d^2$) are plotted (refer to Figure 2.3). This will be a straight line passing through the origin (0, 0) as this point corresponds to a source-detector distance of infinity.

Table (2.1): Data for Inverse Square Law Experiment
Average background in 60 sec is = 92.5

Sl. No.	Distance in cm (d)	Net Counts in 60 sec.	Net Count Rate	$1/d^2$ in $1/m^2$	Log d	Log R	$R.d^2$
1	7	1061.5	17.691	204.081	0.845	1.247	866.89
2	8	842.5	14.041	156.25	0.903	1.147	898.66
3	9	672.5	11.208	123.456	0.954	1.049	907.87
4	10	566	9.433	100	1	0.9746	943.33
5	11	497.5	8.291	82.644	1.0413	0.9186	1003.29
6	12	400	6.666	69.444	1.0791	0.823	960
7	13	337.5	5.625	59.171	1.1139	0.750	950.62
8	14	258	4.3	51.020	1.1461	0.633	842.8
9	15	217	3.616	44.444	1.1760	0.558	813.75
10	16	216.5	3.608	39.062	1.2041	0.557	923.73

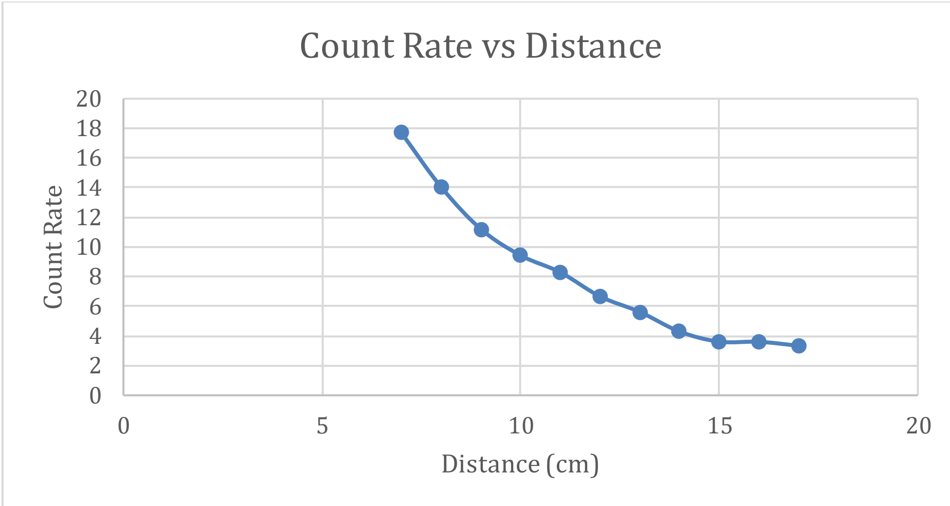


Figure 2.2

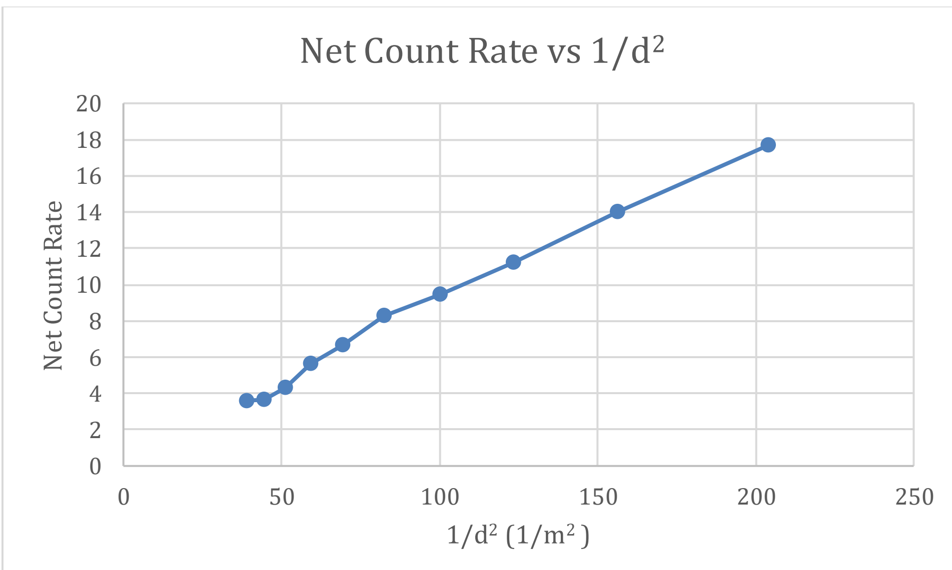


Figure 2.3

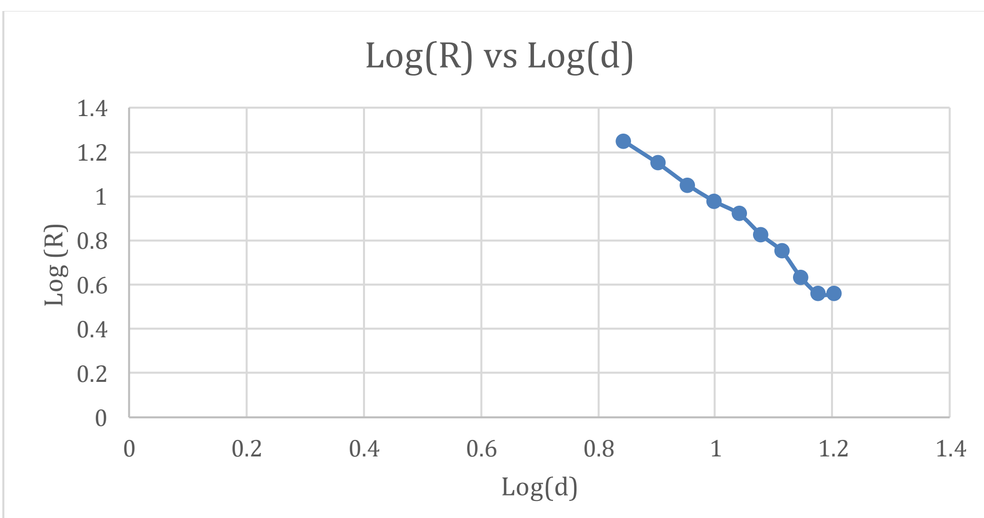


Figure 2.4

Exp: 2. TO STUDY DETERMINATION OF BETA PARTICLE RANGE AND MAXIMUM ENERGY (BY HALF-THICKNESS METHOD)

Range of beta (β) particles:

The range R of a beta (β) particle in a particular absorbing medium is an experimental concept providing the thickness of an absorber that the particle can just penetrate. It depends on the particle's kinetic energy, mass as well as charge, and on the composition of the absorbing medium. In traversing matter, β particles lose their energy in ionizing and radiation collisions that may also result in significant deflections from their incident trajectory. In addition, β particles suffer a large number of deflections as a result of elastic scattering. The mean range of beta particles can be calculated based on their mass, charge, and the electron density of the stopping material. Empirical formulas are used to estimate range for electrons. For example, for electrons, the range of electrons in aluminum (in g/cm^2) is given by

$$R = (0.543E_0 - 0.133)\ g/cm^2$$

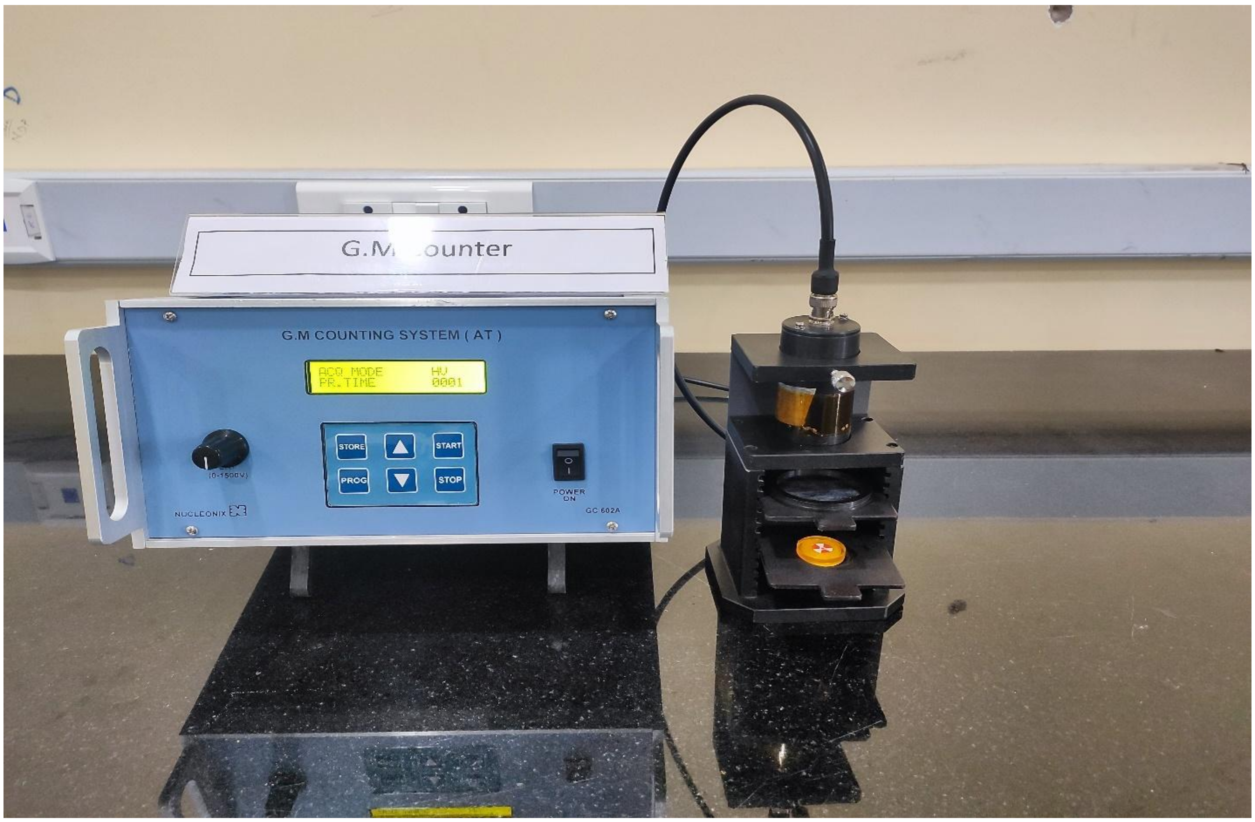
where E_0 is the end point energy of Beta rays from the radioactive source in MeV. The end-point energy of beta particles is the maximum kinetic energy they possess when emitted during beta decay. This energy varies with the specific isotope undergoing decay. We have the ratio of thickness required to the counts of beta rays from one source (source 1) to half to the thickness required for the other source (source 2) in a given material (e.g. aluminum) is given by

$$\frac{(t_{\frac{1}{2}})_1}{(t_{\frac{1}{2}})_2} = \frac{R_1}{R_2}$$

where $(t_{1/2})_1$ is the half thickness for the radiation source 1 in the material, $(t_{1/2})_2$ is the half thickness for the radiation source 2 in the material. R_1 is the range of beta particles from source 1 R_2 is the range of beta particles from source 2. Unlike alpha particles that are emitted from a source with the same energy (nearly 5 MeV), beta particles are emitted with a range of energies, lying between zero MeV and the maximum energy for a given isotope. The velocity of a beta particle is dependent on its energy, and velocities range from zero to about 2.9x108 m/sec, nearly the speed of light. Knowing the maximum energy of a beta particle is very important in that it helps in identifying the isotope.

1. PROCEDURE
   - Make standard connections and arrangements between the G.M. Counting system detector, absorber, and source.
   - Set the GM voltage at the operating voltage of the GM tube.
   - Without source, make a few (about 5 readings) background measurements and take an average of them for a preset time of say 120 sec.

- Compute Average background counts in 120 sec ($Ba = (b_1+b_2+b_3+b_4+b_5)/5$). Compute Background rate = Ba/t (t = 120 sec).
- Place a Beta source in the 3rd tray source from the end window of the GM tube.
- Place an aluminum absorber of zero thickness in the absorber holder at about 2nd tray from the end window of the GM tube and record the counts. Make a setup arrangement.



Experimental Setup for Beta particle Range (Figure 3.1)

- The absorber thickness is increased in steps of 0.06 mm, and every time, counts are recorded.
- This process is repeated until the count rate becomes less than half the count rate with zero absorber thickness.
- Data will be collected from the standard and secondary sources.
- In this case, the standard source is Tl -204 and the second source is Sr-90.
- Tabulate the data as shown in table 3.1 and 3.2.
- Density of Aluminium =2.71g/cm³ (g/cm. cube).
- The below data is taken with Thallium (Tl-204).

Table : 3.1

Counting Time : 120 sec   Absorber : Aluminium

Background : 145 counts   Source : Tl-204 (3.7KBq)

Absorber Thickness (in mm)	Absorber Thickness in mg/cm^2	Counts	Net counts (counts - BG)
0	0	15220	15075
0.06	16.26	11087	10942
0.12	32.52	8614	8602
0.18	48.78	6408	6263
0.24	65.04	4979	4834
0.30	81.3	3763	3618
0.36	97.56	2734	2589
0.42	113.82	1967	1822
0.48	130.08	1421	1276
0.54	146.34	1030	885

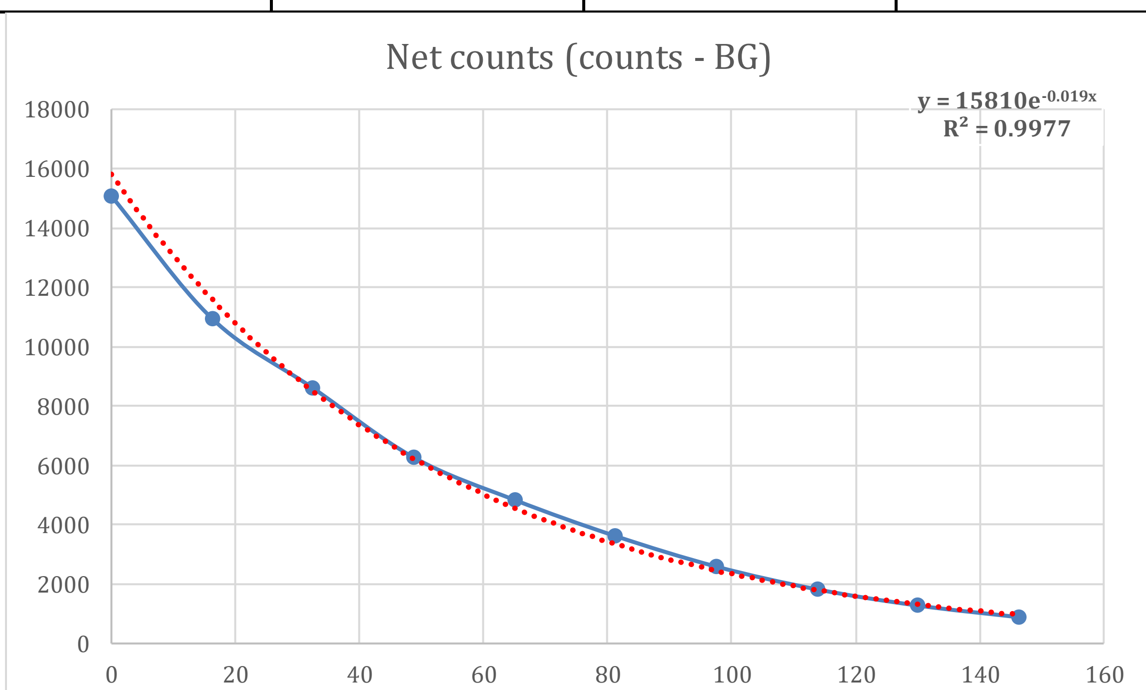


Figure 3.2

The below data is taken with Strontium (Sr^{90}- Y^{90})

Table : 3.2

Counting Time : 120 sec Absorber : Aluminium

Background : 145 counts Source : Sr-90

Absorber Thickness (in mm)	Absorber Thickness in mg/cm^2	Counts	Net counts (Counts - BG)
0	0	16557	16412
0.06	16.26	13571	13426
0.12	32.52	11868	11723
0.18	48.78	10252	10107
0.24	65.04	9324	9179
0.30	81.3	8386	8241
0.36	97.56	7716	7571
0.42	113.82	7254	7109
0.48	130.08	6671	6526
0.54	146.34	6369	6224

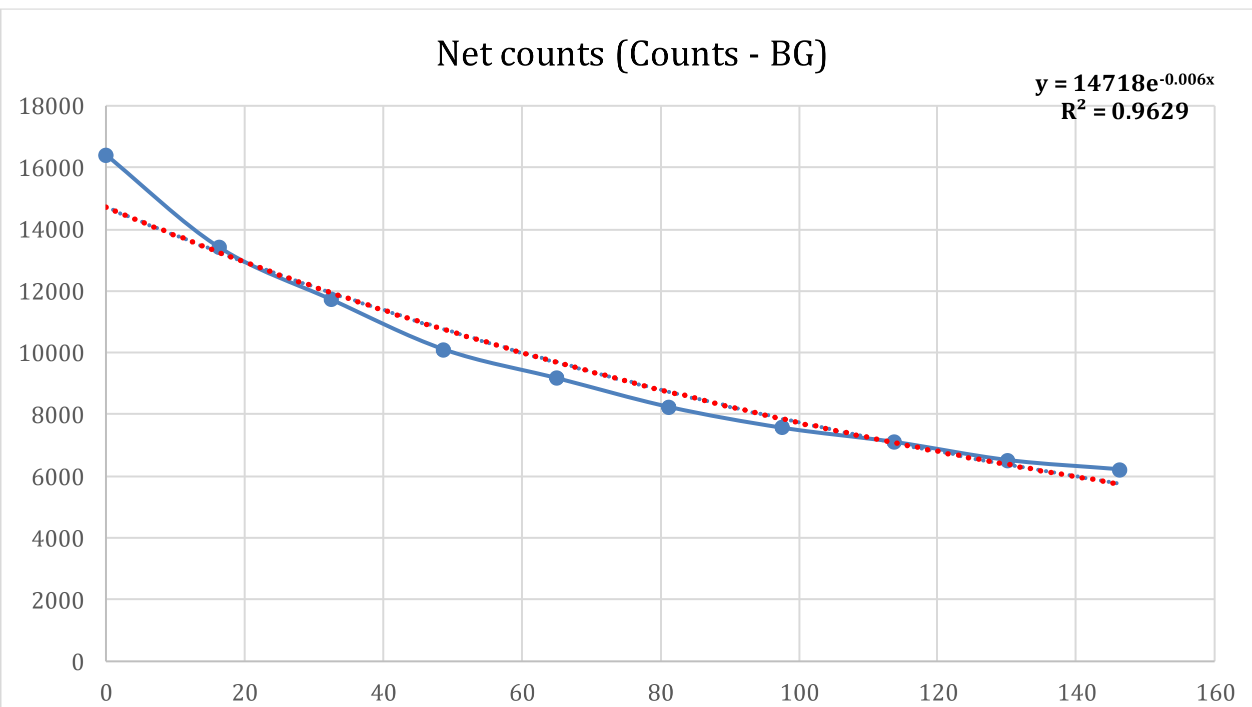


Figure 3.3

3.3 Calculation:

The range of beta particles is given by

$$R = (0.543E_0 - 0.133)\ g/cm^2$$

Where E_0 is the endpoint energy of beta rays from the radioactive source in MeV. We have the ratio of thickness to reduce the counts of beta rays from one source of the half to the thickness required for the other source is given by

$$\frac{(t_{\frac{1}{2}})_{Tl}}{(t_{\frac{1}{2}})_{Sr}} = \frac{R_{Tl}}{R_{Sr}}$$

Endpoint energy of Tl-204, E_{Tl} = 0.764 MeV.

Range of Tl-204:

$$R_{Tl} = (0.543\ E_{Tl} - 0.133)\ g/cm^2$$

$$R_{Tl} = (0.543 x 0.764 - 0.133)\ g/cm^2$$

$$R_{Tl} = 0.282\ g/cm^2$$

Now, as observed from fig. 3.2 and fig. 3.3

1. Thickness of Al absorber required to reduce the count rat of Tl-204 by half $(t_{\frac{1}{2}})_{Tl}$ =36.47 mg/cm^2.
2. Thickness of Al absorber required to reduce the count rat of Sr-90 by half $(t_{\frac{1}{2}})_{Sr}$ =115.5mg/cm^2.

Now, substituting values of R_{Tl}, $(t_{\frac{1}{2}})_{Tl}$ and $(t_{\frac{1}{2}})_{Sr}$ in equation above

$$\frac{36.47}{115.5} = \frac{0.282}{R_{Sr}}$$

$$R_{Sr} = 0.893\ mg/cm^2$$

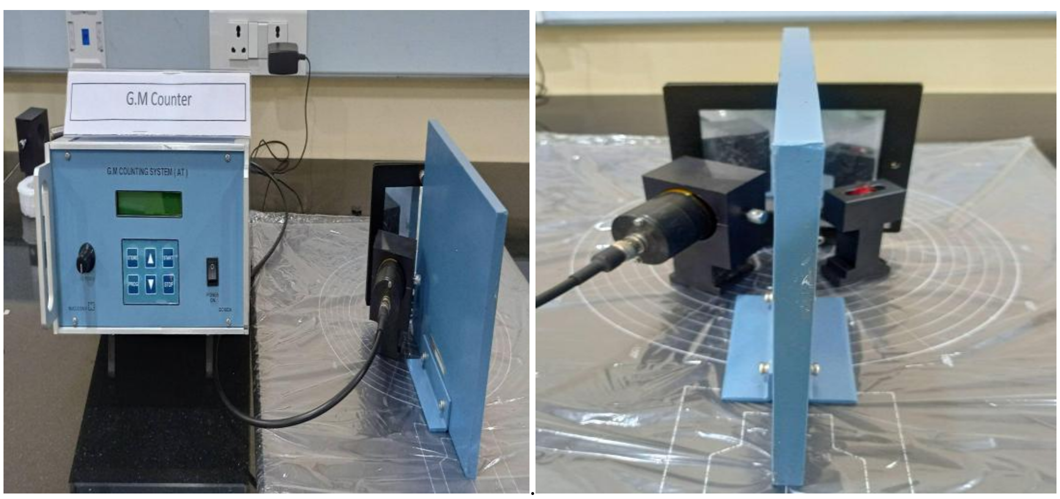
Endpoint energy of Sr-90,

$$E_{Sr} = \frac{R_{Sr} + 0.133}{0.543}\ MeV$$

$$E_{Sr} = 1.89 MeV$$

EXP: 4. BACKSCATTERING OF BETA PARTICLES

1. PROCEDURE
   - Make standard setup by connecting G.M. Counting System (GC602A) with G.M Detector (GM125).
   - In this experimental setup, the detector, Beta source, and scatterer stand with the scatterer placed, as shown in Figure 4.1.
   - A lead block is placed between the Beta source and Detector so the detector does not receive any direct radiation from the Beta source.
   - Switch ON the GC602A Electronic Unit and set the operating High voltage at 500V.
   - To start with, remove the scatterer stand and measure the counts for 200 secs.
   - Now place the scatterer stand and load Aluminum foil (scatterer) of thickness 0.05mm.
   - The apparatus is first set up to give maximum count rate by adjusting the source/ detector positions.
   - After doing this, record the counts for 200 secs. Then increase the thickness of the scatterer in steps of 0.05mm by adding one foil to the previous scatterer, and observe the counts each time for 200 secs. Tabulate the data as shown in Table 4.1



Experimental setup

Figure 4.1

2. EXPERIMENTAL DATA

Source	Sr-90	Unit	GC602A
Activity	3.7KBq	Detector	GM125
Preset Time	200 Sec	Sliding Bench	

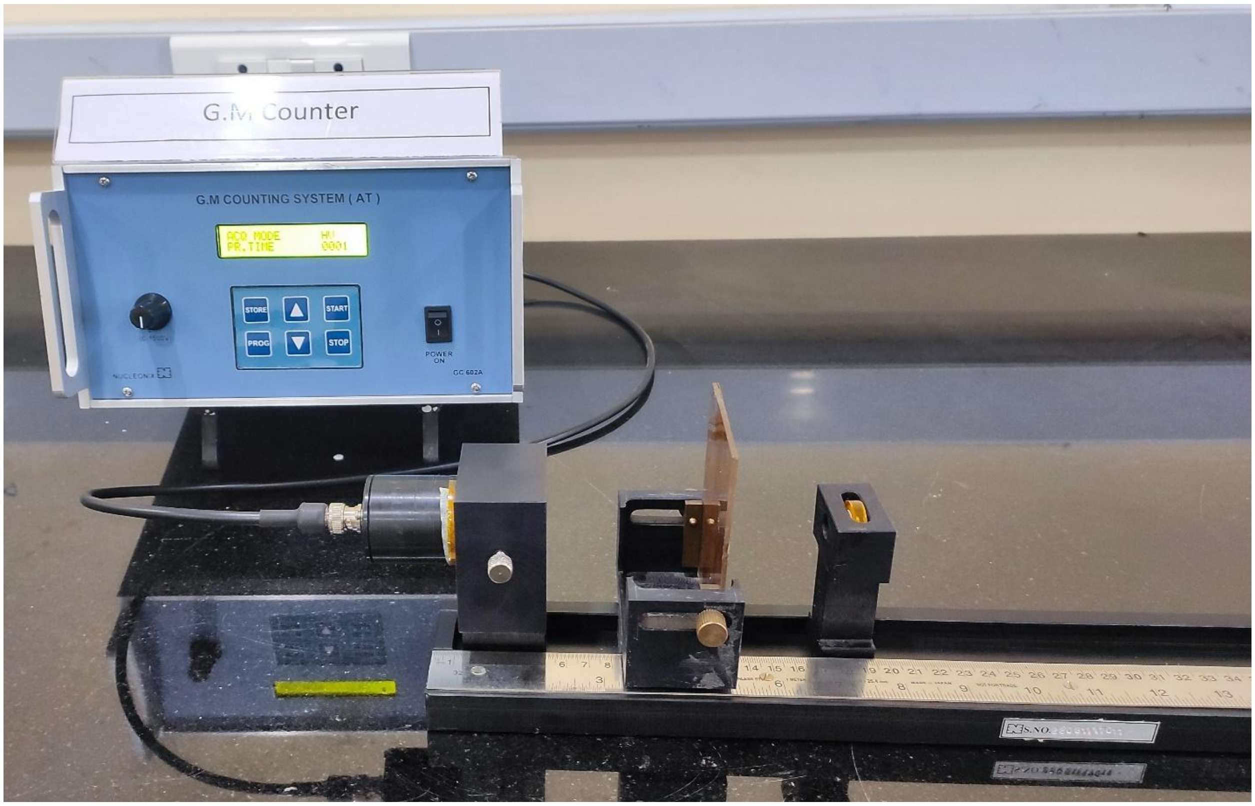
Table 4.1

Sl. No	Material	Thickness (mm)	Counts			Net counts =(Avg. counts – Avg. counts in zero thickness)
			i	ii	Average	
1	Al	0	304	322	313	-
2	Al	0.05	356	340	348	35
3	Al	0.10	371	350	360.5	47.5
4	Al	0.15	377	365	371	58
5	Al	0.20	378	386	382	69
6	Al	0.25	392	380	386	73
7	Al	0.30	379	399	389	76
8	Al	0.35	378	422	400	87
9	Al	0.40	401	418	409.5	96.5
10	Al	0.45	402	423	412.5	99.5
11	Al	0.50	424	421	422.5	109.5

Exp:5. PRODUCTION AND ATTENUATION OF BREMSSTRAHLUNG

5.1 PROCEDURE

- Make a standard setup by connecting GM Counting system GCG02A with G.M Detector (GM125) placed in the optical bench, As shown in figure 5.1.



Experiment setup for production and attenuation of Bremsstrahlung (Figure 5.1).

- Switch ON the GC602A Electronic Unit and set the operating High Voltage at 500V. An absorber consisting of two materials with widely different atomic numbers, say, Perspex (1.8mm thick) and Aluminum (0.7 mm thick) is used and the count rate is measured with the absorber and then with the absorber reversed.
- The absorber thickness must be such that each sheet of absorbent material has about the same mass per unit area.
- The experiment is conducted with following three combinations of materials
    - Al (0.7mm) & Perspex (1.8mm)
    - Perspex (1.8mm) & Cu (0.3mm)
    - Al (0.7mm) & Cu (0.3mm)

5.2 EXPERIMENTAL DATA & RESULTS

Source: Sr-90 Distance between source and detector: 6cm.

Activity: 3.7 kBq Preset Time: 300 sec BG: $\frac{b1+b2+b3+b4+b5}{5} = 353$

For Al (0.7mm) & Perspex (1.8mm) combination:

Sl. No	Absorber position	Counts	Net Counts
1	Without Absorber	10070	9717
2	Perspex facing source	655	302
3	Al. facing source	928	575

For Perspex (1.8mm) & Cu (0.3mm) combination:

Sl. No	Absorber position	Counts	Net Counts
1	Without Absorber	10070	9717
2	Cu facing source	576	223
3	Perspex facing source	547	194

For Al (0.7 mm) & Cu (0.3mm) combination:

Sl. No	Absorber position	Counts	Net Counts
1	Without Absorber	10070	9717
2	Al facing source	532	179
3	Cu facing source	566	213