Physics 1000 Half Life Lab

Determination of Half-Life with a Geiger-Müller Counter

Object: To understand the concept of half-life; to become familiar with the use of a Geiger-Müller counter; to observe natural background radiation; to determine the half-lives of a radioactive isotopes.

Apparatus: Geiger-Müller detector, with kilovolt range power supply; timekeeping device (stopwatch); graph paper; Ba^{137} isotope.

Foreword

A. How the Geiger-Müller tube works:

Three types of radiation (alpha, beta, and gamma) are capable of ionizing gases. The energy of the particles and the amount of radiation absorbed by the gas will determine the degree to which the gas is ionized. This ionization of gas molecules by radiation is the principle behind the Geiger-Müller tube.

A voltage pulse is produced during the brief change in potential that occurs when a discharge takes place. This voltage pulse can be detected and counted by a scaler or count-rate meter.

Scalers display the total counts detected on a lighted panel. By using a separate timer and recording the total counts at various time intervals it is possible to determine the counts per minute (cpm) or counts per any other time interval such as counts per hour (cph), counts per second (cps), etc. The choice of cpm, cps, or cph depends on the activity of the sample being measured. The higher the counting rate, the lower the time interval should be. Some scalers have internal timers that stop the counting after a preset time interval.

A rate meter directly displays the average counting rate by means of a needle on an analog meter. Due to the electronic averaging of the number of counts received during a short period of time, the needle will fluctuate back and forth quite a bit. It is because of this fluctuation that a scaler-timer is preferred over a rate meter.

If a Geiger-Müller tube is placed in the vicinity of a radiation source and there is not an applied potential difference, no counts will be observed on the counter. As the tube voltage is slowly increased, the tube will start detecting particles and the counter will display these counts. The lowest applied potential difference that produces a count in the scaler is referred to as the "starting voltage" or "threshold voltage."

As the potential difference is increased beyond the threshold voltage, the number of counts per minute rapidly increases. In this region (approximately 50 V wide) the count rate is almost linearly proportional to the voltage. This is due to the fact that, as the voltage increases, more of the less energetic particles are able to be counted. Therefore, in this region the tube discriminates between radiation of different energy levels. At any given voltage, only particles above a certain energy level are detected. The tube is therefore acting as a proportional counter, with the voltage being proportional to the energies of the incident particles.

As the voltage is increased even further, the number of counts per minute eventually becomes nearly independent of the applied voltage. This region, (approximately 200 V wide) is referred to as the "plateau region" or simply as the "plateau." In the plateau region, a change in voltage has little effect on the number of counts detected. It is because of this nearly constant number of counts detected that the Geiger-Müller tube is normally operated in this region. An operating voltage is selected around the center of the plateau. Now, fluctuations in the potential difference delivered from the power supply will have little effect on the counting rate.

The potential difference should never be raised too far beyond the end of the plateau region. At such a high voltage, the tube may be damaged from the resulting continuous discharge that occurs.

B. <u>How to determine the Half Life of $Ba^{137}m$</u>

The source of the $Ba^{137}m$ is a mini generator. The $Ba^{137}m$ is formed by the disintegration of Cs^{137}. The m in $Ba^{137}m$ means that the nucleus of the newly formed barium atom is in an excited state. The excited nucleus emits energy (via a gamma ray) and becomes stable.

(2) $Cs^{137} \rightarrow Ba^{137}m + {}_{-1}e^{0}$

(3) $Ba^{137}m \rightarrow Ba^{137} + {}_{0}\gamma^{0}$

Our Geiger-Müller detector can detect these gamma rays and the count rate, CR, is proportionally to the number of radioactive nuclei present at that time.

According to theory, the number of radioactive nuclei present at any given time is given by

(4) $N = N_0 e^{-\lambda t}$

where,

λ = the decay constant
N_0 = the number of radioactive nuclei at t = 0
N = the number of radioactive nuclei at any time t
t = time

Since the count rate is proportional to N, this expression may be rewritten as

(5) $CR = CR_0 e^{-\lambda t}$

where,: CR_0 = the counting rate at t = 0
CR = the counting rate at any time t

(6) $T_{1/2} = \frac{\ln 2}{\lambda}$ Thus allowing us to determine the half life.

(7) Or the half-life can be estimated by determining the time necessary for a count rate to be halved from a plot of count rate versus time.

Procedure

Part I. Determining the Background Radiation Count.

1. Check to make sure all connections are made. The GM tube should be securely connected to the counter device, and the counter device should be connected to a power outlet. Find the red power button on the back of the counter device and turn it on.

2. Move the clear plastic shelf to the fourth level below the detector. Place the empty metal sample pan on the plastic shelf.

3. Select the "HIGH VOLTAGE" mode by pressing the **DISPLAY SELECT** button.

4. Set the operating potential specified for your Geiger-Müller tube by pressing the **UP** button.

    a. The operating potential will be provided for you.

5. Select the "Time" mode by pressing the **DISPLAY SELECT** button.

6. Set the time to count to sixty (60) seconds by pressing the **UP** button.

7. Select the "COUNTS" mode, and press the **RESET** button.

8. With the empty metal sample pan on the plastic shelf, press the **COUNT** button to take a 60 second background count; The LED light above the **COUNT** button will be lit during the 60 second count. The counter will automatically stop after 60 seconds.

9. Record the number of "background" counts on the Data Sheet. Divide this number by 10, and round the number to the nearest whole number, and record this value in the data table.

Part II. Determining the half-life of a radioisotope.

1. Select the "Time" mode by pressing the **DISPLAY SELECT** button.

2. Set the time to count to six (6) seconds.

3. Select the "COUNTS" mode, and press the **RESET** button.

4. Your lab instructor will give you a sample of Ba^{137}. As soon as the instructor puts the sample in the tray, begin taking 6 second readings every 30 seconds for ten minutes.

    a. This sounds more complicated than it is. The counter will be on for six seconds, it will then be off for twenty-four seconds while you record your data and reset the counter by pressing the **RESET** button. If you begin your first reading when the stop watch is started, the reading will stop when the stopwatch is at 6 seconds. Record the values, reset the "COUNTS", and begin the next reading when the stopwatch is at 30 seconds and so on.
    b. Your first count should be greater than 200 counts. If the count is not near 200 or greater, you waited too long to start taking counts, or the Ba^{137} generator needs more time for Ba^{137} to accumulate before samples are distributed by the TA.
    c. You may have to move the plastic shelf closer to the detector.

5. Record the six second counts on your data sheet. When the background count is subtracted, the value will represent your corrected counts.

6. Plot the Corrected Counts versus Time using graph paper.

    a. Make the plot as large as possible.
    b. Draw a continuous curve that best "fits" your data. Do not draw line segments to connect the dots. Not all of your points need to be on the curve. Typically when a curve is considered to be a "best fit", approximately half of the points that do not lie on the curve will be slightly above the curve, and approximately half of the points not on the curve should be a little below the curve.
7. Now determine the following:
    a. How much time does it take for the count to decrease by ½ from the 2nd highest count that you recorded?
    b. How much time does it take for the count to decrease by ½ from the 3rd highest count that you recorded?
    c. Starting with the count when the time equals 100 seconds, determine how much time it takes for the count to decrease by ½.

DATA AND CALCULATION SUMMARY

Part I. Determining the Background Radiation Count.

60 Second Background Count	60 Second Background Count Divided by 10 and Rounded to the Nearest Whole Integer

Part II. Determining the half-life of a radioisotope.

Measurement Time	***Counts for 6 sec***	***60 sec background count divided by 10***	***Corrected Counts***	***Plot at (sec)***
0:00 - 0:06				3
0:30 - 0:36				33
1:00 - 1:06				63
1:30 - 1:36				93
2:00 - 2:06				123
2:30 - 2:36				153
3:00 - 3:06				183
3:30 - 3:36				213
4:00 - 4:06				243
4:30 - 4:36				273
5:00 - 5:06				303
5:30 - 5:36				333
6:00 - 6:06				363
6:30 - 6:36				393
7:00 - 7:06				423
7:30 - 7:36				453
8:00 - 8:06				483
8:30 - 8:36				513
9:00 - 9:06				543
9:30 - 9:36				573
10:00 - 10:06				603

Value of 2^{nd} Highest Count	
Time to reach ½ the value of the 2^{nd} Highest Count	

Value of 3^{rd} Highest Count	
Time to reach ½ the value of the 3rd Highest Count	

Count Value when t = 100 seconds	
Time to reach ½ the count value when t = 100 s	

Determine your experimental half-life of Ba^{137} from your data and explain your reasoning.

Experimental Half-life of Ba^{137}: ______________________________ (A)

Explanation:

____

____

____

____

____

____

____

____

Accepted value of $T_{1/2}$ for Ba^{137} ______________________________ (B)

%Error = $\frac{|A-B|}{B}\ x\ 100\%$ = __________________________________