Exp:5. TO STUDY DETERMINATION OF BETA PARTICLE RANGE AND MAXIMUM ENERGY (BY HALF THICKNESS METHOD)

5.1 PURPOSE

To carry out the absorption studies on β-rays with the aid of a GM Counter and hence to determine the end point energy of β-rays emitted from a radioactive source.

5.2 EQUIPMENT/ACCESSORIES REQUIRED

- G.M Counting System 601A/602A with A.C main cord.
- G.M Detector (End window) stand (or) G.M Detector/source holder bench
- Radioactive source kit
- Aluminium absorber set

5.3 PROCEDURE

- Make standard connections and arrangement between 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 60 sec.
- Compute Average background counts in 60sec ($Ba = (b_1+b_2+b_3+b_4+b_5) / 5$).
- Compute Background rate = Ba/t (t = 60sec).
- Place a Beta source in the source tray at about 3 cm from the end window of the GM tube.
- Take the Aluminium absorber set.
- Place an aluminium absorber of zero thickness in the absorber holder at about 2 cm from the end window of the GM tube and record the counts.
- The absorber thickness is increased in steps of 0.05mm and every time counts are recorded.
- This process is repeated until the count rate becomes equal to or less than half the count rate with zero absorber thickness.
- Data is to be collected for the standard source and the second source.
- Here in this case the standard source is Tl - 204 and the second source is Sr - 90.
- Tabulate the data as shown in table.
- Density of Aluminium = 2.71g/cm_3 (g/cm. cube).
- The below data is taken with Thallium (Tl - 204)

Table : 1

Counting Time : 180 sec
Background : 146 counts

Absorber : Aluminium
Source : Tl-204 (4 KBq)

Absorber Thickness (in mm)	Absorber Thickness in mg/cm^2	Counts	Net counts (counts-BG)
0	0	2620	2474
0.05	13.55	2003	1857
0.10	27.10	1556	1410
0.15	40.65	1293	1147
0.20	54.20	1054	908
0.25	67.75	835	689
0.30	81.30	676	530
0.35	94.85	597	451
0.40	108.40	499	353
0.45	121.95	448	302

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

Table : 2

Counting Time : 100 sec
Background : 79 counts

Absorber : Aluminium
Source : Sr-90

Absorber Thickness (in mm)	Absorber Thickness in mg/cm^2	Counts	Net counts (counts-BG)
0	0	5828	5749
0.05	13.55	5130	5051
0.10	27.10	4589	4510
0.15	40.65	4252	4173
0.20	54.20	3893	3814
0.25	67.75	3618	3539
0.30	81.30	3458	3379
0.35	94.85	3189	3110
0.40	108.40	3092	3013
0.45	121.95	2877	2798
0.50	135.50	2773	2694
0.55	149.05	2612	2533
0.60	162.60	2582	2503
0.65	176.15	2367	2288
0.70	189.70	2222	2143

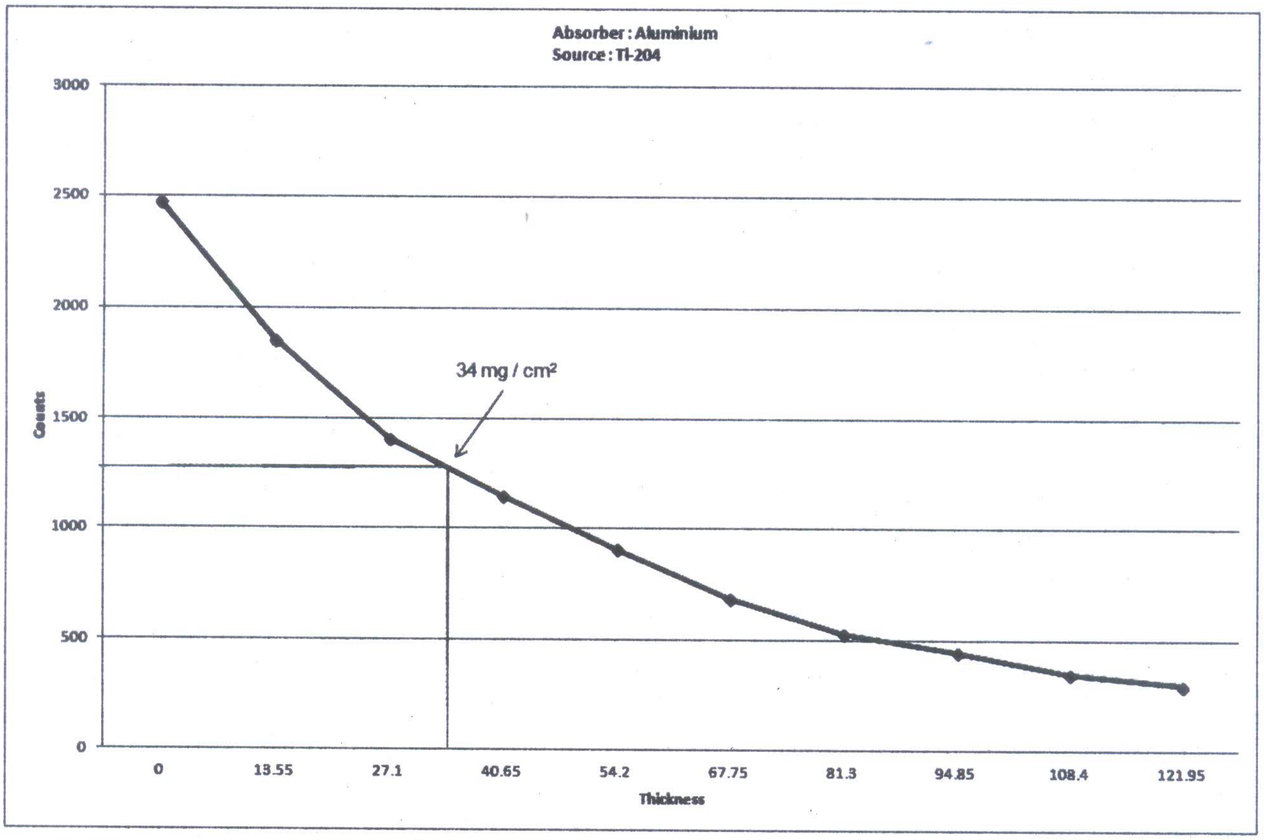


Figure : 16

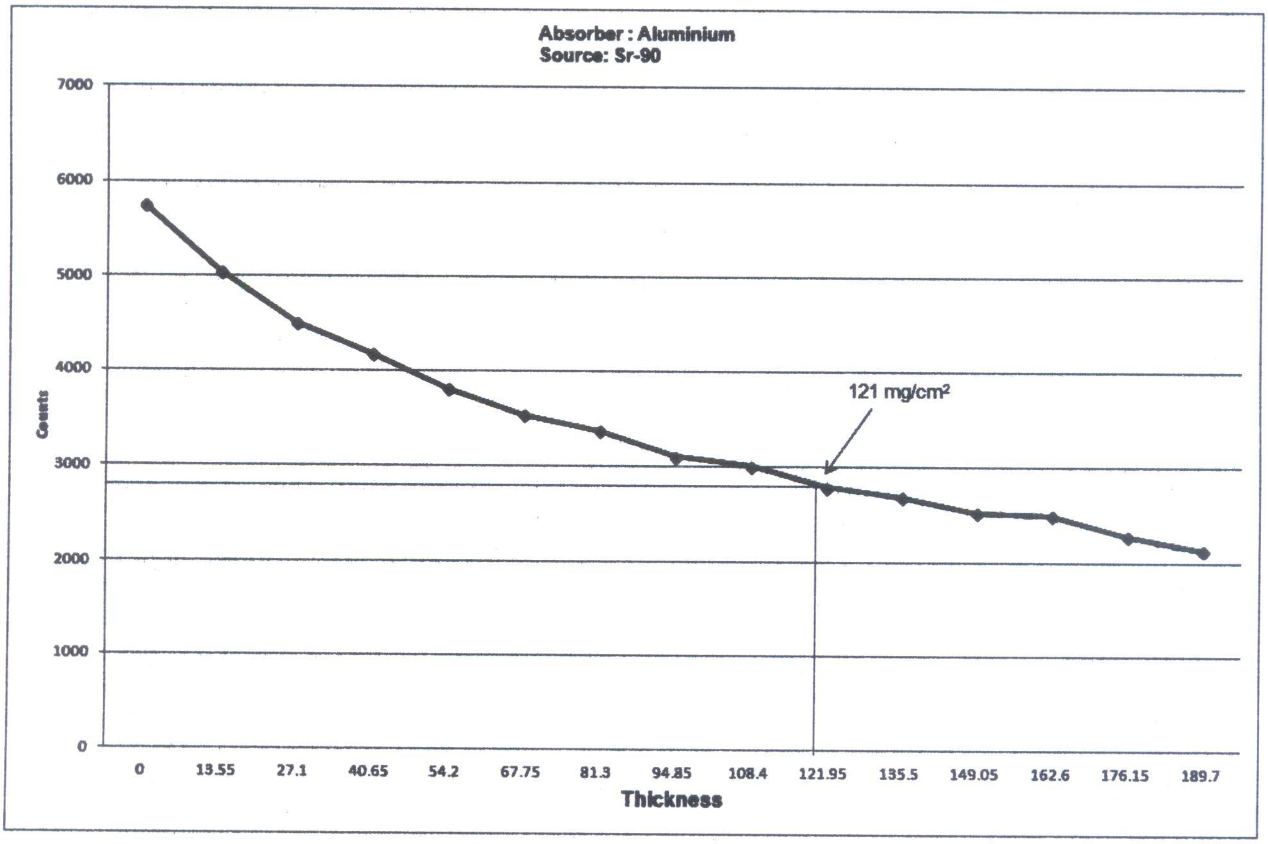


Figure : 17

5.4 ANALYSIS & COMPUTATIONS:

5.4.1 PRINCIPLE

The range of Beta particles is given by

$$R_0 = (0.52\ E_0\ - 0.09)\ \text{g/cm}^2 \qquad \text{-- (1)}$$

Where E_0 is the end point energy of of Beta rays from the radioactive source in MeV.

We have the ratio of thickness required to reduce the counts of Beta rays from one source to half to the thickness required for the other source is given by

$$\frac{t_1½}{t_2½} = \frac{\text{Range of Beta rays from first source}}{\text{Range of Beta rays from second source}}$$

$$\frac{t_1½}{t_2½} = \frac{R_1}{R_2} \qquad \text{-- (2)}$$

5.4.2 EXERCISE

- Subtract the background count rate from each measured count rate.
- Plot a graph of Net countrate (CPS) Vs absorber thickness (mg/cm^2) for both sources.
- Draw the curve through these points as shown in Figures 16 & 17.
- From the plotted graph extrapolate and obtain thickness of aluminium absorber required to reduce the countrate of Thallium and Strontium Beta rays by half ($t_1½$ and $t_2½$).
- Substitute $t_1½$ and $t_2½$ in the above equation (2) and calculate the range of βrays (R_2) from Sr90 source.
- Once we know the R_2, we can find out the energy (E_2) of Sr^{90} from equation-1

5.4.3 For Thallium-204

End point energy of Tl-204 = 0.764 MeV

$\therefore$ Range of ^{204}Tl $= R_1$ $= (0.52\ E_0 - 0.09)\ \text{g/cm}^2$

$= (0.52 \times 0.764\ \text{Mev} - 0.09)\ \text{g/cm}^2$

$= 0.30728\ \text{g/cm}^2$

- Thickness of Al absorber required to reduce the count rate of ^{204}Tl by half, $t_1½$ = 34mg/cm square

- Thickness of Al absorber required to reduce the count rate of Sr-90 by half $t_2½$ = 121mg/cm^2

From Equation (2).

$$\frac{t_1½}{t_2½} = \frac{R_1}{R_2}$$

$$\Rightarrow \quad R_2 = R_1 \ X\ \frac{t_2½}{t_1½} = \frac{0.30728\ X\ 121\ X\ 10^{-3}}{34\ X\ 10^{-3}}$$

$$R_2 = \frac{0.30728\ X\ 121}{34} = 1.09355\ \text{gm/cm}^2$$

$\therefore$ End point energy of ^{90}Sr/ ^{90}Y

$$E_2 = \frac{R2 + 0.09}{0.52} = \frac{1.09355 + 0.09}{0.52}$$

$$E_2 = 2.276\ \text{Mev}$$

5.4.4 RESULT

End point energy of β-rays from ^{90}Sr = 2.28 MeV.

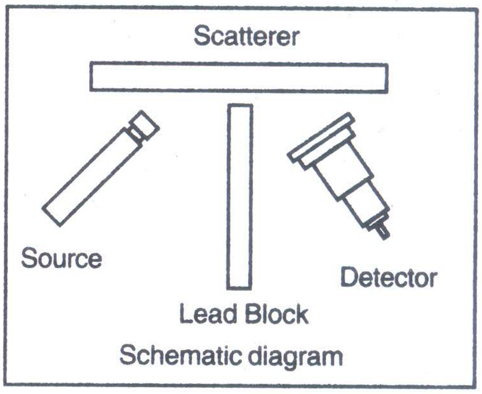
Exp:6. BACK SCATTERING OF BETA PARTICLES

6.1 INTRODUCTION

When Beta Particles collide with matter, absorption may occur. Another possible result is the occurrence of scattering by collisions of Beta particles with electrons in the material. Such a collision changes the speed and direction of the Beta particles. With increasing atomic number Z of the material, the chance that a collision results in a scattering of the Beta particle increases too. Back scattering occurs, when the angle of deflection is greater than 90°. The Back-scattering rate is predominately dependent on the atomic number Z of the back scattering material. With an atom of high atomic number, the scattering occurs at a large angle and with little loss of energy. The back scattering factor is approximately proportional to the square root of atomic number. The mass per unit area (thickness x density) or the thickness of the irradiated material only influence the back scattering factor up to a saturation value. The maximum back scattering is practically attained at a mass per unit area which is smaller than half the range of the Beta particle in the material, because large layer thicknesses lead to absorption of the scattered electrons. The saturation value is less than 200 mg/cm^2 for all materials. This corresponds to a saturation larger thickness of $x \leq 0.74$ mm for Aluminum and ≤ 0.17 mm for Lead.

6.2 EQUIPMENT AND ACCESSORIES REQUIRED

i. Electronic Unit
ii. Wide end window GM Detector (GM125)
iii. Absorber stand for Back scattering of Beta
iv. Absorber set (Beta particle scattering experiment)
v. Beta source (Sr-90)
vi. Lead Block for Isolation



Schematic diagram

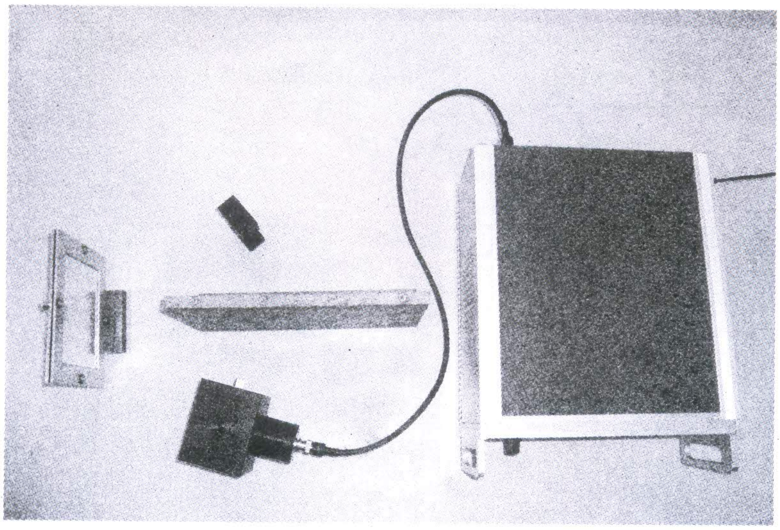


Fig. 18: Experimental setup

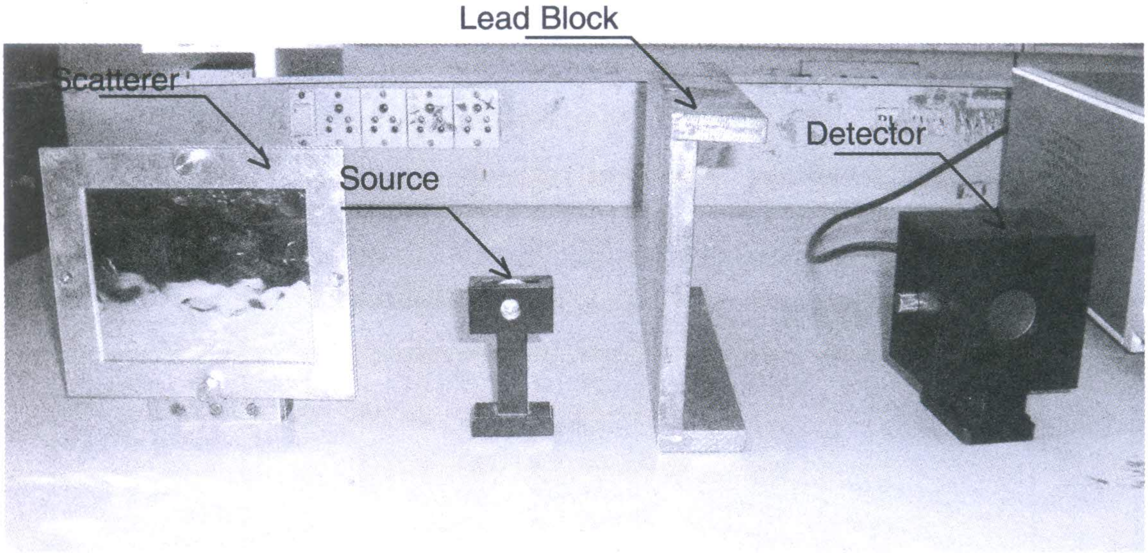


Fig. 19 : Individual blocks of experiment setup

6.3 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 scatterer are placed as shown in Fig.18.

A lead block is placed in between the Beta source and Detector, so that 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.

6.4 EXPERIMENTAL DATA

Source	: Sr-90	Unit: GC602A	
Activity	: 0.1mCi	Detector: GM125	
Preset Time	: 200 secs.	Sliding Bench	

Sl.No	Material	Thickness (mm)	Counts			Net counts
			I	II	Average	
1	Al	0	361	401	381	-
2	Al	0.05	621	645	633	252
3	Al	0.10	676	657	666.5	285.5
4	Al	0.15	789	737	763	382
5	Al	0.20	858	834	846	465
6	Al	0.25	1032	985	1008.5	627.5
7	Al	0.30	1107	1174	1140.5	759.5
8	Al	0.35	1250	1246	1248	867
9	Al	0.40	1226	1400	1313	932
10	Al	0.45	1508	1629	1568.5	1187.5
11	Al	0.50	1696	1707	1701.5	1320.5
12	Al	0.55	1708	1668	1688	1307
13	Al	0.60	1791	1699	1745	1364
14	Al	0.65	1798	1678	1738	1357

6.5 RESULTS & CONCLUSIONS

From the obtained results, it can be concluded that the counts due to Back scattering increases upto certain thickness of the scattering material and almost remains constant beyond that thickness. The thickness of the scatterer, where the counts reach their maximum is called the Saturation thickness.

Exp 7 : PRODUCTION AND ATTENUATION OF BREMSSTRAHLUNG

7.1 INTRODUCTION

Bremsstrahlung is electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged partice, typically an electron by an atomic nucleus. The moving particle loses kinetic energy, which is converted into a photon because energy is conserved. The term is also used to refer to the process of producing the radiation. Bremsstrahlung has a continuous spectrum which becomes more intense and whose intensity shifts toward higher frequencies as the change of the energy of the accelerated particles increases.

Beta – particle emitting substances sometimes exhibit a weak radiation with continuous spectrum that is due to Bremsstrahlung. In this context, Bremsstrahlung is a type of "secondary radiation", in that it is produced as a result of stopping (or slowing) the primary radiation (Beta particles). It is very similar to x-rays produced by bombarding metal targets with electrons in X-ray machines.

The amount of Bremsstrahlung increases as the atomic number/density of the absorbing material goes up. If the mass per unit area (thickness X density) of the plates used as absorbers is such that the beta particles are completely absorbed, then for materials of higher atomic number/density, correspondingly higher bremsstrahlung count rates are obtained.

7.2 EQUIPMENT AND ACCESSORIES REQUIRED

- Electronic Unit (GC 602A)
- G.M Detector (GM125)
- G.M. Detector Holder
- Sliding Bench
- Source Holder
- Absorber Holder for Bremsstrahlung experiment
- Beta Source (Sr-90)
- Al (0.7mm), Cu (0.3mm) & Perspex (1.8mm) absorber set

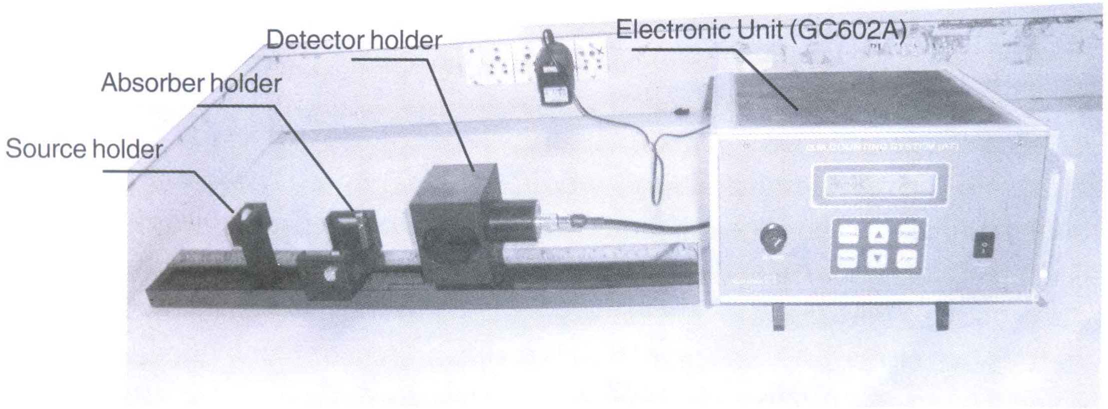


Fig. 20: Expermental setup

7.3 PROCEDURE

Make standard setup by connecting G.M Counting system GC602A with G.M Detector (GM125) placed in the optical bench as shown in Fig.20 above. The GM Detector, Absorber and the Source are mounted as shown in Fig.20.

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

i. Al (0.7mm) & Perspex (1.8mm)
ii. Perspex (1.8mm) & Cu (0.3mm)
iii. Al (0.7mm) & Cu (0.3mm)

7.4 EXPERIMENTAL DATA & RESULTS

→Beta

Source : Sr-90 Distance between source and detector : 6cms
Activity : 0.1mCi Preset Time : 300Sec BG : 1065 counts

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

S.No	Absorber position	Counts	Net Counts
1	-	40342	39277
2	Perspex facing source	6400	5335
3	Al. facing source	9122	8057

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

S.No	Absorber position	Counts	Net Counts
1	-	40342	39277
2	Cu facing source	4749	3681
3	Perspex facing source	4183	3118

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

S.No	Absorber position	Counts	Net Counts
1	-	40342	39277
2	Al facing source	5100	4035
3	Cu facing source	5858	4793

7.5 RESULT & CONCLUSIONS

The count rate for the bremsstrahlung produced depends on the order in which the absorbent materials are arranged. If, firstly, the sheet of metal faces towards the source, then a higher count rate is measured since bremsstraulung is generated in the aluminium but is absorbed to a very small extent in the sheet of "Perspex "which follows.If, however, the beta rays first strike the sheet of plastic, then the bremsstrahlung generated is of low energy and a large proportion of it is absorbed in the sheet of metal which follows.

These conclusions can be extended to other combinations of materials also.

Exp: 8. MEASUREMENT OF SHORT HALF-LIFE

8.1 PURPOSE

To determine short half-life of a given source, which can be obtained from a mini generator or produced with a neutron source by activation.

8.2 EQUIPMENT/ACCESSORIES REQUIRED

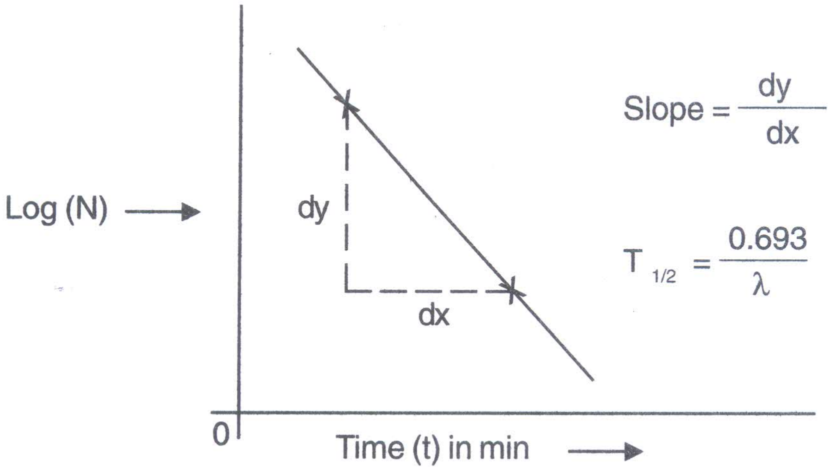
G.M. Counting system	Type: GC 601A/GC 602A
G.M. Stand	Type: SG 200
End window G.M. detector	Type: GM 120

Short Half life source (Neutron activated Indium foil or Cs-137/Ba-137m isotope generator, flask with eluting solution for generator)

8.3 PROCEDURE

An Am-Be neutron source of strength of about 5Ci is in the Neutron Howitzer. The maximum thermal neutron flux produced by this neutron source is about 4×10^4 n/cm^2-sec.

- Irradiate the given indium foil for about 12 hours by placing it in appropriate position in the Neutron Howitzer (normally at the centre of the column).
- Apply the required operating voltage for the GM tube.
- Place the irradiated indium foil under the window of the GM tube at a convenient distance (1 cm) in order to get a good number of counts per second.
- Collect the counts for every 5 minutes for at least one hour.
- Note down the back ground count rate for 5 minutes, before and after the experiment in order to subtract from the observed counts and record your observations as shown in the Table below.
- Determine the count rate (N) for each interval of 300 seconds (5 minutes).
- Plot graph of log of the count rate (log N) versus time (minutes)
- It will be a straight line as shown below.



$$\text{Slope} = \frac{dy}{dx} = \text{decay constant}$$

$$T_{1/2} = \frac{0.693}{\lambda} \text{ sec}$$

- Find the slope of the straight line graph using the least square fit methods (use the formula)
  $m = (n\Sigma xy - \Sigma xy) / (\Sigma nx^2 - (\Sigma x)^2)$
  to determine the slope of the graph which gives the value of the decay constant.
  Where n = number of observations
  x = time interval, y = Log N

OBSERVATIONS

S.No.	Elapsed Time	Duration (min)	Counts Reading	Corrected counts / min	Log (N)
1	300	5	1355	252.6	5.54
2	600	10	2660	247.6	5.50
3	900	15	3862	239.06	5.47
4	1200	20	5006	231.9	5.44
5	1500	25	6047	223.48	5.40
6	1800	30	7103	218.36	5.38
7	2100	35	8138	214.11	5.36
8	2400	40	9043	207.67	5.33
9	2700	45	9923	202.11	5.31
10	3000	50	10750	196.6	5.28
11	3300	55	11593	192.38	5.26
12	3600	60	12348	187.4	5.23

Background = 92/5 min = 18.4/min

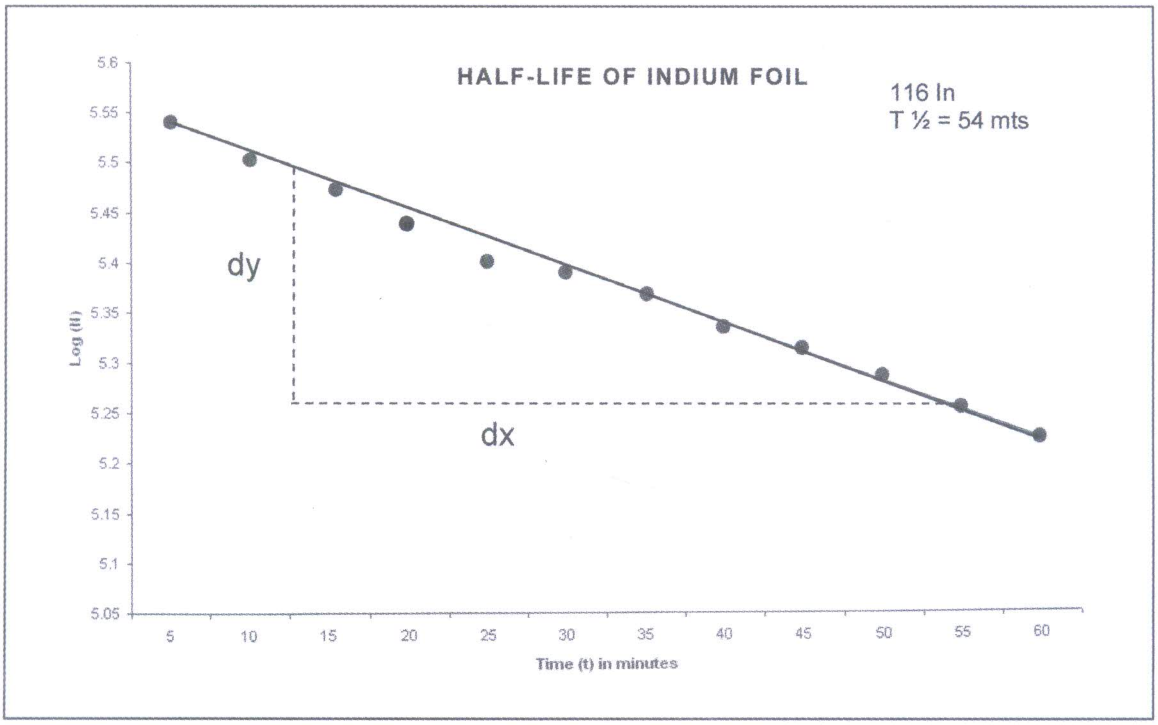


Fig.22 : Half-life of Indium Foil

8.4 ANALYSIS AND COMPUTATIONS

Intensity of radioactive source changes with time in accordance with relation

$$I = I_o e^{-\lambda t} \text{ ----- } (1)$$

λ is the decay constant,

I is the intensity at any time t and I_o is initial intensity.

The $T_{1/2}$ by definition is the time required for the intensity to fall to one half of its initial value.

Hence from equation (1) we have

$$\ln (I/I_0) = -\lambda T_{½}$$
$$\ln (0.5) = -\lambda T_{½}$$

$$\frac{0.693}{\lambda} = T_{½}$$

Where $T_{1/2}$ is half - life.

The above equation can be written as

$$\lambda = \frac{0.693}{T_{1/2}}$$

Given the value of $T_{1/2}$, one can calculate the value of λ.

8.5 HALF LIFE DETERMINATION:

The Log is actually natural Log and should be denoted by In.

8.5 EXERCISE

- Subtract the background countrate from each measured countrate.
- Plot a graph of In (N) vs. elapsed time (min).
- This should give a straight line graph.
- From the plotted graph extrapolate and obtain $T_{1/2}$
- Substitute $T_{1/2}$ in the above equation to calculate the decay constant λ