VL-M2: DETERMINATION OF THE LINEAR ABSORPTION COEFFICIENT AND MASS ABSORPTION COEFFICIENT OF LEAD (Pb) AND ALUMINUM (Al) USING ^{60}Co RADIOACTIVE SOURCE

Objective:

- To explore exponential decay laws of radiations.
- T explore the radiation absorbance characteristics of different materials.

System Requirements:

Computer (Desktop/Laptop), Operating systems: Windows, Alpha Beta Gamma_vle (zipped) File.

Advise:

Students are advised to follow the **procedures written in this manual very strictly** while performing the experiment. **Do not try to explore anything else in the experiment.**

Theory:

The elements those exhibits radioactivity are known as radioactive substances. When the nucleus of an atom emits α, β and γ-radiations, the process is known as radioactive decay. One of the important characteristics of radioactivity is that it decays exponentially with time.

When ionizing radiations passed through a material, it will absorb the radiations. The absorbance of a material is characterized by the linear absorption coefficient or mass absorption coefficient. For measuring these parameters, ionizing radiation is to be recorded. Geiger-Müller (G-M) counter is an instrument used for measuring ionization radiations (α, β and γ-radiation).

A G-M tube consists of a chamber filled with a gas mixture at a low pressure of about 0.1 atmosphere. The chamber contains two electrodes, between which there is a potential difference of several hundred volts. The walls of the tube are either metal or have their inside surface coated with a conducting material or a spiral wire to form the cathode, while the anode is a wire mounted axially in the centre of the chamber. The Geiger Muller counter operates within a specific region of the applied voltage, generally between 300 and 400 volts.

Let I_0 be the initial intensity of the γ-ray beam incident normally on absorber (Fig. 1), I be the intensity of the outgoing γ- ray beam and x be the thickness through which the radiation passes.

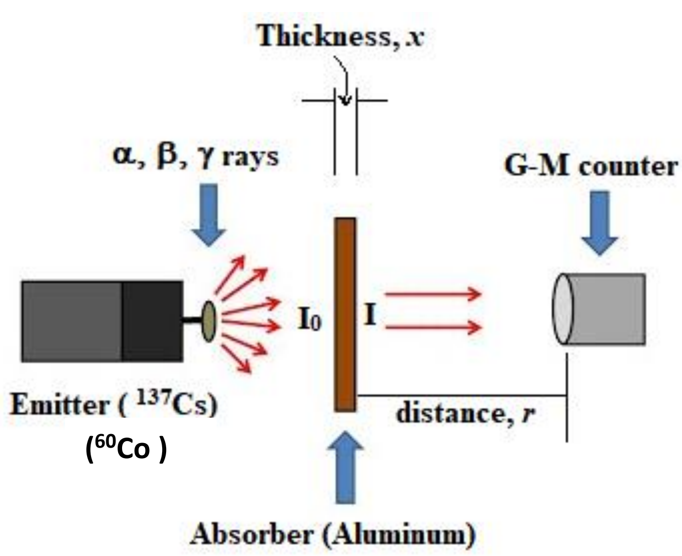

Fig. 1: G-M counter and α, β and γ radiation

If dI represents a diminution of intensity of the beam as it travels a small distance dx, then the decreasing rate of intensity $-\frac{dI}{dx}$ is proportional to I, therefore,

$$-\frac{dI}{dx} = \mu I$$

$$\text{or, } -\frac{dI}{I} = -\mu dx \qquad (1)$$

where, μ is the proportionality constant and is called the linear absorption coefficient of the absorber material for the γ- ray of a particular energy. This μ varies with γ- ray energy and absorber material and is independent of the thickness x of the absorber.

Now integrating equation (1), we get,

$$lnI = -\mu x + C \qquad (2)$$

To find the constant of integration C, the initial condition can be imposed. When $x = 0$ then $I=I_0$ therefore, equation (2) becomes

$$C = lnI_0$$

Substituting the value of C in Equation (2)

$$lnI = -\mu x + lnI_0 \qquad (3)$$

Therefore, linear absorption coefficient

$$\mu = \frac{1}{x} ln\left(\frac{I_0}{I}\right) \qquad (4)$$

And mass absorption coefficient,

$$\mu_m = \frac{\mu}{\rho} = \frac{1}{x\rho} ln\left(\frac{I_0}{I}\right) \qquad (5)$$

Here, ρ is the mass density of the absorber.

If we plot a graph with the thickness of the material (x) along the abscissa and the corresponding logarithm of the intensity of outgoing γ- ray beam (lnI) along the ordinate, the graph will be a straight line with slope μ and Y-axis intercept $C = lnI_0$.

Again, the equation (3) can be rearranged as

$$ln\frac{I}{I_0} = -\mu x$$

$$\text{or, } I = I_0 e^{-\mu x} \qquad (6)$$

Thus, the absorption of gamma ray phenomenon appears to obey exponential law. When the thickness x of the absorber increases, the gamma ray intensity I decreases exponentially.

Procedures:

1. At first unzip "Alpha Beta Gamma_vle (zipped)" File. Click on the executable file "**Alpha Beta Gamma_vle**" then a window will open as shown in Fig. 2.

2. Without placing any radioactive source in front of the GM counter, record the count for a suitable period of time (say 100 sec) and deternime the count per minute. This count is called the background count rate which is due to cosmic radiation and other radiations from radioactive substance present in the building material and environment, etc.

3. The counter timer autometically starts counting when you click on **start**. Click on **freeze** to read the display and click on **reset** to start again (As shown in Fig. 2).

4. To measure the background radiation count rate, click in the **start button** and record the count for around 100 second without placing any sources of radiation. Record the data in the Table 1.

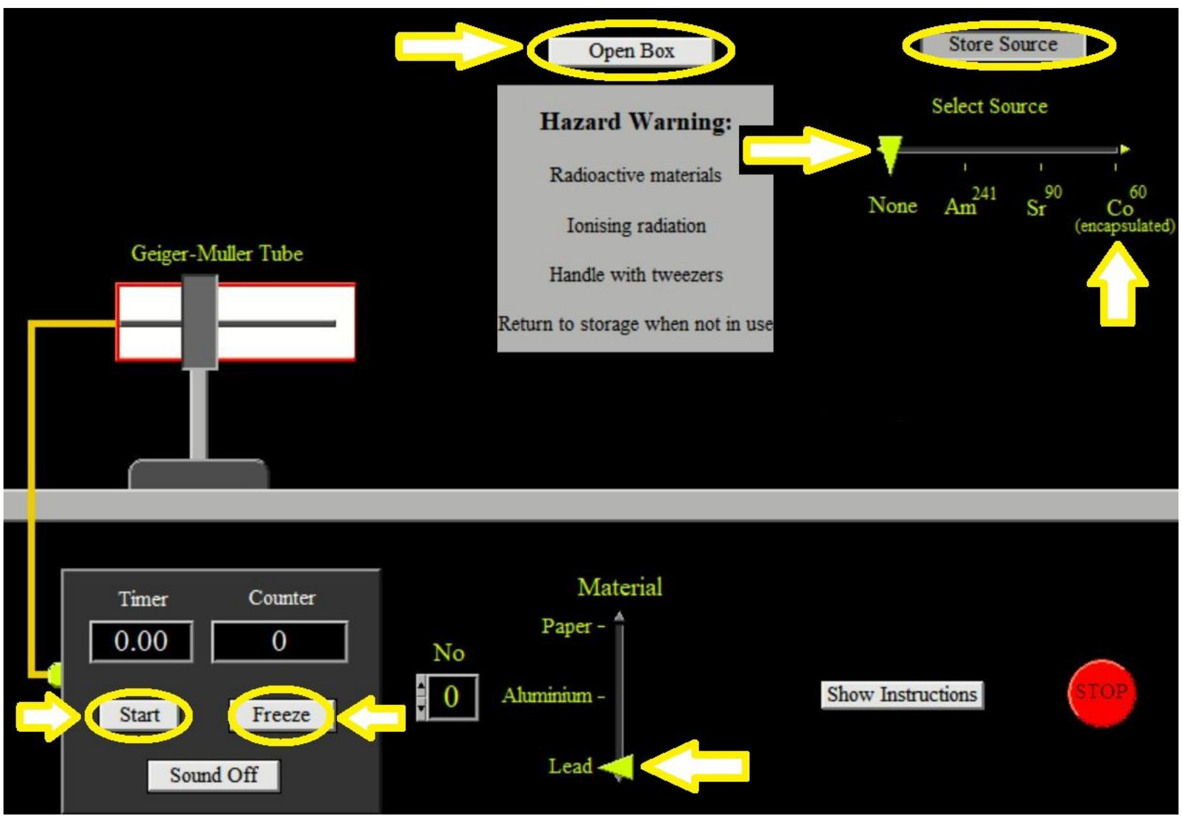

Fig. 2: Experimental setup for background radiation

5. Click on **"Open Box"** in the upper right corner so that you will find the required source. There are three different sources such as ^{241}Am, ^{90}Sr and ^{60}Co. Move the arrow on the Source Scale and select ^{60}Co source so that the source will appear in front of the G-M Counter as shown in Fig. 3.

6. There are three different materials such as Lead (Pb), Aluminum (Al) and Paper whose thickness of each sheet are 2 mm, 0.2 mm and 0.1 mm, respectively . Click on the arrow and move along the materials scale and select **Lead (Pb)** first (as shown in Fig. 3)

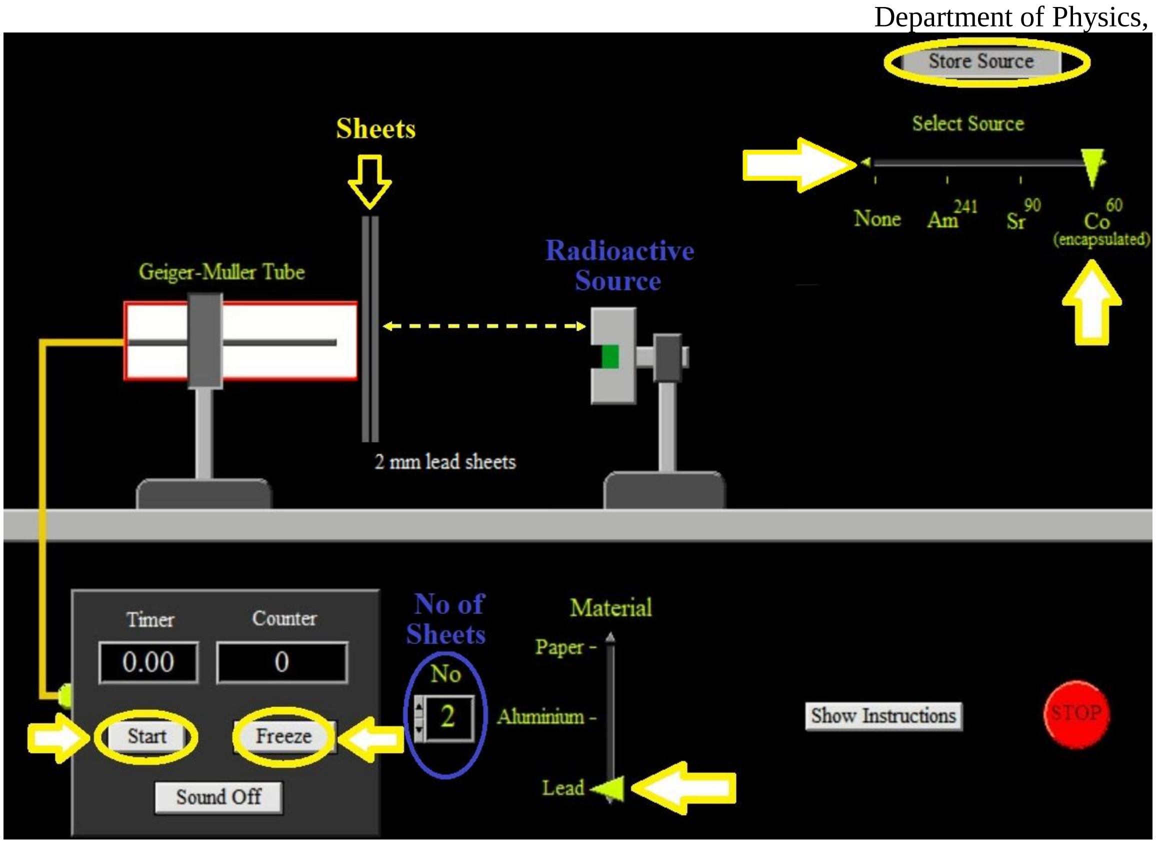

Fig. 3: Count rate measurement setup for Pb and Al.

7. There are 20 sheets of each material and Click in the upper or lower arrow button of "**No**" infront of the Materials Scale to change number of sheets (shown in Fig. 3).

8. Keep the ^{60}Co radiation source at a fixed place and record the radiation count for about 100 sec without placing any materials sheet in between the source and GM counter. Now, select 4, 8, 12, 16, …….40 mm thickness of material by increasing number of sheets respectively and record the readings in Table 2 for about 100 second for each thickness. Repeat the reading twice for each thickness.

9. Repeat the steps from (7) to (8) for Aluminum (Al) and record the data in the Table 3.

10. Plot a graph with the logarithmic value of count rate $ln\, I$ along the Y-axis and thickness of the sheets of (Pb and Al), x along X-axis. The graph will be a straight line as shown in Fig.4.

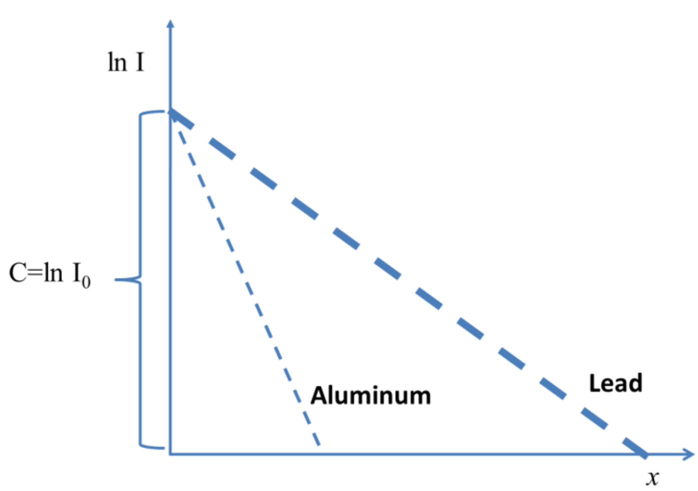

Fig.4: *ln I* versus *x* graph

11. From the graph, determine the intercept $C = lnI_0$ and the slope. According to equation (3), the slope of the graph would be the linear absorption coefficient μ of the given material for the radiation of given energy.

Data Collections:

Table-1: Data for background count rate

Obs. No	Counts	Time in sec	Count per minute	Count per minute (I_b)
1				
2				
3				

Table 2: Data for count rate as a function of thickness for Lead (Pb).

No of Sheets	Thickness (mm)	Count	Time (sec)	Count per min	Count rate with background (I_m)	Count rate without background $I=I_m - I_b$	*lnI*
0							

Table 3: Data for count rate as a function of thickness for Aluminum (Al).

No of Sheets	Thickness (mm)	Count	Time (sec)	Count per min	Count rate with background (I_m)	Count rate without background $I=I_m-I_b$	lnI
0							

Calculations:

(1) From the graph ln I versus x

Intercept, $C = lnI_0$, Thus $I_0 = e^C = \cdots$ … … … … … … …

Slope = Linear Absorption Coefficient

μ_{Pb}= ……….. cm^{-1} μ_{Al} = ……….. cm^{-1}

ρ_{Pb} = density of Pb = 11.34gm/cm^3

ρ_{Al} = density of Al = 2.70 gm/cm^3

Mass absorption coefficient

$$\mu_{m,Pb} = \frac{\mu_{Pb}}{\rho_{Pb}} = \cdots \dots \dots \dots \dots$$

$$\mu_{m,Al} = \frac{\mu_{Al}}{\rho_{Al}} = \cdots \dots \dots \dots \dots$$

Results:

The linear absorption coefficient of Pb, μ_{Pb} = ………… cm^{-1}

The mass absorption coefficient of Pb, $\mu_{m,\ Pb}$ = ………….. cm^2/gm.

The linear absorption coefficient of Al, μ_{Al} = ………….. cm^{-1}

The mass absorption coefficient of Al, $\mu_{m,Al}$ = ………….. cm^2/gm.

Discussion:

Based on your understanding from this experiment, answer the following questions:

1) What are the distinct processes by which radiations can interact with matter? Briefly mention them.
2) Compare the absorption coefficients of Pb and Al and write your opinion.
3) On what factors mass absorption coefficient depend?
4) If you change the source distance from GM counter, what changes in the count rate would you observe?
5) If you change the source of radiation, what changes in the count rate would you observe?
6) Find the half value layer of Pb and Al. Which material has higher half value layer?