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Comparative experimental study of radiation shielding parameters H.V.T & attenuation coefficient of β particle in ${}^{60}_{27}Co$ and ${}^{22}_{11}Na$

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Abstract
In this research we work with radioactive source to learn about attenuation of radiation by different material. Effect of radiation is harmful for human tissue but here with safety measures we use these radiations for investigation of various parameters of different sample. Here we are interested to find Attenuation of beta particles in a thin layer of an absorber and find half value thickness of absorbing material sample. In the present work half value thickness and attenuation coefficient of various sample like Al-foil, Gift wrapper, and paper foil has been reported and calculated experimentally. In the present investigation we calculated the values of linear attenuation coefficient and half value thickness (HVT) of β+ and β-in Co and Na. We estimated Half value thickness of β- Particle in Co= 134± 1mg/cm^2, Half value thickness of β+ particle in Na = 373±2 mg/cm^2. It is found that Half Value thickness of any sources does not depend on material but it depends on material thickness. The results of this investigation have shown that, the Attenuation coefficient of β+ particle by Al foil =0.0015 Attenuation coefficient of β+ particle by Paper foil = 0.0013, Attenuation coefficient of β+ particle by gift wrapper = 0.0015.The Attenuation coefficient of β- by Al foil, Paper foil and gift wrapper is 0.0060, 0.0057 and 0.0060 respectively. The attenuation coefficients are an important parameter for characterizing the penetration and attenuation properties of alpha, beta and gamma rays in materials.
Keywords: - Half Value Layer (HVL), Linear Attenuation Coefficient, Tenth Value Thickness (TVL).

1. Introduction

Radioactivity refers to the particles which are emitted from nuclei as a result of nuclear instability. . The most common forms of radiation emitted have been traditionally classified as alpha (a), beta (b), and gamma (g) radiation. Nuclear radiation occurs in other forms, including the emission of protons or neutrons or spontaneous fission of a massive nucleus. For radiation protection design, a commonly specified entity is the half-value thickness, which characterizes suitable materials for any particular type of radiation and the energy involved. As the name indicates, this number directly gives the thickness required to reduce the intensity of the incoming radiation by half. Half value layer (HVL) is the most frequently used quantitative factor for describing both the penetrating ability of specific radiations and the penetration through specific objects. When HVL and TVL values are known the penetration through other thicknesses can be easily determined. The linear attenuation coefficient varies with photon energy, type of material, and physical density of material. The study of attenuation coefficient of various materials has been an important part of research in Radiation Chemistry, Physics, agriculture and human health. The parameter attenuation coefficient usually depends upon the energy of radiations and nature of the material.
The interactions of the various radiations with matter are unique and determine their penetrability through matter and, consequently, the type and amount of shielding needed for radiation protection. Being electrically neutral, the interaction of gamma rays with matter is a statistical process and depends on the nature of the absorber as well as the energy of the gamma. There is always a finite probability for a gamma to penetrate a given thickness of absorbing material

2. Materials and Method

Radio nuclides are chosen according to the type and character of the radiation they emit, intensity of emission, and the half-life of their decay. Evolution of the techniques of nuclear radiation detection has played the most vital role in unraveling the mysteries of the atomic nucleus. The radiation coming out of the nucleus, such as the α,β, γ-rays in spontaneous transformation or various types of subatomic particles (both charged and uncharged) in induced transformation are the signals which carry with them information about the properties of nucleus. Hence their detection and measurement are prime importance in understanding the structure of nucleus [1].

In present days there are number of techniques to detection and measure the radiation which are based on free charge charier, light sensing method and visualization of the tracks. In this manuscript we used G-M counter system to detect the radiation by using various materials like Al foil, Paper foil, Gift wrapper, and Coin.

In this investigation we used Cobalt (60) and Sodium (22) materials to obtain the half values thickness and attenuation coefficient from Al foil, Paper foil, Gift wrapper, and Coin.Cobalt-60 decays to Nickel-60 plus an electron and an electron antineutrino. The decay is initially to a nuclear excited state of Nickel-60 from which it emits either one or two gamma ray photons to reach the ground state of the Nickel isotope.

Sodium-22 is a man-made isotope it decays by emitting a positron (β+ decay) into stable neon-22.The excited neon state passes into the ground state whereby a 1275 keV γ quantum is emitted.

2.1 Linear Attenuation Coefficient

The linear attenuation coefficient (μ) describes the fraction of a beam of x-rays or gamma rays that is absorbed or scattered per unit thickness of the absorber. This value basically accounts for the number of atoms in a cubic cm volume of material and the probability of a photon being scattered or absorbed from the nucleus or an electron of one of these atoms.

The interactions can be characterized by a fixed probability of occurrence per unit path length in the absorber. The sum of these probabilities is called the linear attenuation coefficient.

$$\mu = \tau(\text{photoelectric}) + \sigma(\text{Compton}) + \kappa(\text{pair})$$

Following equation.

$$\mathbf{I=I_0.}e^{-\mu x}$$

where I be intensity after attenuation, Io is incident intensity; μ is the linear attenuation coefficient (cm^{-1}), and physical thickness of absorber (cm).

2.2 Mass Attenuation Coefficient

The mass attenuation coefficient (μ_m) is define by relation

$$\mu_{m}= \frac{\mu}{\rho}$$

Where ρ is density of medium.

For Mass attenuation coefficient we observe number of particle according to taken time by GM counter with matter and without matter then becomes an equation:

$$N = N_0 e^{-\mu x}$$

Where: N= number of particle with matter
N_0 =Number of particle without matter
μ=mass attenuation coefficient
x =number of foil

$$-\mu x = ln\frac{N}{N0}$$

2.3 Half-Value Thickness

The half-value thickness (HVT) is used to determine the strength of radiation shielding. The HVT is the thickness of an absorber sample that will reduce the initial radiation intensity to one-half. Half value thickness is important parameter for explaining both the penetrating ability of particular radiations and the penetration through specific objects or materials.The intensity of the radiation is thus decreased as a function of thickness of the absorbing material. The mathematical expression for intensity I is

$$\mathbf{I=I_0.}e^{-\mu x}$$

If we rearrange above equation and take the natural logarithm of both sides, the expressionbecomes,

$$-\boldsymbol{\mu x = ln\frac{I}{Io}}$$

The half value thickness of the absorbing material is defined as the thickness $x_{1/2}$ which will decrease the initial intensity by half.

This is, $\mathbf{I = I_o/2.}$

we get

$$\mathbf{ln(2) = \mu x1/2}$$

In this paper we calculated half value thickness of Al-foil, ordinary paper sheet, Gift paper

$$\mathbf{x_{1/2}= 0.693/\mu}$$

3. Result Analysis and Discussion

In this section we present the calculation of HVT and Attenuation Coefficient (AC) with and without using the absorbing materials as mention in section -2. We calculated the HVT and AC for beta particle and gamma radiation emitted in the disintegration of cobalt and sodium nucleus.

3.1 Analysis for β⁻ Decay by $^{60}_{27}Co$

^{60}Co decays by beta decay to the stable isotope nickel-60 (^{60}Ni). The activated nickel nucleus emits two gamma rays with energies of 1.17 and 1.33 MeV, hence the overall nuclear equation of the reaction [2].

$$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + e^{-} + \bar{\nu}_e + \text{gamma rays.}$$

We keep our source 3cm distance (i.e. 7th Plate) from GM tube. We take time 60 second and change voltage in steps of 50 volt of G-M tube.Again, we keep our source 2cm distance from GM tube i.e. for 8thplate for 60 second with same voltage.Table-3.1 and 3.2 Shows the experimental data and fig.3.1 & 3.2 shows the plateau characteristics of the source without any absorber present.

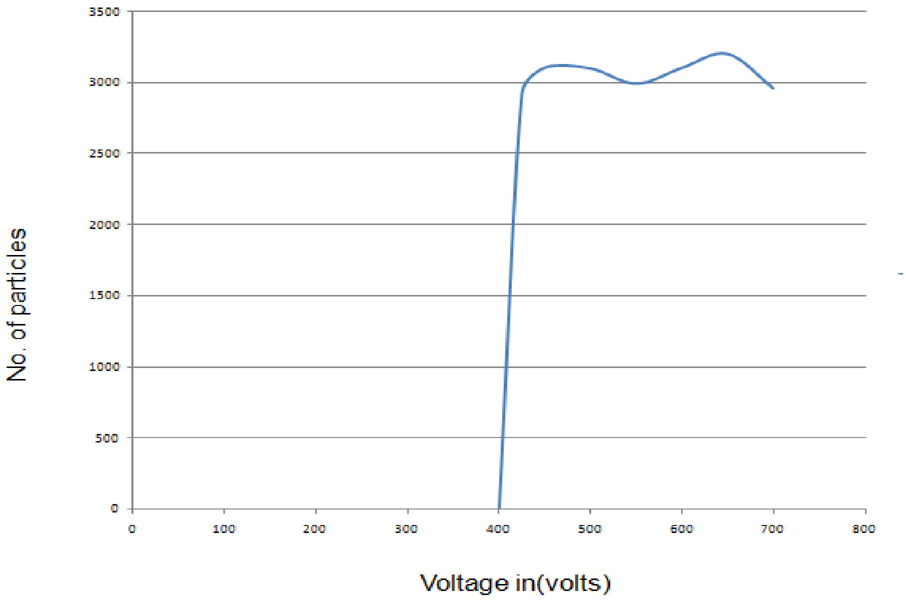


Figure-3.1 Plateau graph of $^{60}_{27}Co$(7th Plate)

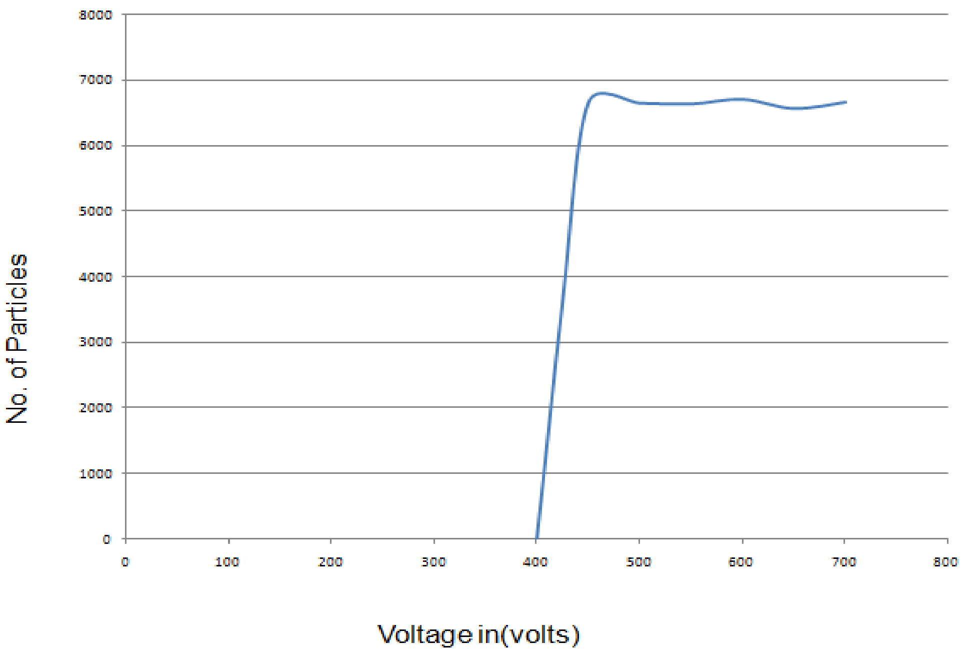


Figure-3.2 Plateau graph of $^{60}_{27}Co$(8th Plate)

3.1.1 Using Al Foil

We know that β⁻ particle penetration is higher than α- particle and lower γ-ray. So, we use Al foil.

Figure-3.3 Aluminum foil

$$thickness = \frac{weight}{area}$$

We take Al foil of length =30 cm

Breadth=21.3cm

Weight =2.2mg

$$thickness of Al foil = \frac{2.2}{30 \times 21.3}$$

$$thickness of Al foil \approx 34\ micron$$

Half Value thickness of 4 Al foil=136 mg/cm^2

Table-3.3 and 3.4 shows the experimental data for 7th and 8th plate respectively for various number of foils we consider. Fig. 3.4 & 3.5 below show the respective HVT of Al foil for 7th and 8th plate of G-M tube.

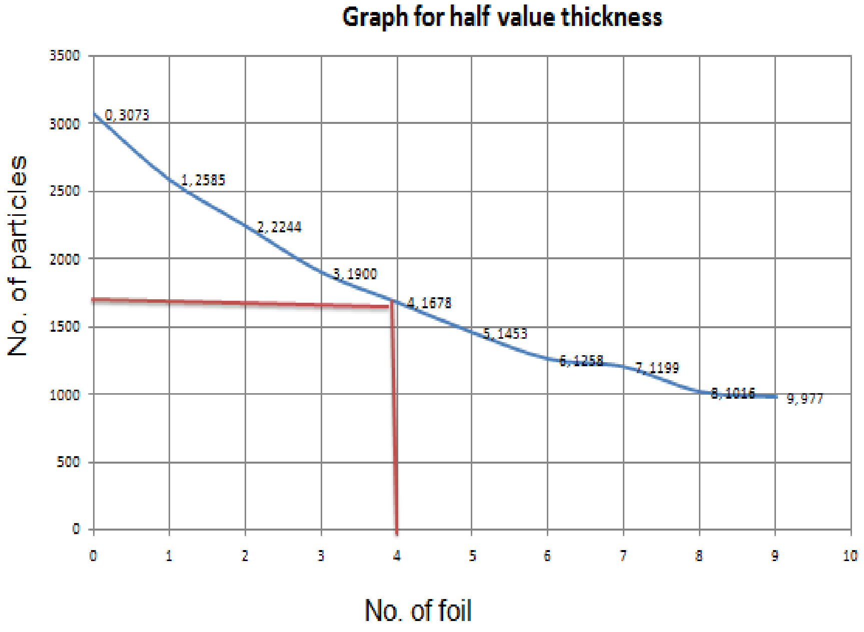


Figure-3.4 Graph of H.V.T of $^{60}_{27}Co$(7th Plate)

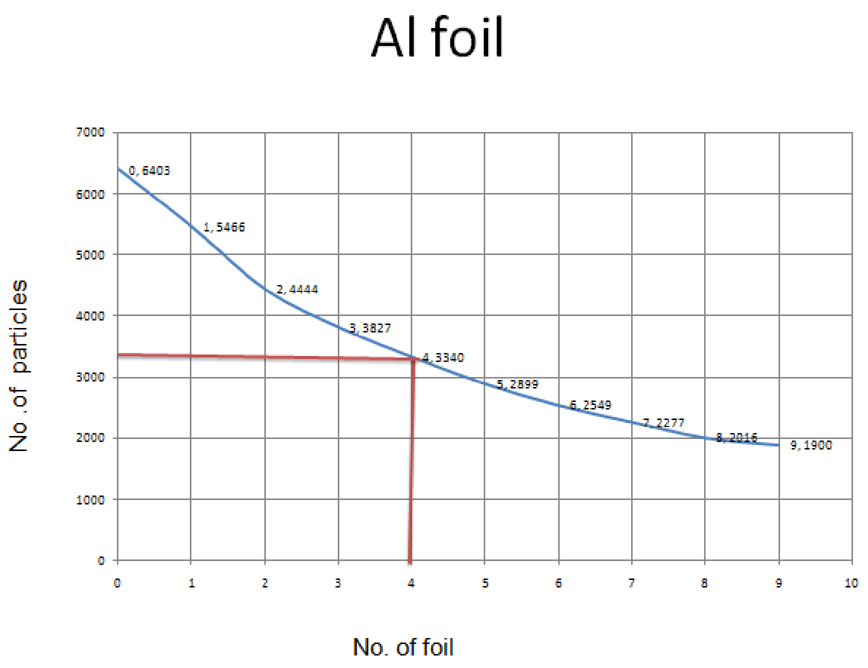


Figure-3.5 Graph of H.V.T of $^{60}_{27}Co$(8^{th} Plate)

The experimental data and graphs of attenuation coefficient of Al foil for 7^{th} and 8^{th} plate is shown in table-3.5 and 3.6, fig.3.6 & 3.7 respectively.

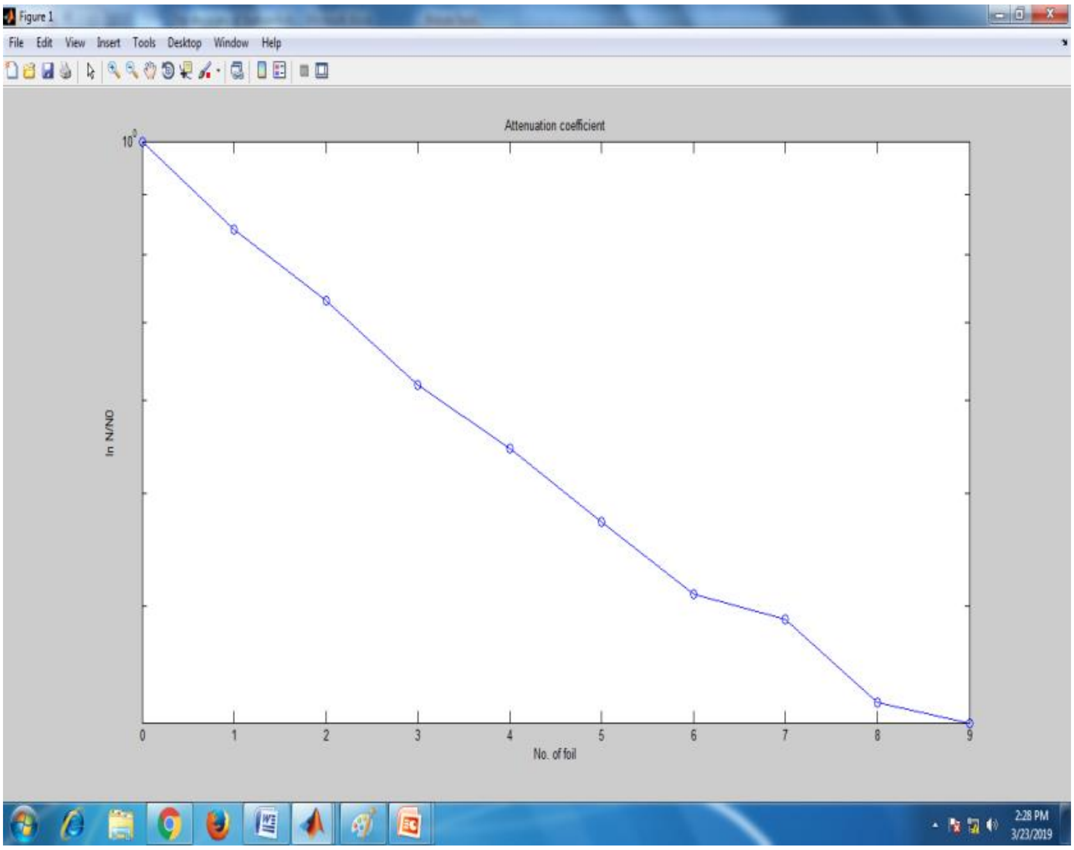


Figure-3.6 Graph of A.C. of $^{60}_{27}Co$(7^{th} Plate)

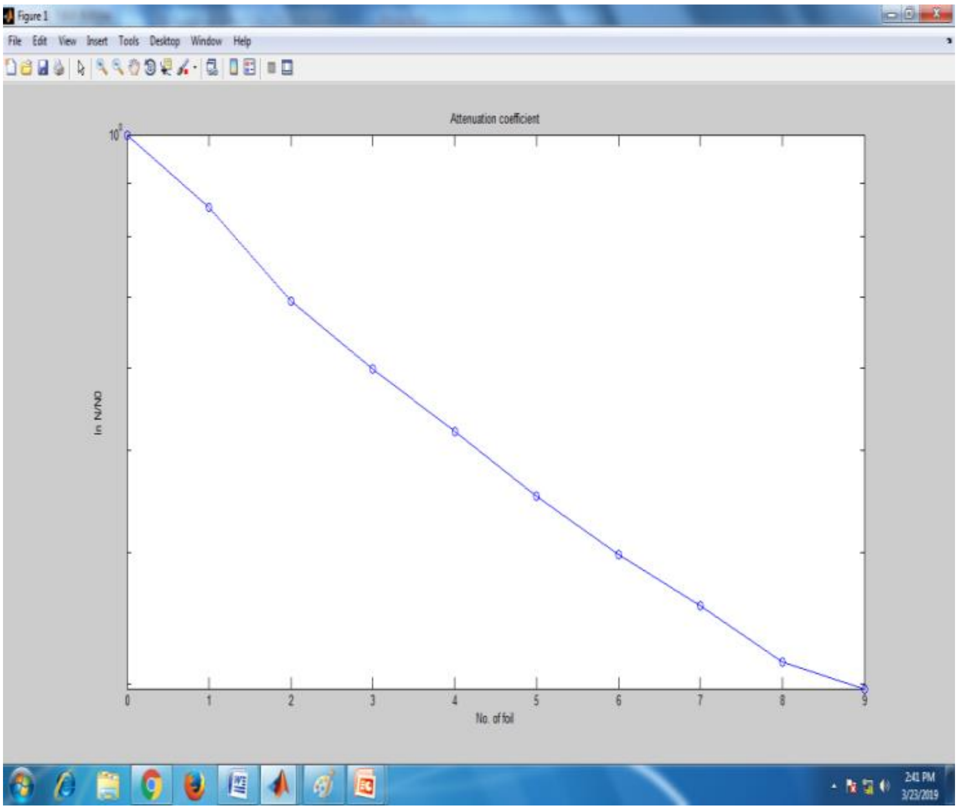


Figure-3.7 Graph of A.C of ${}^{60}_{27}Co$(8th Plate)

3.1.2 Using Paper Foil

By using the paper as an obstacle in the path of beta particles, we determined the HVT and AC for 7th and 8th plate again.

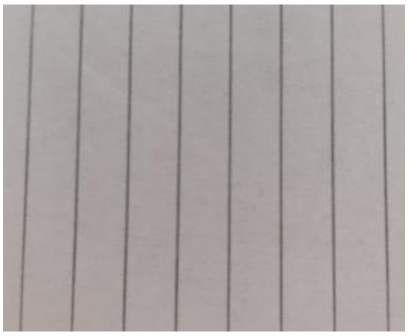


Figure-3.8 Paper foil.

$$thickness = \frac{weight}{area}$$

We take a paper which length =26.5cm

Breadth=19.2 cm

Weight=2.7mg

$$thickness of paper = \frac{2.7}{26.5 \times 19.2}$$

$$thickness of paper \approx 53 micron$$

Table-3.7 and 3.8 shows the experimental data for 7th and 8th plate respectively for various number of paper foils we consider. Fig. 3.9& 3.10 below show the respective HVT of Al foil for 7th and 8th plate of G-M tube.

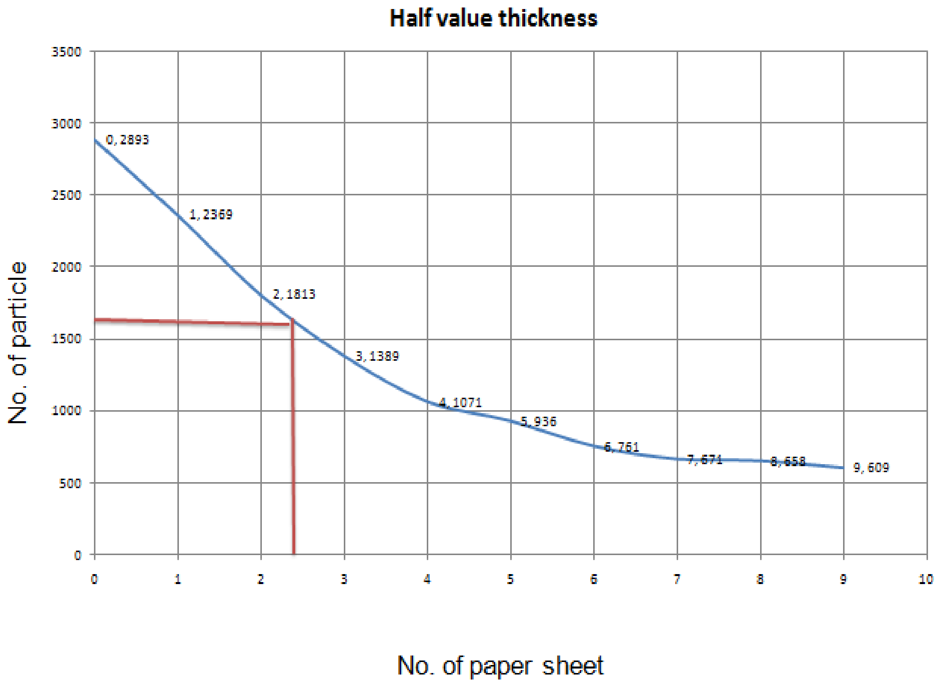


Figure-3.9 Graph of H.V.T of $^{60}_{27}Co$(7th Plate)

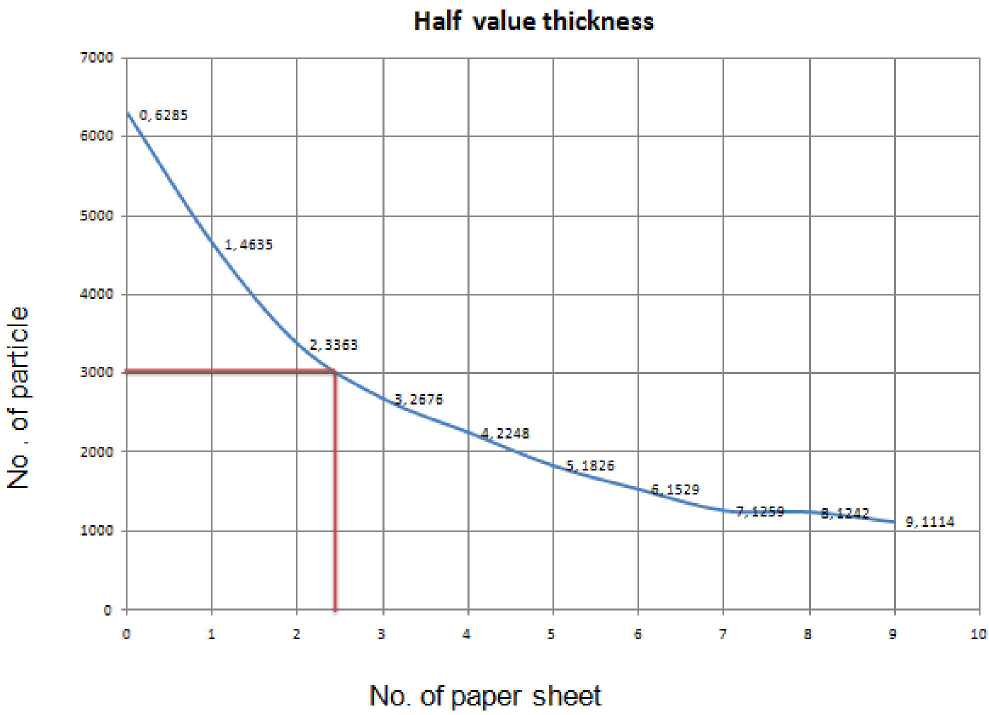


Figure-3.10 Graph of H.V.Tof $^{60}_{27}Co$(8th Plate)

The experimental data and graphs of attenuation coefficient of Al foil for 7th and 8th plate is shown in table-3.9 and 3.10, fig.3.11& 3.12 respectively. We have found the AC in this case is 0.0057.

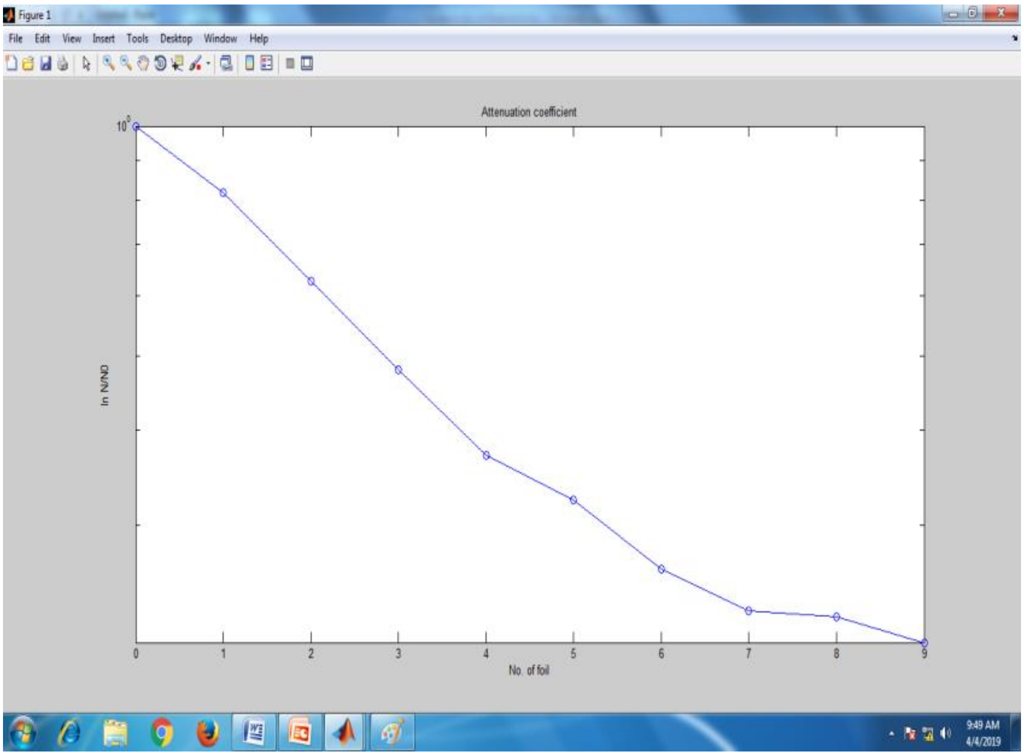


Figure-3.11 Graph of A.C of $^{60}_{27}Co$(7th Plate)

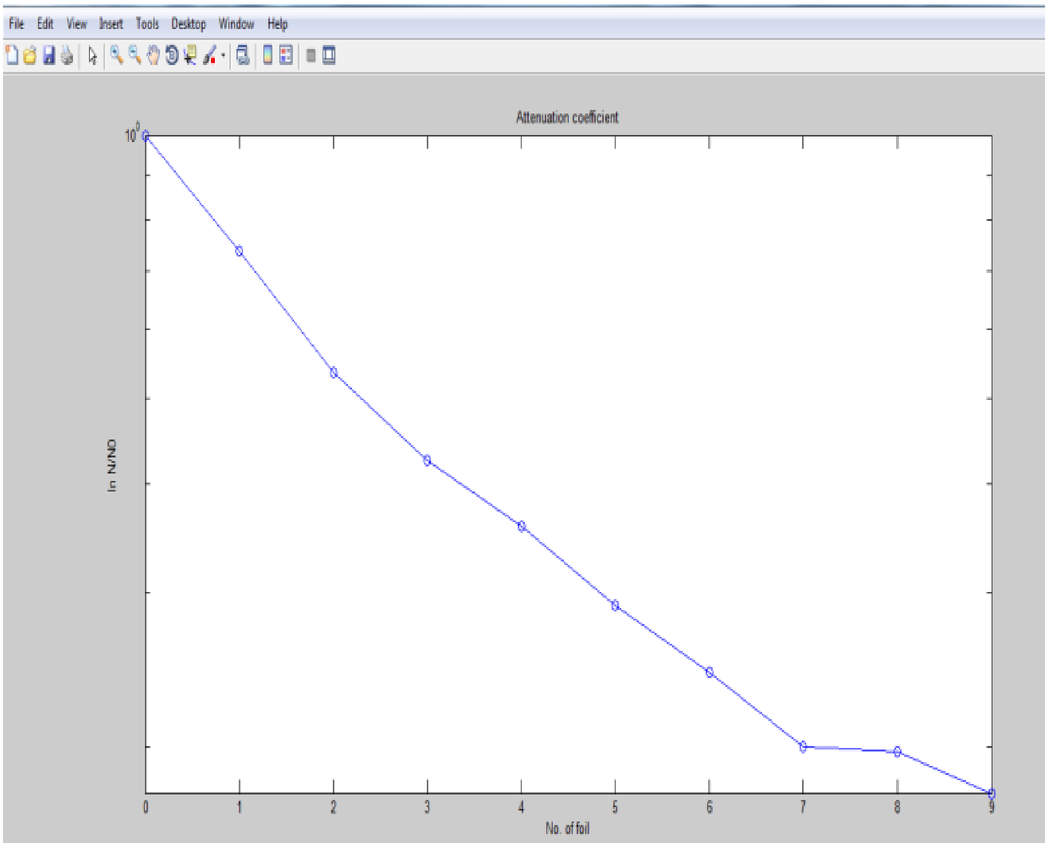


Figure-3.12 Graph of A.C of $^{60}_{27}Co$(8th Plate)

3.1.3 Using Gift Wrapper

Again, we have used the gift wrapper to determine the HVT and AC for 7th and 8th plate.

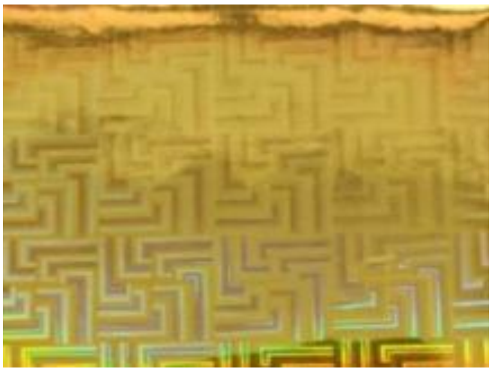


Figure-3.13 Gift Wrapper

$$thickness = \frac{Mass}{area}$$

We take a gift wrapper which length is = 48 cm

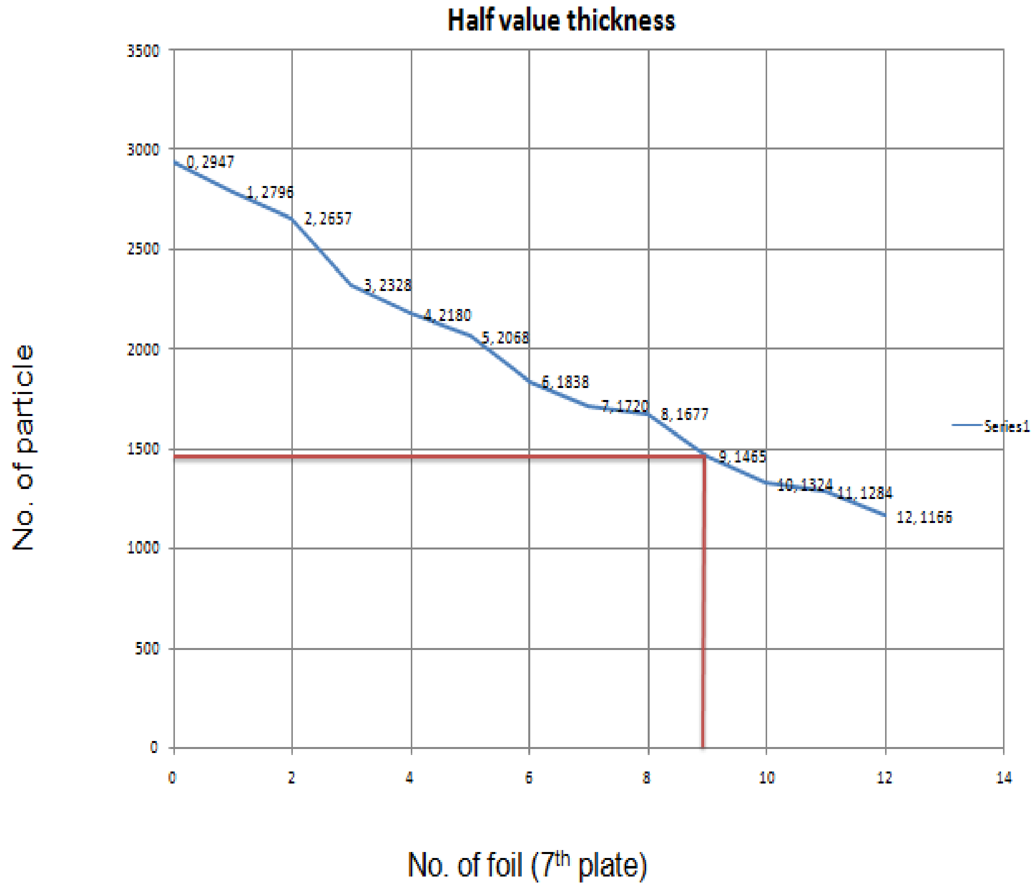
Breadth =34.1 cm

Weight=2.4 mg

$$thickness of gift wrapper = \frac{2.4}{48 \times 34.1}$$

$$thickness of gift wrapper \approx 15\ micron$$

Table-3.11 and 3.12 shows the experimental data for 7th and 8th plate respectively for various gift wrappers we consider. Fig. 3.14& 3.15 below show the respective HVT of Al foil for 7th and 8th plate of G-M tube.



Figur-3.14 Graph of H.V.T in $^{60}_{27}Co$(7th Plate)

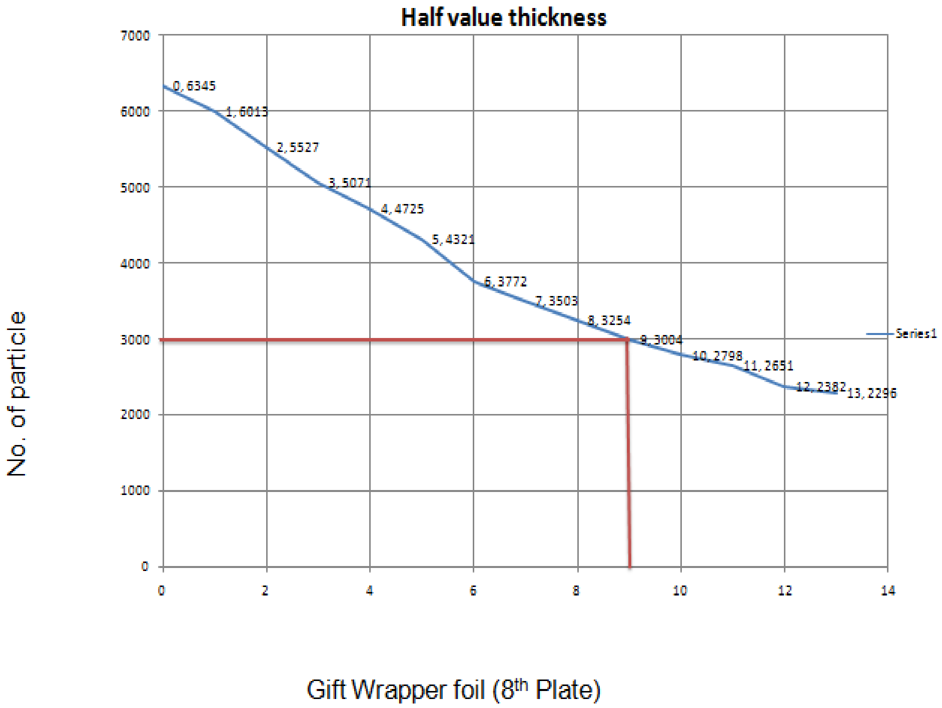


Figure-3.15 Graph of H.V.T in $^{60}_{27}Co$(8th Plate)

The experimental data and graphs of attenuation coefficient of Al foil for 7th and 8th plate is shown in table-3.13 and 3.14, fig.3.16& 3.17 respectively. We have found the AC in this case is 0.0060.

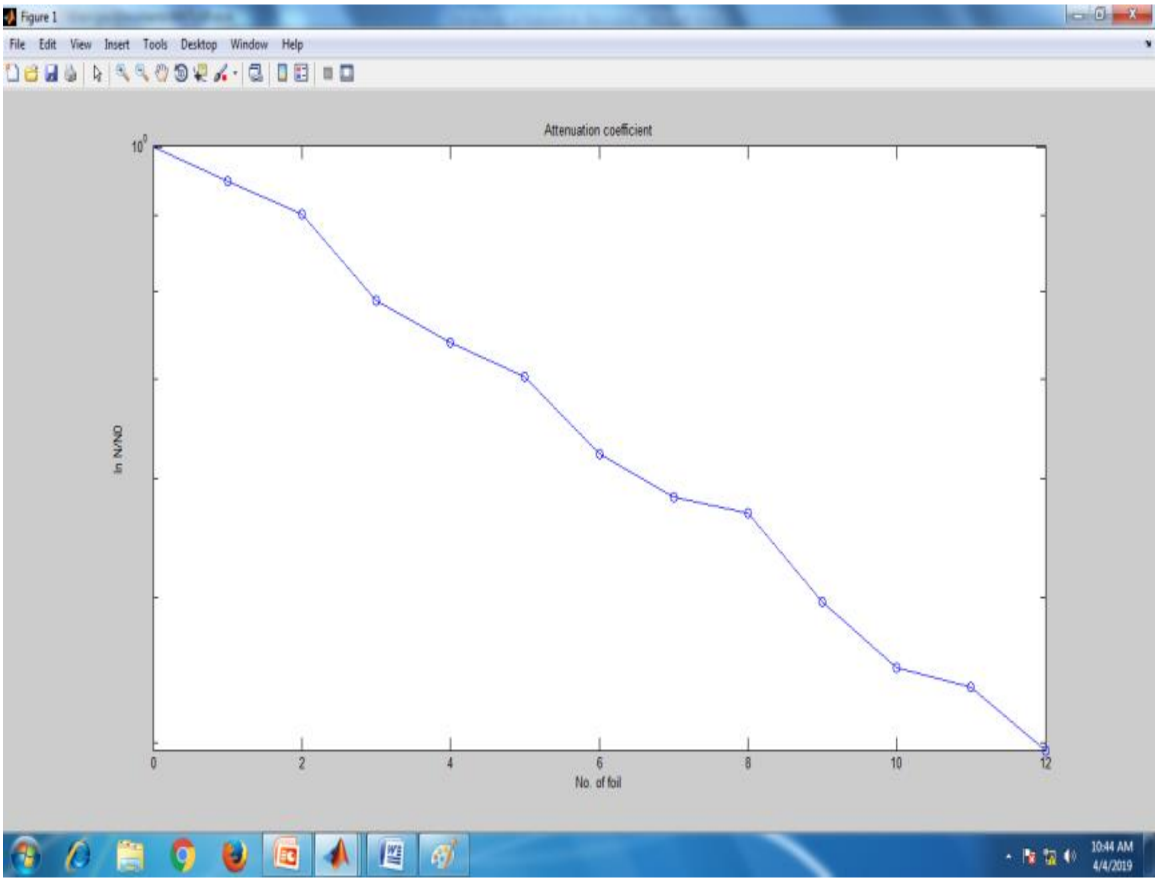


Figure-3.16 Graph of A.C in $^{60}_{27}Co$(7th Plate)

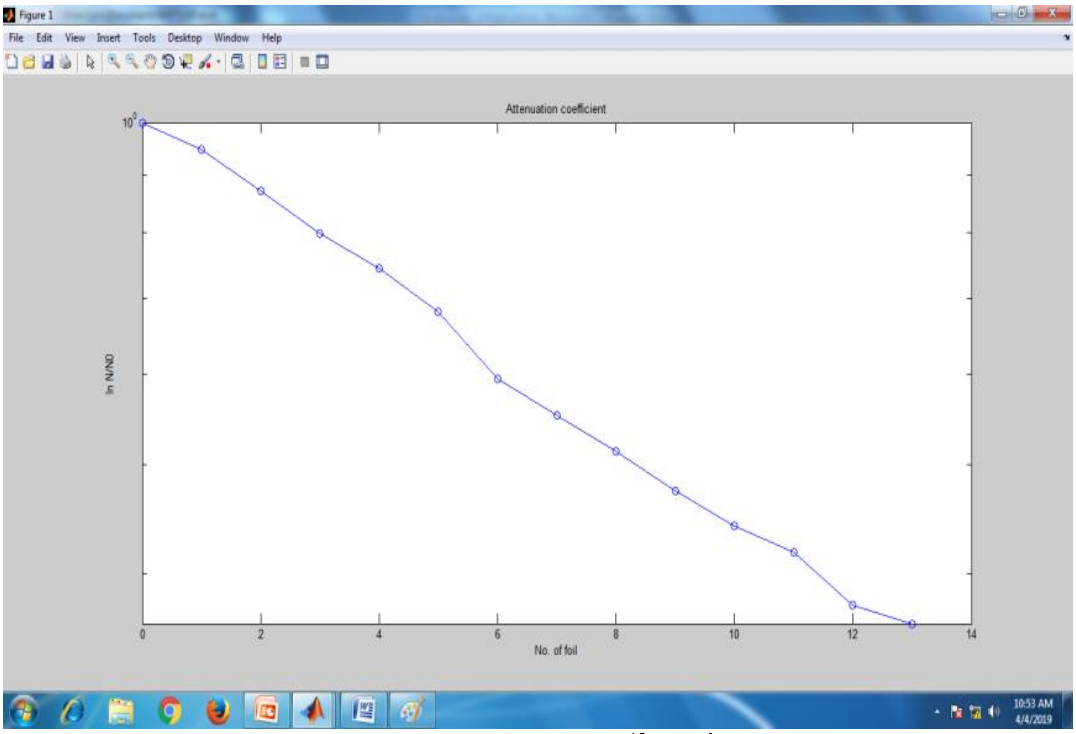


Figure-3.17 Graph of A.C in ${}^{60}_{27}Co$(8th Plate)

3.2 Analysis for β$^+$ Decay by${}^{22}_{11}Na$

Sodium-22 is a man-made isotope with a half-life of 2.6 years. It decays emitting a positron (β+ decay) into stable neon-22.The excited neon state passes into the ground state whereby a 1275 keV γ quantum is emitted. The lifetime of this excited neon is only 3.7 ps. As the time delay between the 1275 keV line and the annihilation radiation is unresolvable small, there appears also a line at 1275 + 511 = 1786 keV as a result of simultaneous absorption of both γ quanta.

$$^{22}_{11}\mathrm{Na} \rightarrow ^{22}_{10}\mathrm{Ne} + \beta^{+} + \nu_{e},$$

Again, we have used 7thPlate and 8th plate of GM tube. We take time 30 second and change voltage in steps of 50 volt of G-M tube.Table-3.15and 3.16 shows the experimental data and fig.3.18& 3.19 shows the plateau characteristics of the source without any absorber present.

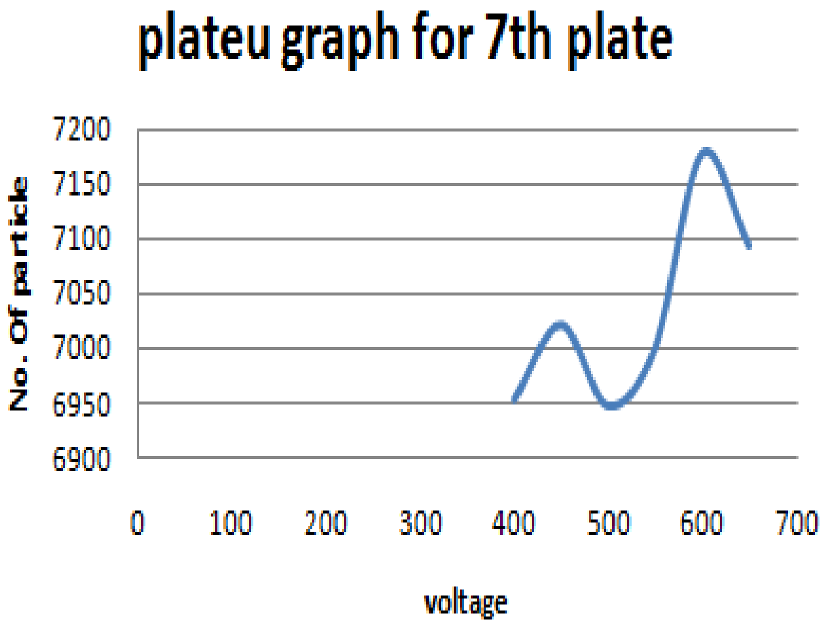


Figure-3.18 plateau graph of ${}^{22}_{11}Na$of 7th plate

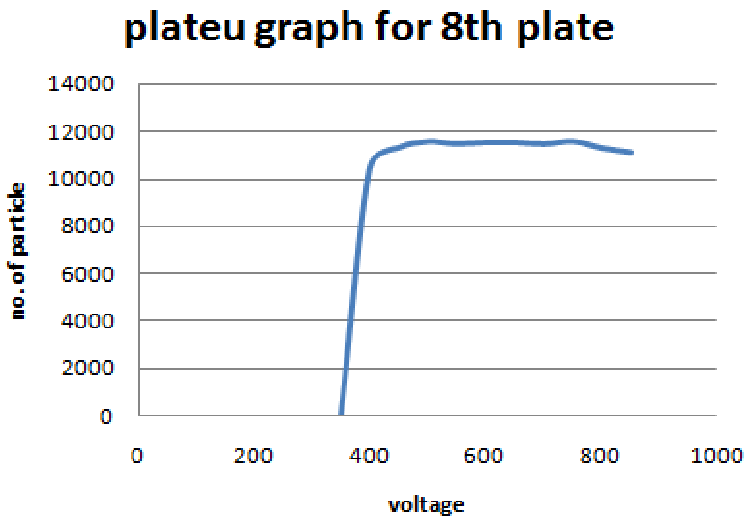


Figure-3.19 Plateau Graph in $^{22}_{11}Na$ (8thPlate)

3.2.1 Using Al Foil

Table-3.17 and 3.18 shows the experimental data for 7th and 8th plate respectively for different number of foils. Fig. 3.20& 3.21 below show the respective HVT of Al foil for 7th and 8th plate of G-M tube.

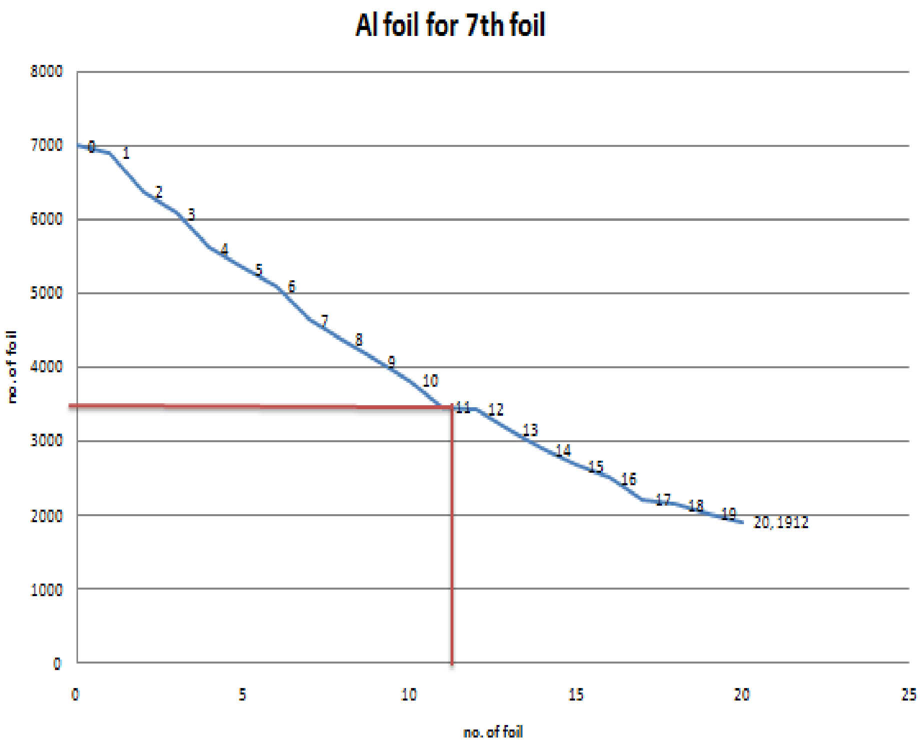


Figure-3.20 Graph of H.V.T. in $^{22}_{11}Na$ (7th Plate)

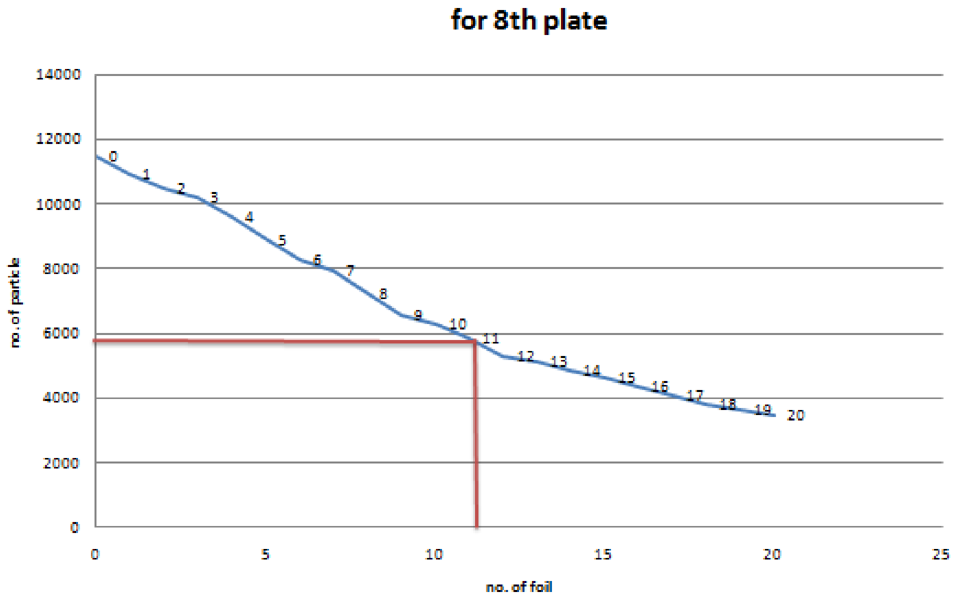


Figure-3.21 Graph of H.V.T. in $^{22}_{11}Na$ (8th Plate)

The experimental data and graphs for attenuation coefficient of Al foil for 7th and 8th plate is shown in table-3.19 and 3.20, fig.3.22& 3.23 respectively. We have found the AC in this case is 0.0015.

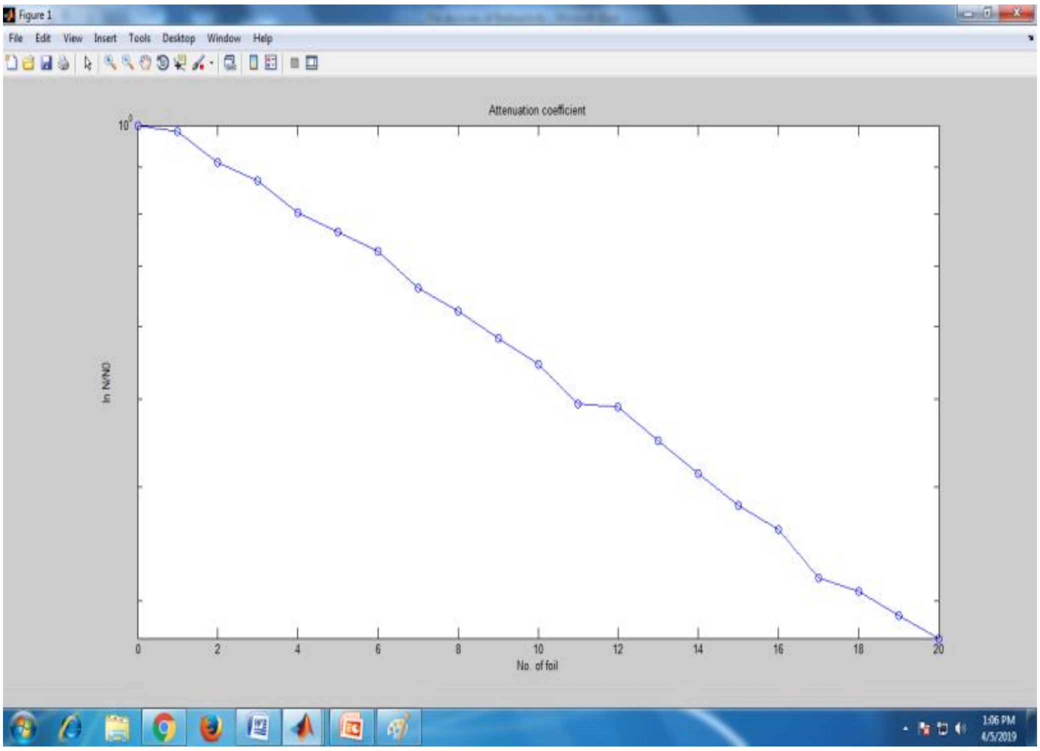


Figure-3.22 Graph of A.C. in $^{22}_{11}Na$ (7th Plate)

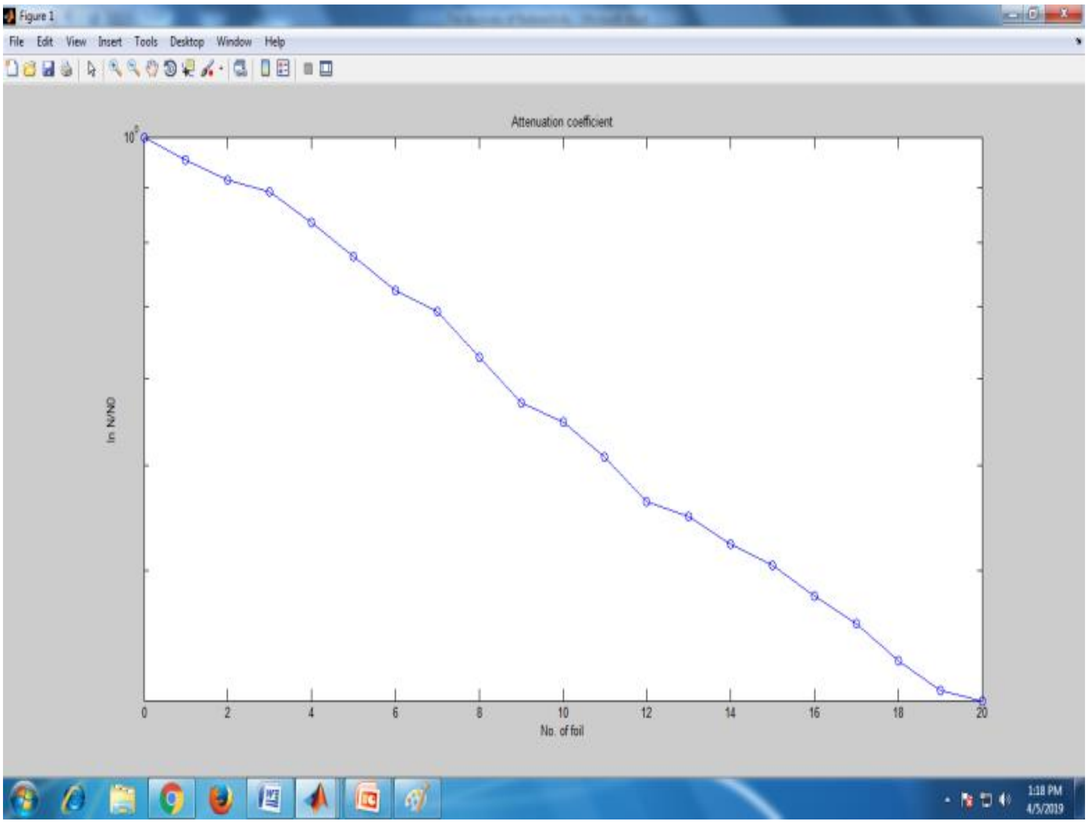


Figure-3.23 Graph of A.C. in $^{22}_{11}Na$ (8th Plate)

3.2.2 Using Paper Foil

By using the paper again calculate the HVT and AC for 7th and 8th plate of G-M tube. Experimental data for HVT is given below in table-3.21 and 3.22.

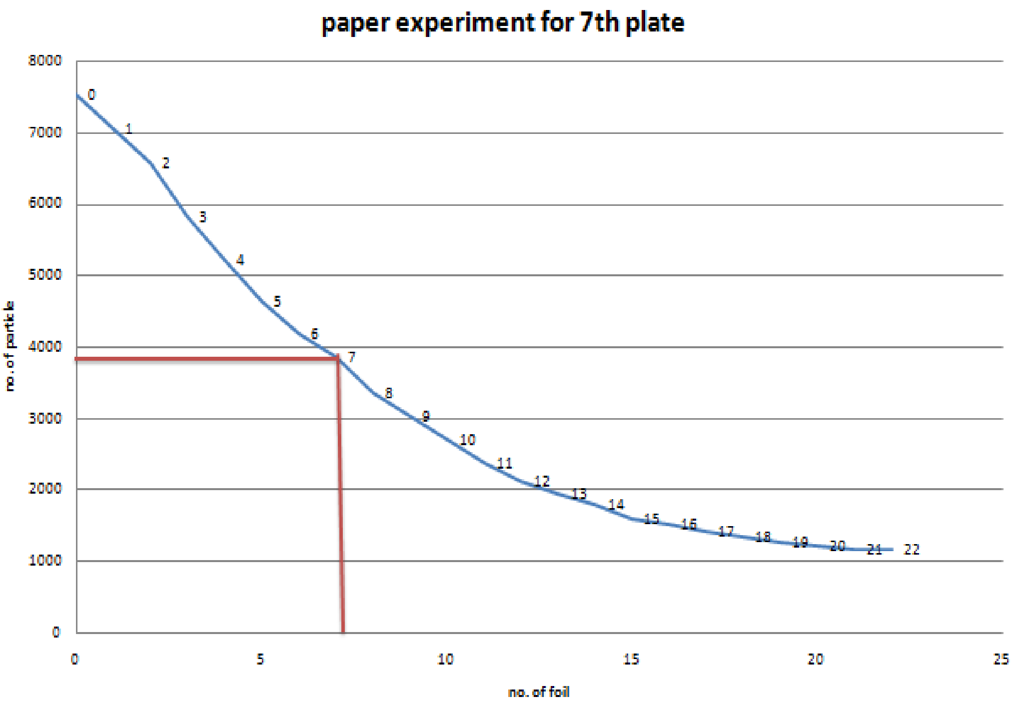


Figure-3.24 Graph of A.C. in $^{22}_{11}Na$ (7th Plate)

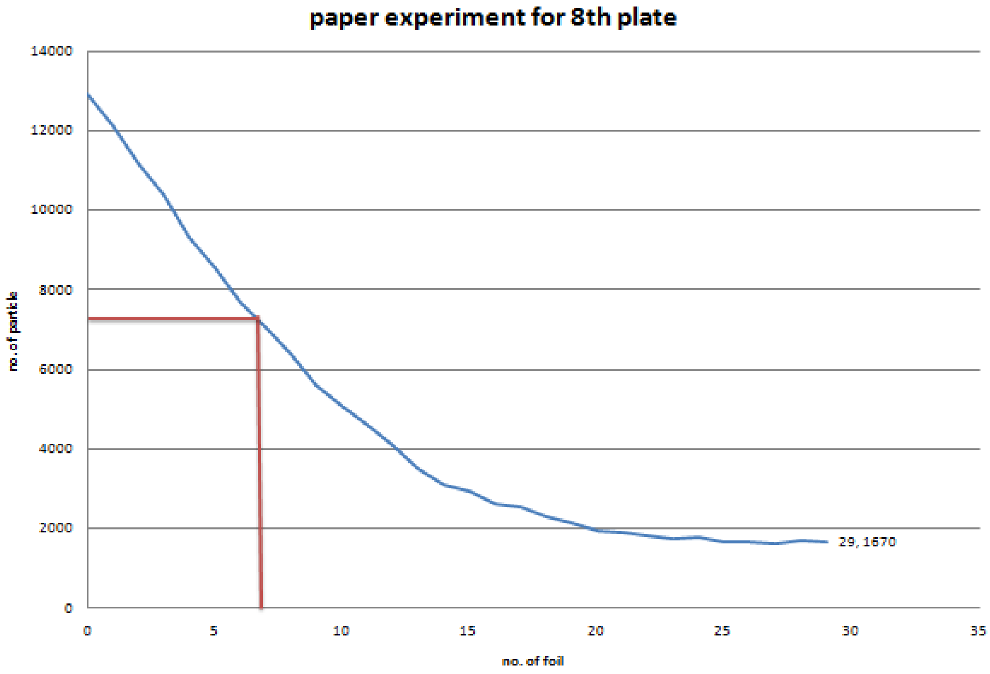


Figure-3.25 Graph of H.V.T. in $^{22}_{11}Na$ (7^{th} Plate)

With the paper foil again determine the AC(0.0013) for the same position of the G-M tube. Shown in figures below.

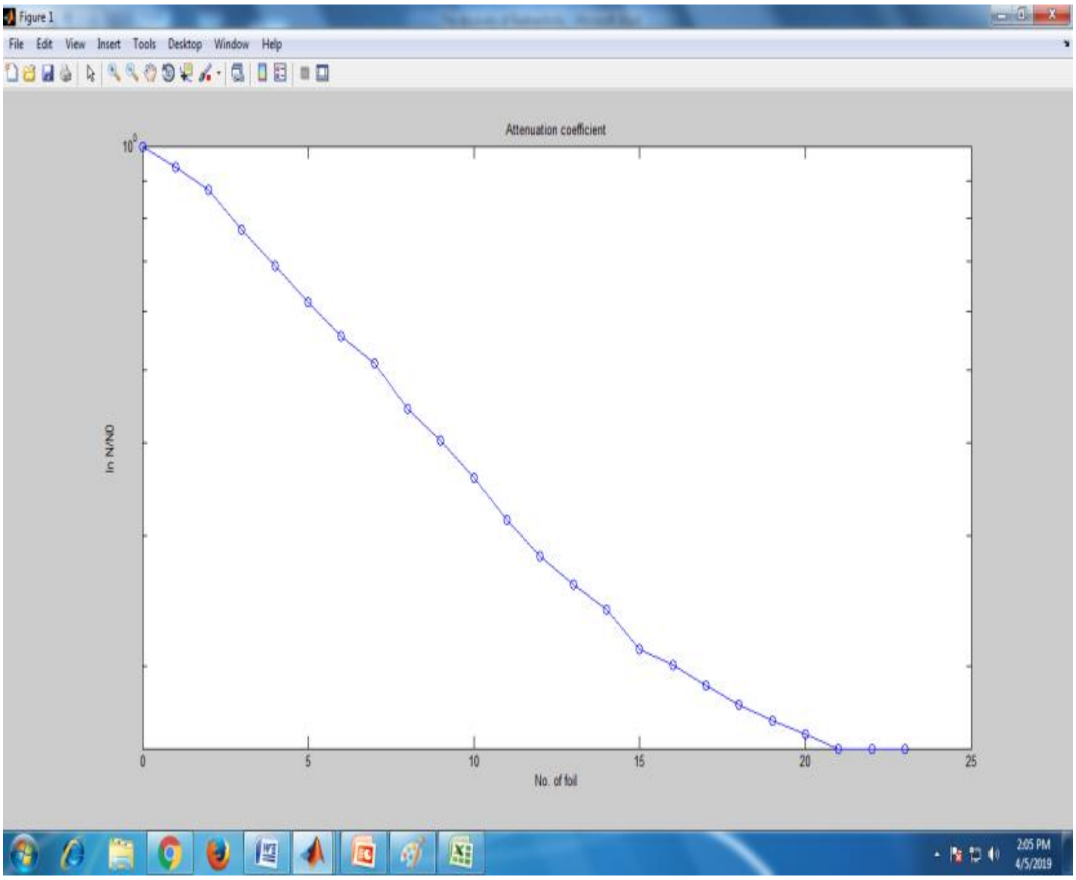


Figure-3.26 Graph of A.C. in $^{22}_{11}Na$ (7^{th} Plate)

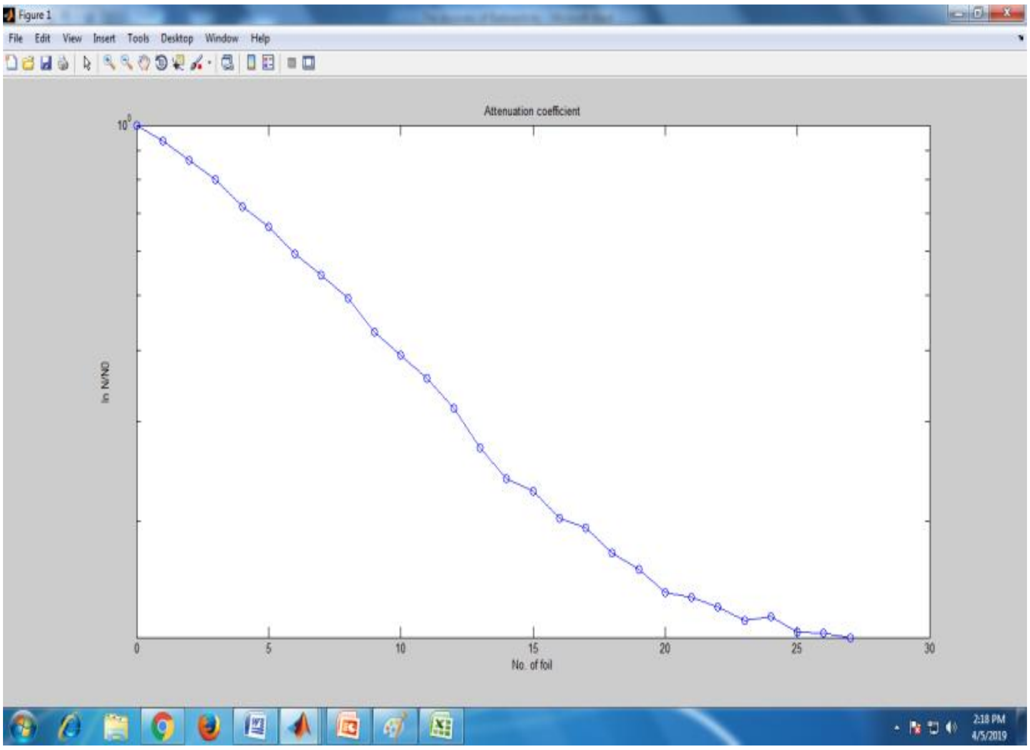


Figure-3.27 Graph of A.C. in $^{22}_{11}Na$ (8th Plate)

3.2.3 Using Gift Wrapper

By using the gift wrapper calculate the HVT and AC for 7th plate of G-M tube. Experimental data for HVT and AC is given below in table-3.25 and 3.26 repectively.

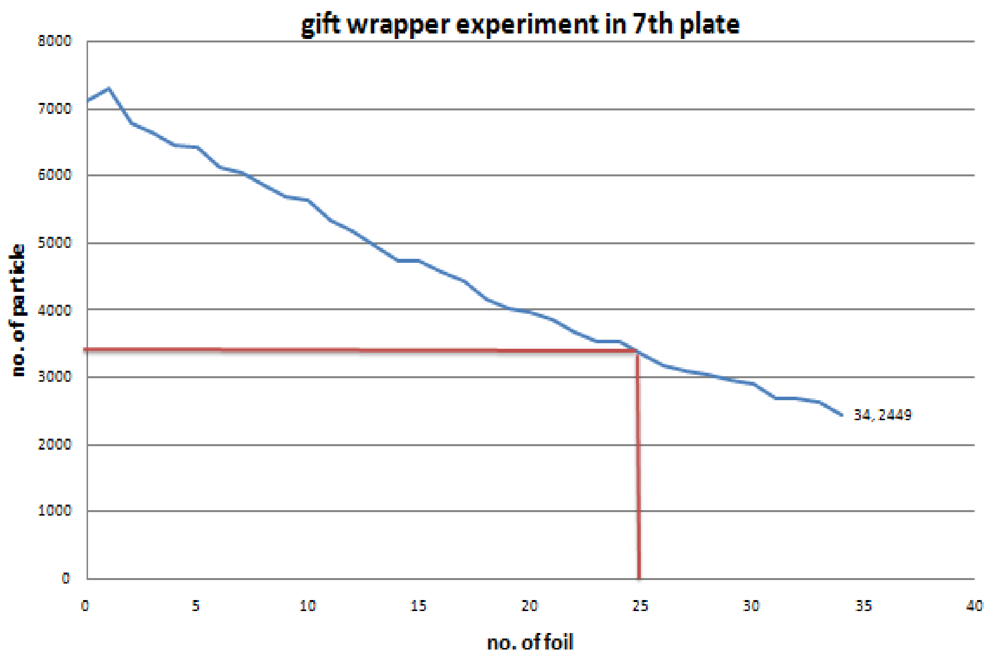


Figure-3.28 Graph of H.V.T. in $^{22}_{11}Na$ (7th Plate)

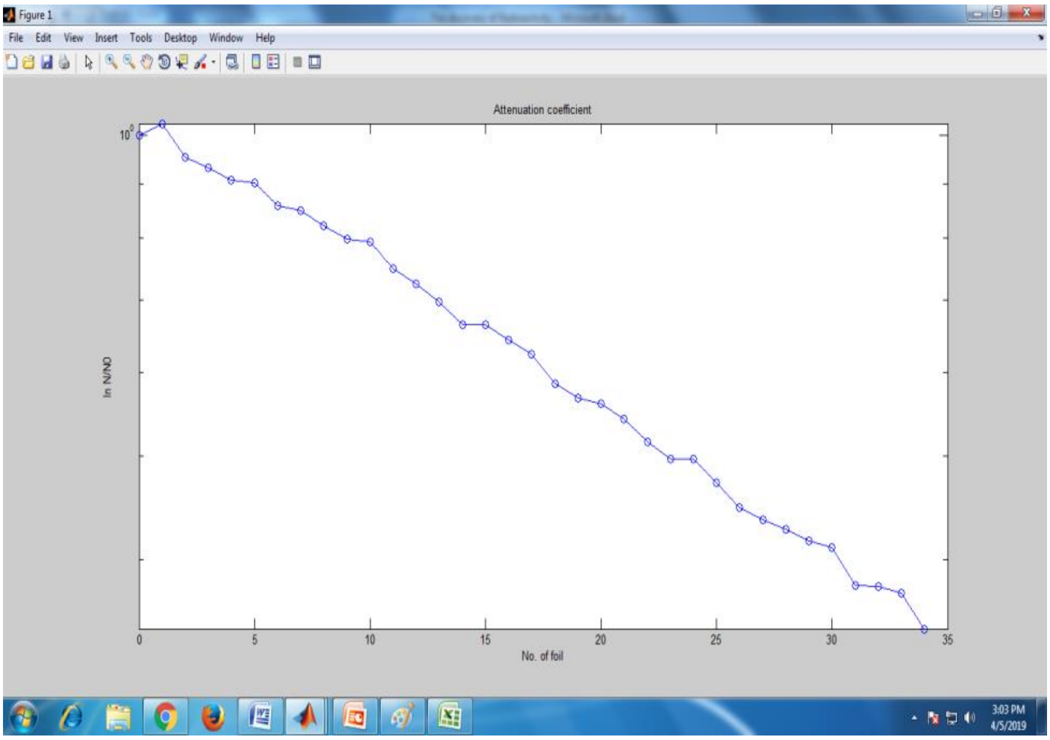


Figure-3.29 Graph of A.C. in $^{22}_{11}Na$ (7th Plate)

The half value thickness and Attenuation coefficient of β^- Particle and β^+ Particle in both sources are different.We have concluded that;

- ✓ Half Value thickness of any sources does not depend on material. It depends on material thickness. Example β^+ Particle
  Al foil thickness =135 mg /cm^2
  Paper foil thickness =133 mg /cm^2
  Gift wrapper thickness=135 mg /cm^2
- ✓ Half value thickness and Attenuation coefficient of β^- Particle and β^+ Particle in both sources are different because it depends on their energy.
- ✓ When β^- particle interact with matter there have no change in matter while β^+ particle interact with matter there will be annihilation process with matter and produce photon in nature.

4. Conclusion and Recommendation

The present experimental study was carried out to obtain information on linear attenuation coefficient and related parameters such as half value thickness (HVT), for interaction of Beta particles with different samples. We concluded that Half Value thickness of any sources does not depend on material. It depends on material thickness. When β^- particle interact with matter there have no change in matter but when β^+ particle interact with matter there will be annihilation process with matter and produce photon in nature. Nuclear Physics is a very specialized field of Physics understanding the behavior of matter at a very atomic level comprising of neutrons and protons and their subsequent fusion, fission involving vast amount of energy. Like most other nations, even India wishes to make itself dependent in terms of energy, defense and medical technological advancements. By using nuclear techniques, we can calculate linear attenuation coefficient other parameters such as HVT, TVL and mean free path that will be very useful in industrial, biological, technological, shielding and other applications, solar cell and recently in sensors field. This technique is also very helpful for selecting shielding material.

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Conflict of Interest

The authors of the manuscript strongly declare that no conflict of interest at all.

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Table-3.1 Experimental data of $^{60}_{27}Co$ for 7th plate.

Voltage	Forward	Reverse
400	0	0
425	2927	685
450	3107	712
500	3101	697
550	2992	680
600	3105	671
650	3203	705
700	2961	753

Table-3.2 Experimental data of $^{60}_{27}Co$ for 8th plate.

Voltage	Forward	Reverse
400	0	0
425	3623	1008
450	6652	1081
500	6646	1106
550	6634	1095
600	6705	1102
650	6565	1094
700	6660	1097

Table-3.3 Experimental data for H.V.T in $^{60}_{27}Co$ by using Al foil.(7th plate)

No of plate	count particle
0	3073
1	2585
2	2244
3	1900
4	1678
5	1453
6	1258
7	1199
8	1016
9	977

Table-3.4 Experimental data for H.V.T in $^{60}_{27}Co$ by using Al foil.(8th plate)

No of plate	count particle
0	6403
1	5466
2	4444
3	3827
4	3340
5	2899
6	2549
7	2277
8	2016
9	1900

Table-3.5 Experimental data for A. C in $^{60}_{27}Co$ (7th Plate)for Al foil

No of foil	N/No
0	1
1	0.8411
2	0.7302
3	0.6182
4	0.546
5	0.4728
6	0.4093
7	0.3901
8	0.3306
9	0.3179

Table- 3.6 Experimental data for A. C in $^{60}_{27}Co$ (8th plate)for Al foil

No. of foil	N/No	No of foil	N/No
0	1	5	0.4527
1	0.8536	6	0.398
2	0.694	7	0.3556
3	0.5976	8	0.3148
4	0.5216	9	0.2967

Table-3.7 Experimental data for H.V.T in $^{60}_{27}Co$ (7th plate) using paper foil

No. of paper sheet	No of particle	No of paper sheet	No of particle
0	2893	5	936
1	2369	6	761
2	1813	7	671
3	1389	8	658
4	1071	9	609

Table- 3.8 Experimental data for H.V.T in $^{60}_{27}Co$ (8th plate) using paper foil

No. of paper sheet	No of particle	No of paper sheet	No of particle
0	6285	5	1826
1	4635	6	1529
2	3363	7	1259
3	2676	8	1242
4	2248	9	1114

Table-3.9 Experimental data for A.C $^{60}_{27}Co$ (7th plate) using paper foil

No of foil	N/No	No of foil	N/No
0	1	5	0.3235
1	0.8188	6	0.263
2	0.6266	7	0.2319
3	0.4801	8	0.2274
4	0.3702	9	0.2105

Table-3.10 Experimental data for A.C $^{60}_{27}Co$ (8th plate) using paper foil

No of foil	N/No	No of foil	N/No
0	1	5	0.2905
1	0.7374	6	0.2432
2	0.535	7	0.2003
3	0.4257	8	0.1976
4	0.3576	9	0.1772

Table- 3.11 Experimental data for H.V.T in $^{60}_{27}Co$ (7th plate) using gift wrapper

No of foil	No. of particle	No of foil	No of particle
0	2947	7	1720
1	2796	8	1677
2	2657	9	1465
3	2328	10	1324
4	2180	11	1284
5	2068	12	1166
6	1838	-	-

Table- 3.12 Experimental data for H.V.T in $^{60}_{27}Co$ (8th plate) using gift wrapper

No of foil	No. of particle	No of foil	No of particle
0	6345	7	3203
1	6013	8	3254
2	5527	9	3004
3	5071	10	2798
4	4725	11	2651
5	4321	12	2382
6	3772	13	2296

Table-3.13 Experimental data for A.C in $^{60}_{27}Co$ (7th plate) using gift wrapper

No of foil	N/No	No of foil	N/No
0	1	7	0.5836
1	0.9487	8	0.569
2	0.9015	9	0.4971
3	0.7899	10	0.4492
4	0.7397	11	0.4356
5	0.7017	12	0.3956
6	0.6236	-	-

Table-3.14 Experimental data for A.C in $^{60}_{27}Co$ (8th plate) using gift wrapper

No of foil	N/No	No of foil	N/No
0	1	7	0.552
1	0.9476	8	0.5128
2	0.871	9	0.4734
3	0.7992	10	0.4409
4	0.7446	11	0.4178
5	0.681	12	0.3754
6	0.5944	13	0.3618

Table-3.15 Experimental data for Plateau graph in $^{22}_{11}Na$ (7th plate , time t= 30 sec)

voltage	No. of particle	voltage	No. of particle
350	0	650	7095
400	6954	700	7228
450	7022	750	6999
500	6948	800	7162
550	7001	850	7049
600	7179	.	

Table-3.16 Experimental data for Plateau graph in $^{22}_{11}Na$ (8th plate , time t= 30 sec)

voltage	No. of particle	voltage	No. of particle
350	0	650	11557
400	10520	700	11481
450	11327	750	11593
500	11589	800	11310
550	11488	850	11128
600	11553	.	.

Table-3.17 Experimental data for H.V.T. in $^{22}_{11}Na$ (7th plate)using Al foil at 550V

No of foil	No. of particle	No of foil	No of particle
0	7001	10	3824
1	6891	11	3459
2	6367	12	3430
3	6077	13	3155
4	5608	14	2902
5	5338	15	2676
6	5091	16	2514
7	4640	17	2230
8	4371	18	2151
9	4088	19	2023
		20	1912

Table-3.18 Experimental data for H.V.T. in $^{22}_{11}Na$ (8th plate)using Al foil at 550V

No of foil	No. of particle	No of foil	No of particle
0	11488	10	6296
1	10954	11	5842
2	10485	12	5319
3	10230	13	5160
4	9591	14	4863
5	8927	15	4651
6	8314	16	4367
7	7954	17	4109
8	7222	18	3804
9	6556	19	3640
		20	3495

Table-3.19 Experimental data for A.C in $^{22}_{11}Na$ (7th plate)using Al foil

No of foil	N/No	No of foil	N/No
0	1	11	0.4946
1	0.9842	12	0.4899
2	0.9094	13	0.4506
3	0.868	14	0.4145
4	0.801	15	0.3822
5	0.7624	16	0.3596
6	0.7271	17	0.3185
7	0.6627	18	0.3072
8	0.6243	19	0.2889
9	0.5839	20	0.2731
10	0.5462	-	-

Table-3.20 Experimental data for A.C in $^{22}_{11}Na$ (8th plate)using Al foil

No of foil	N/No	No of foil	N/No
0	1	11	0.5085
1	0.9535	12	0.463
2	0.9126	13	0.4491
3	0.8904	14	0.4233
4	0.8348	15	0.4048
5	0.777	16	0.3796
6	0.7237	17	0.3576
7	0.6923	18	0.3311
8	0.6286	19	0.3168
9	0.5706	20	0.3042
10	0.548	-	-

Table-3.21 Experimental data for H.V.T. in $^{22}_{11}Na$ (7th plate) Using paper foil

No of foil	No. of particle	No of foil	No of particle
0	7532	12	2119
1	7051	13	1942
2	6576	14	1800
3	5819	15	1589
4	5211	16	1516
5	4650	17	1423
6	4180	18	1341
7	3851	19	1276
8	3349	20	1222
9	3033	21	1170
10	2700	22	1170
11	2370	23	1170

Table-3.22 Experimental data for H.V.T. in $^{22}_{11}Na$ (8th plate) Using paper foil

No of foil	No. of particle	No of foil	No of particle
0	12921	15	2920
1	12116	16	2620
2	11182	17	2520
3	10364	18	2275
4	9280	19	2131
5	8543	20	1937
6	7651	21	1901
7	7032	22	1829
8	6385	23	1730
9	5576	24	1754
10	5068	25	1647
11	4619	26	1643

12	4101	27	1614
13	3486	28	1704
14	3080	29	1670

Table-3.23 Experimental data for A.C in $^{22}_{11}Na$ (7th plate) Using paper foil

No of foil	N/No	No of foil	N/No
0	1	12	0.2813
1	0.9361	13	0.2578
2	0.873	14	0.2389
3	0.7725	15	0.2109
4	0.6918	16	0.2012
5	0.6173	17	0.1889
6	0.5549	18	0.178
7	0.5112	19	0.1694
8	0.4446	20	0.1622
9	0.4026	21	0.1553
10	0.3584	22	0.1553
11	0.3146	23	0.1553

Table-3.24 Experimental data for A.C in $^{22}_{11}Na$ (8th plate) Using paper foil

No of foil	N/No	No of foil	N/No
0	1	15	0.2259
1	0.9376	16	0.2027
2	0.8654	17	0.195
3	0.8021	18	0.176
4	0.7182	19	0.1649
5	0.6611	20	0.1499
6	0.5921	21	0.1471
7	0.5443	22	0.1415
8	0.4941	23	0.1338
9	0.4315	24	0.1357
10	0.3922	25	0.1274
11	0.3574	26	0.1271
12	0.3173	27	0.1249
13	0.2697	28	0.1318
14	0.2383	29	0.1292

Table-3.25 Experimental data for H.V.T. in $^{22}_{11}Na$ (7th plate) using gift wrapper

No of foil	No. of particle	No of foil	No of particle	No of foil	No of particle
0	7109	15	4720	30	2921
1	7288	16	4568	31	2693

2	6771	17	4431	32	2687
3	6624	18	4157	33	2646
4	6444	19	4033	34	2449
5	6414	20	3984		
6	6106	21	3855		
7	6038	22	3666		
8	5841	23	3537		
9	5680	24	3534		
10	5643	25	3359		
11	5325	26	3183		
12	5156	27	3099		
13	4963	28	3040		
14	4722	29	2967		

Table-3.26 Calculation data for A.C. in $^{22}_{11}Na$ (7^{th} plate) using gift wrapper

No. of foil	N/No	No. of foil	N/No
0	1	18	0.5847
1	1.025	19	0.5673
2	0.9524	20	0.5604
3	0.9317	21	0.5422
4	0.9064	22	0.5156
5	0.9022	23	0.4975
6	0.8589	24	0.4971
7	0.8493	25	0.4724
8	0.8216	26	0.4477
9	0.7989	27	0.4359
10	0.7937	28	0.4276
11	0.749	29	0.4173
12	0.7252	30	0.4108
13	0.6981	31	0.3788
14	0.6642	32	0.3779
15	0.664	33	0.3722
16	0.6425	34	0.3449
17	0.6232		