Geiger-Mueller Tube Plateau and Linear Absorption Coefficient

EXPERIMENT 2.1: OPERATING PLATEAU FOR THE GEIGER TUBE

PURPOSE

The purpose of this experiment is to determine the voltage plateau for the Geiger tube and to establish a reasonable operating point for the tube. Figure 2.1 shows a counts-vs-voltage curve for a typical Geiger tube that has an operating point in the vicinity of 1000 V.

The region between R_1 and R_2, corresponding to operating voltages V_1 and V_2, is called the Geiger region. Voltages greater than V_2 in Fig. 2.1 cause a continuous discharge in the tube and will definitely shorten the life of the tube.

PROCEDURE

1. Set up the electronics as shown in Fig. 2.2.

2. Set the 484 Scaler at minimum threshold.

3. Place beta source ^{204}Tl from Source Kit 1 at a distance of approximately 2 cm from the window of the Geiger tube.

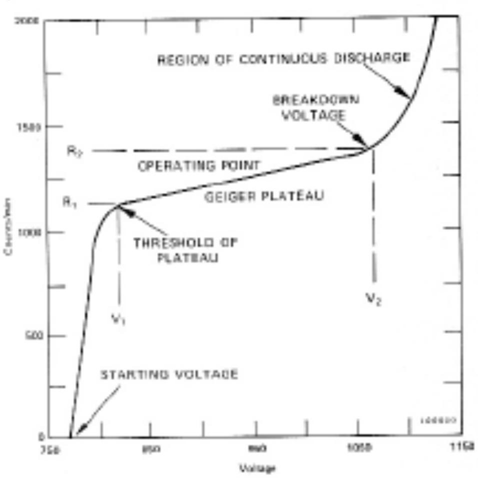

Fig. 2.1. Geiger Tube Plateau.

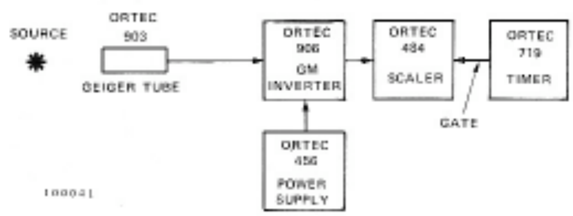

Fig. 2.2. Electronics for Geiger Counting.

4. Adjust the 719 Timer for a long period of time (~30 min).

5. Increase the (positive) high voltage until the 484 Scaler just begins registering counts. This point is called the starting voltage in Fig. 2.1. Starting voltages are rarely greater than 900 V and can be as low as 250 V.

6. Reset the 484 Scaler, set the 719 Timer for 1 min timing intervals, and count for 1 min. Increase the high voltage by 50 V and count again for 1 min.

Exercise a. Continue making measurements at 50-V intervals until you have enough data to plot a curve, on linear graph paper, similar to that in Fig. 2.1 (caution: use only values below V_2). The region between V_1 and V_2 is usually less than 300 V. A sharp rise in the counting rate will be observed if you go just above V_2. When this happens, the upper end of the plateau has been reached. Reduce the voltage to V_2 immediately. Choose the operating point for your instrument at about 50 to 70% of the plateau range.

Exercise b. Evaluate your Geiger tube by measuring the slope of the plateau in the graph; it should be less than 10%. The slope of the plateau is defined as

$$\text{slope} = \left[\frac{100\,(R_2 - R_1)}{R_1}\right]\left[\frac{100}{V_2 - V_1}\right]\%. \qquad (1)$$

EXPERIMENT 2.4: LINEAR ABSORPTION COEFFICIENT

PURPOSE

When gamma radiation passes through matter, it undergoes absorption primarily by Compton, photoelectric, and pair-production interactions. The intensity of the radiation is thus decreased as a function of distance in the absorbing medium. The mathematical expression for intensity I is given by the following expression:

$$I = I_0 e^{-\mu x}, \qquad (4)$$

where

- I_0 = original intensity of the beam,
- I = intensity transmission through an absorber to a distance, depth, or thickness x,
- μ = linear absorption coefficient for the absorbing medium.

If we rearrange Eq. (4) and take the logarithm of both sides, the expression becomes

$$\ln (I/I_0) = -\mu x . \qquad (5)$$

The Half-Value Layer (HVL) of the absorbing medium is defined as that thickness $x_{1/2}$ which will cut the initial intensity in half. That is, $I/I_0 = 0.5$. If we substitute this into Eq. (5),

$$\ln (0.5) = -\mu x_{1/2} . \qquad (6)$$

Putting in numerical values and rearranging, Eq. (6) becomes

$$x_{1/2} = 0.693/\mu \text{ or } \mu = \frac{0.693}{x_{1/2}} . \qquad (7)$$

Experimentally, the usual procedure is to measure $x_{1/2}$ and then calculate μ from Eq. (7).

PROCEDURE

1. Set the voltage of the Geiger tube at its operating value.
2. Place the ^{60}Co source (SK1) about 3 cm from the window of the GM tube, and make a 2-min count. Record the number of counts.
3. Place a 1/16-in. sheet of lead between the source and the GM window, and take another 2-min count and record the value.
4. Place a second sheet on top of the first and make another count.
5. Continue adding lead sheets until the number of counts is 25% of the number recorded with no absorber.
6. Make a 2-min background run and subtract this value from each of the above counts.

Exercise. Calculate the density-thickness of the lead in g/cm^2 and plot on semilog paper the corrected counts as a function of absorber density in g/cm^2. The density-thickness is defined as the product of density in g/cm^3 times the thickness in cm of the absorber. Draw the best straight line through the points and determine $x_{1/2}$ and μ. How do your values compare with those indicated in ref 4? See also Experiment 3 in this manual, in which this same experiment is done with a sodium iodide detector.

Compton Scattering

Gamma rays may hit the thin absorbers and scatter an electron out by Compton scattering.

$$\lambda_f - \lambda_i = \frac{h}{m_e c}(1 - \cos\theta)$$

The electron count will record in the GM tube. To suppress this background add a thin brass sheet near the GM tube to absorb these Compton electrons, before adding other absorbers.

Measure the attenuation of the brass with a beta source.