Experiment III

Operation and Characteristics of a Geiger-Müller Counter

In Chapters 4 & 5, we presented a detailed discussion of the nature and construction of Geiger-Müller (G-M) counters. We saw that they are ionization chambers operated at a voltage high enough to give the maximum usable gas amplification for an ionizing event within them. Because of the avalanche-type gas multiplication taking place in the detector volume, the output pulse of the G-M counter has a height which is independent of the radiation energy deposit in the detector. G-M counters are among the most widely used detectors for radioactivity measurements because of their simplicity of operation and low cost. This laboratory experiment is designed to serve as an introduction to some of the operating characteristics of a G-M counter.

A. Components of a Geiger-Müller Counter Assembly

Figure III-1 shows a block diagram of the components of a Geiger-Müller counter assembly. While the detailed principles of operation of all these components have been discussed in Chapters 4 and 5, we shall briefly review some of the salient features of these components as found in G-M counters.

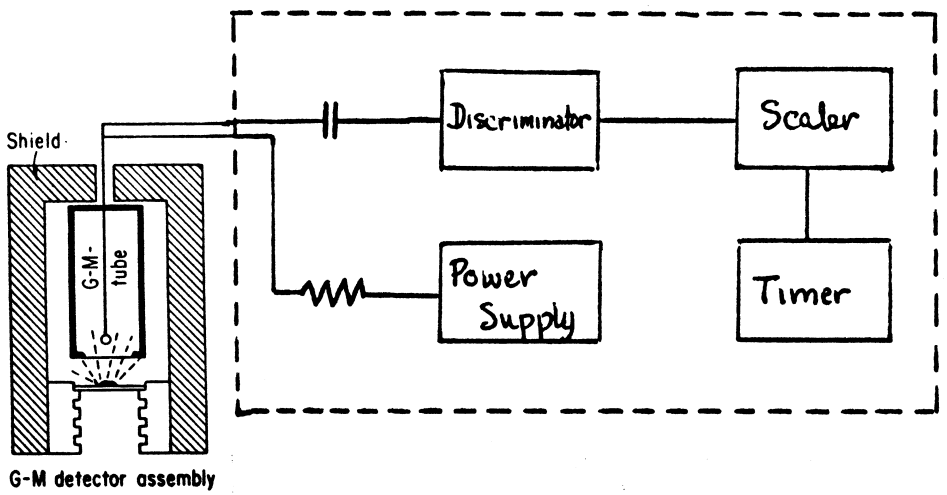

Figure III-1 Block diagram of a Geiger-Müller counter assembly. Components within dotted lines are frequently packaged in a single box.

1. Power Supply

This unit provides the d-c voltage for the G-M tube so that gas amplification and electron collection can occur. Voltages supplied range from 500-5000 volts with most G-M counters operating with a voltage of ~1500 volts. A G-M tube power supply doesn't need to be extremely stable since minor voltage fluctuations do not significantly change the observed count rate when the detector is operating at its proper voltage.

2. G-M Detector Assembly

The term detector is used to designate the G-M tube; counter refers to the entire counting assembly. The detector itself is usually surrounded by a lead shield to reduce the count rate due to background radiation. In order to maintain a defined sample-to-detector geometry, a rigid sample-holding device, with several shelves, is included in the assembly.

3. Discriminator

Because the pulses from the G-M detector are several volts high, little or no amplification or shaping of the pulses is necessary before pulse height selection. The discriminator serves as a pulse height selector and is used to: a) prevent noise pulses from triggering the scaler and b) to provide a standard shaped pulse to operate the scaler.

4. Scaler and Timer

The scaler and timer circuits count the number of pulses and the length of the counting time in a given measurement. Frequently measurements can be made for a preset length of time (set on the timer) where the number of counts occurring is recorded by the scaler or alternatively, the measurement is made for a preset number of counts (set on the scaler unit) and the duratio of the measurement is recorded by the timer unit. Once one has the number of counts occurring in a known time interval, one can quickly calculate the count rate.

5. G-M Counter

In many commercially available instruments, the power supply, discriminator, scaler and timer are grouped together in a single assembly which is, unfortunately, referred to as a "scaler" even though it contains several other components. The "scaler", used in conjunction with a G-M detector in a lead shield and sample support, constitutes a "G-M counter". In the most modern equipment, however, the individual componenets are not grouped in a single box but used as separate, readily accessible components operating with common power supply voltage for all components. Such an arrangement, called the NIM (Nuclear Instrument Module) approach, has several advantages. Firstly, it is easier to understand the function and operation of each component if it is easily accessible rather than being hidden in a "black box", not to mention the advantages for diagnosing component malfunction in the NIM approach. Secondly, because of an agreement amongst manufacturers to make their components compatible, one can use a scaler made by one manufacturer coupled to a discriminator made by another manufacturer, etc. Thus one is able to pick the best quality or lowest price, etc., for each component in the counting system without regard to manufacturer. This arrangement has the further advantage in case of component malfunction, of allowing one to quickly replace an entire malfunctioning component easily.

B. Operation of a Geiger Müller Counter

1. General Instructions

Although certain fundamental steps apply to the operation of all G-M counters, each counter has distinctive individual features. Consequently, before operating a given counter, read through the instruction manual provided by the manufacturer.

G-M tubes can be permanently damaged by the continued operation of the tube in the continuous discharge region (ie, at too high values of the applied voltage). Always be certain that the high voltage control is turned off, or as far down as possible, before turning on the counter.

The sample holder under the G-M tube usually has several shelf positions on which the radioactive samples may be placed for counting. These shelf positions, define the relative sample-detector geometry. Be careful to avoid contact between the counting sample and the detector window, because the window may be either broken or contaminated in this way.

2. G-M Plateau and Operating Potential

As described in Chapter 5, the Geiger-Müller counter shows a "plateau" in the count rate vs. applied voltage curve (see Figure 5-13). This plateau occurs when the voltage applied to the tube is sufficient to insure that all ionizing radiation events entering the tube will trigger an avalanche discharge of the tube. Let us now investigate this phenomenon experimentally.

Procedure

1. Turn on the counter power switch and wait 30 seconds. Turn on the high voltage switch. After another 30 second wait, insert a radioactive sample (^{14}C or RaDEF, for example) obtained from your instructor into a set of slots in the sample holder.
2. Turn the "count" switch of the counter to the "on" position and slowly increase the high voltage until the scaler begins to register counts. Record the voltage and measure the count rate at this voltage setting. Acquire ~3000-5000 counts, noting the counting time. Record the data in Table I-1.

Table I-1

Voltage Applied To Tube	Total Number Of Counts	Counting Time	Count Rate (cpm)

3. Repeat the measurement of the count rate after successive 50 volt increments in the applied voltage. The count rate will rise rapidly and then level off when the G-M plateau is reached. The plateau should extend for $\sim$300 volts and then the count rate will rise sharply. Do not attempt to measure this sharp rise since it represents continuous discharge in the G-M tube and may damage it.

4. Using the data in Table I-1, plot a graph of count rate vs. voltage applied to the tube. It should resemble Figure 5-13. The proper operating voltage for the tube is usually chosen to be one third of the plateau width above the voltage at which counts began to be detected. (the threshold voltage).

   Proper Operating Voltage for G-M Tube____________.

4. Using the data in Table III-1 and the formulas below compute the slope

of the voltage plateau in %. (see Figure III-2)

L ≡ Length of Plateau Region in Volts= ______________ v.

R_1 ≡ Count Rate at left edge of plateau= ______________ cpm.

R_2 ≡ Count Rate at right edge of plateau= ______________ cpm.

$$\text{slope}=\frac{R_2-R_1}{R_1}\cdot\frac{10{,}000}{L}\,\% = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\%/100\text{ v.}$$

A good G-M tube has a plateau slope of less than 10%/100 v.

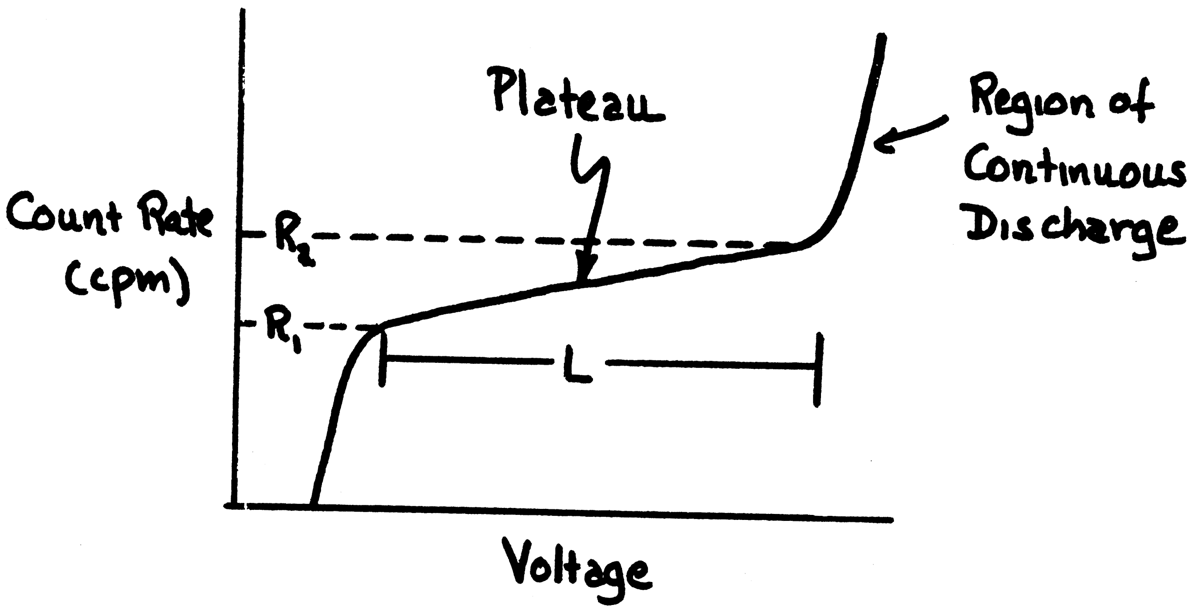

Figure III-2 Schematic diagram of G-M counter plateau curve.

3. <u>Counter Resolving Time-Coincidence Loss</u>

In Chapter 5, it was indicated that because of the finite time required to sweep away the electrons and positive ions following an avalanche discharge in a G-M tube, the counter would be unable to record any event occurring within some time interval, τ, of the primary ionizing event. This time interval, τ, is called the <u>resolving time</u> of the detector. Because of this factor, the observed count rate may be less than the true rate especially at high count rates. The difference between the true and observed count rates is termed the <u>coincidence loss</u>.

The resolving time of a G-M counter can be determined by the paired source method as discussed in Chapter 13. The procedure for such operations is outlined below.

Procedure:

1. Cut a flat metal planchet into two equal halves. Number them at the outer edge #1 and #2, respectively (see Figure III-3). Toward the center of each, place roughly equal amounts of a suitable radioactive material. Aqueous solutions of $NaH_2{}^{32}PO_4$ or $^{60}CoCl_2$ or powdered U_3O_8 are suggested. Each planchet half should give a count rate of 7000-10,000 cpm on the top shelf of the sample support.

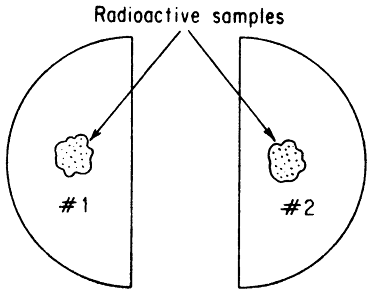

Figure III-3 Paired sources for resolving time determination.

2. Insert the two sources into the appropriate shelf of the sample support without any overlapping of the two halves. Now count the samples ($m_{1,2}$) for 1 minute and record the result in Table III-2. Carefully remove sample #2 without disturbing #1. Count sample #1 (m_1) for 1 minute and record count rate in Table III-2. Replace sample #2 in its original position and remove sample #1. Again determine the count rate (m_2) for 1 minute. Finally remove both samples from the vicinity of the counter and count the background (m_b) for at least 10 minutes. Repeat each **measurement three times.**
3. Average each of the three measurements of the count rates and record in Table III-2. Subtract background from each average rate to get a net average count rate. Calculate the counter resolving time, τ, by the approximate relationship (see Chapter 13 for derivation).

$$\tau = \frac{m_1 + m_2 - m_{1,2} - m_b}{m_{1,2}^2 - m_1^2 - m_2^2} \qquad \text{(III-1)}$$

Table III-2

Sample	Counting Time	Total Counts	cpm	Gross Average cpm	Background	Net c

Since the count rates were expressed in cpm, τ will be in minutes and will be quite small.

Convert τ to μ seconds (1 minute = 6×10^7 μsec.) and report below.

Counter Resolving Time was ____________ μsec.

(Usual values of τ range from 100-300 μsec).

4. The true count rate of a sample may be determined, when the resolving time is known, by the equation

$$n = \frac{m}{1 - m\tau} \qquad \text{(III-2)}$$

where n is the true count rate, m is the observed count rate and τ is the resolving time. (If n and m are in cpm, τ should be expresse in minutes.) Using your measured value of τ, construct a curve which shows % coincidence loss vs. count rate using equation III-2.

Note that coincidence loss with G-M detectors begins to be significant over 3000 cpm and becomes considerable at count rates approaching 10,000 cpm. Hence sample counting rates should be kept below 3000 cpm to avoid the necessity for coincidence loss corrections. This is usually done by moving the sample further away from the detector.

5. Shelf Ratios and Geometry

A radioactive sample can be centered under the G-M tube window by correct positioning on the sample support. Its distance from the detector will depend upon which shelf of the sample support is used. To compare counts made on different shelves, it is valuable to find the ratio of count rates of a single source for the various shelves (the shelf ratios). Comparisons can be made only between samples of the same isotope and under the same sample conditions.

Procedure

1. Using the sample used to measure the plateau curve, determine the count rate of the source on each of the shelves of the sample holder. Record the data in Table III-3.

Shelf Number	Number of Counts	Counting Time	Rate (cpm)	Bkg.	Net Rate

2. Assign a shelf ratio of 1.0 to the top shelf and compute shelf ratios for each of the shelves by dividing the top shelf net count rate into the count rate for every other shelf. Record result below in Table III-4.

Table III-4

Shelf Number	Shelf Ratio

Note that the shelf ratio then clearly indicates the fraction of counts observed on the given shelf compared to what would be observed on the top shelf. Note further that these values apply only to the isotope and detector employed. A detector with a thicker window would transmit less radiation. Likewise, a nuclide emitting lower energy radiation will suffer greater air absorption.

SUMMARY

In this experiment, several important operational characteristics of the G-M counter have been examined. To operate the counter correctly, the position of the G-M plateau must be found. The relatively long resolving time of the G-M counter necessitates keeping count rates fairly low and/or making corrections for coincidence loss. If shelf ratios are calculated, count rates for samples of the same type counted on different shelf positions may be compared.