Lab NUC

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 determine the half-lives of radioactive isotopes; to observe natural background radiation; to determine decay products from a nuclide chart.

Apparatus: Geiger-Müller detector, with kilovolt range power supply; timekeeping device (stopwatch); GRAPHICAL ANALYSIS software; radioactive isotopes such as $^{90}Sr, ^{204}Tl$ or ^{241}Am for calibrating operating potential; unknown half-life radioactive 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 increase. 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.   *How to determine the Half Life of Ba^{137}m*

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) $Cs^{137} \rightarrow Ba^{137}m + _{-1}e^{0}$
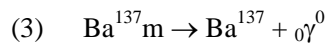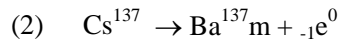
(3) $Ba^{137}m \rightarrow Ba^{137} + _{0}\gamma^{0}$
Our Geiger-Müller detector can detect these gamma rays and the count rate, CR, is proportionally to the number of radioactive nuclei present at that time.

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) $T_{1/2} = \dfrac{\ln 2}{\lambda}$

Thus allowing us to determine the half life.

Procedure

Part I. Determining the Operating Potential of the Geiger-Müller detector.

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 switch on the back of the machine and turn the switch on.

2. Position the clear plastic shelf 5 to 6 levels below the detector.

3. Obtain a Cs-137 (beta/gamma emitting) source from your lab instructor. A picture ID will be necessary to obtain a sample. Your lab Instructor will keep your picture ID until the source is returned. Place the CS-137 sample on the plastic shelf with the label down.

4. Select the "COUNTS" mode by pressing the **DISPLAY SELECT** button until the LED next to "COUNTS" is lit.

5. Press the **RESET** button.

6. Press the **COUNT** button. Note that there is no activity.

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

8. While observing the "ACTIVITY/VOLUME" LED bars, slowly increase the high voltage by pressing the **UP** button. The "ACTIVITY/VOLUME" LED bars are located at the very left edge of the display. The "ACTIVITY/VOLUME" LED bars will probably not light until the high voltage is near 700 volts.

9. Once the first "ACTIVITY/VOLUME" LED is lit, press the **STOP** button.

10. Decrease the high voltage by 60 volts by pressing the **DOWN** button.

11. Select the "TIME" mode.

12. Set the time to 10 seconds by pressing the **UP** button.

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

14. Press the **COUNT** button; the counter will count for 10 seconds and then automatically stop.

15. Record the number of counts on the Data Sheet.

16. Record the high voltage on the Data Sheet.

17. Increase the high voltage by 20 volts.

18. Repeat steps 13 through 17 until a count is obtain with a high voltage of 1220 Volts.

19. Using a scatter Plot in Excel, plot Number of Counts vs Voltage.

20. Determine the optimum G-M tube operating voltage.

21. Set the "HIGH VOLTAGE" to the optimum operating voltage.

C:\Users\Dave Patrick\Documents\Labs\Lab NUC\NUC Rev3.doc

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

1. Set the operating potential of the Geiger-Müller detector at the appropriate voltage.

2. Set the counter to count for 1 minute (60 seconds).

3. Move the clear plastic shelf 4 levels below the detector.

4. With no sample in the sample holder, press the **COUNT** button to take a one-minute background reading. Divide this number by 10, and round the number to the nearest whole number. Record the values in the data table.

5. Set the counter to count for only 6 seconds.

5. Your lab instructor will give you a sample of Ba^{137}.

6. As soon as the instructor puts the sample in the tray, begin taking 6 second readings every 30 seconds for ten minutes.
   • 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 value, reset the "COUNTS", and begin the next reading when the stopwatch is at 30 seconds and so on.
   • 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 to be flushed out better before samples are distributed by the TA.
   • You may have to move the plastic shelf closer to the detector.

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

8. Plot the Corrected Counts versus Time using a scatter plot in Excel, and generate a curve by choosing an appropriate fit. Also, display the equation of the fit on the graph.

9. Using the fit equation, determine the decay constant (λ).

10. From the decay constant, determine the half-life for the radioisotope Ba^{137}.

Questions and Problems

1. A Co-60 source has a measured activity of 18,000 cpm. After how long would the observed activity be 1125 cpm? (The half-life of Co-60 is 5.27 years.)

2. If a 10 microcurie (10 µCi) Cs-137 source is obtained for use in laboratory experiments, what will be the strength of the source in µCi after 5 years? Also, give the activity of the source after 5 years in disintegrations per second (dps) and becquerels (Bq). (Cs-137 has a half-life of 30 years.)

3. What is the decay constant of Co-60?

4. What is the decay constant of Cs-137?

DATA AND CALCULATION SUMMARY

Part I: Determining the Operating Voltage

Voltage	Counts

Voltage	Counts

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

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

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

Experimental value of λ...λ = _____

Experimental value of $T_{1/2}$...Exp $T_{1/2}$ = _____

Accepted value of $T_{1/2}$ .... Accept $T_{1/2}$ = _____

%Error ....%Error = _____