Geiger Counter and Gas-Flow Proportional Counting Lab

I. Geiger Counter

The Geiger-Mueller Counter is one of the oldest radiation detector types around. It was introduced by Geiger and Mueller in 1928. It is very simple in its construction and operation. It is a widely used pulse-counting instrument that uses gas amplification. In order to be better prepared for this lab, you should re-read **Knoll pp. 207-210** (3rd edition). This will give you a better understanding of some of the experiments that will be done. Search the literature for additional information that you need to familiarize yourself with this lab before you begin. It's best to have the oscilloscope handy so that you can be sure your instruments are working properly.

Purpose:

- To help familiarize students with the operations and set up of the Geiger-Mueller tube;
- To determine the GM operating plateau;
- To calculate the detector dead time; and
- To analyze counting data.

Procedures:

The amplifiers are sensitive to rapid changes of the high voltage (detector bias) and can be damaged by such. When the amplifier is connected during HV changes, please make those changes SLOWLY (we know from experience that the cost is ~$300 to repair an amplifier from this type of damage).

Setup

1. Connect the GM detector to the NIM electronics and set all amplifier and SCA settings as described in Lab 1.
2. Making sure the HV toggle switch is in the OFF position, flip on the NIM power switch.
3. Turn the HV power supply dial fully CCW (zero volts) and flip on the HV toggle switch.
4. **SLOWLY** (~100 V/sec) increase the applied bias (HV to detector) to 900 Volts.
5. Using the oscilloscope, set up the course and fine gain to result in a 1 to 2 Volt signal pulse from the amplifier.
6. **SLOWLY** reduce the detector bias back to zero and turn OFF the HV toggle switch.

Determining the Operating Plateau for the Geiger Counter

1. Place a photon source under the open window of the GM counter (2nd shelf).
2. Begin collecting counts on the counter/timer.
3. The HV power should start at zero (0), with a **SLOW** (~50 V/sec) increase until the counter starts to record counts. This point is the starting voltage. [Notice that there is a lag between the dial setting and the actual voltage on the detector, as seen on the kV

display]. Record the starting voltage (which should be somewhere around 600 or 700 Volts).

4. From the point where the HV setting starts giving you counts, reduce the HV back to the nearest 50 Volts to begin data collection.
5. Choose a counting time and set the counter accordingly. Collect counts, increase the voltage between each count by ~20 Volts. After each adjustment, allow the HV to stabilize before counting. (*Do not increase the voltage more than 500 volts beyond its starting voltage).
6. Create a table and graph your results showing count rate vs. applied voltage and explain your findings. Theoretically, how would you expect the plot to look? On your graph label the starting voltage and the plateau region.
7. Choose the operating voltage of the counter at approximately 50-70% of the plateau range.

660V	0
700V	0
720	368
740	407
780	952
820	1014
860	1059
900	1061
940	1100
980	1084
1000	1130
1040	1182
1100	1166
1140	1184
1180	1517
1220	3328

Questions:

1. Measure the slope (as a percentage) of the plateau region. Your slope should be < 10%.
2. If the voltage is raised sufficiently high (in the lab though don't go more than 500 V beyond your starting value), is the plateau expected to end? What is expected? Did your data behave as expected? If not, why not?

Determining the Dead Time of the Geiger Counter

1. Two sources will be used (two "split sources") to determine the system dead time.
2. Set the applied voltage to your chosen operating voltage. 940V
3. Set the counter for an appropriate counting time.
4. Count one of the split sources (#1). 25019
5. Count the two sources together (#1 & #2). 44673
6. Count the other split source (#2) alone. 20761

(Caution: be certain to keep the geometry of each source constant; this will impact your results)

Questions:

1. Define dead time.
2. Calculate the dead time for your system.
3. Why is geometry so important?

Determining the Count-Rate Dependence on Source/Detector Geometry

1. Using a ^{137}Cs disk source, collect counts for the source located at each shelf level and for a no-source configuration.
2. Plot measured count rate as a function of distance from the detector. On the same graph, plot the count rate that you might expect as you change detector-to-source distance.

Shelf	w/Source Counts	w/out
1	1854	24
2	1024	28
3	552	22
4	342	12
5	280	28

Questions:

1. Explain the relationship between distance and count rate, and support this explanation with your plot. How do your results compare to what you expected to occur?

Counting Statistics

1. Set the counter to an appropriate collection time. 12secs 15-20 cnts
2. Set the operating voltage to the value chosen above. 940V
3. Using a ^{137}Cs disk source, conduct enough counting trials (record the data) to produce a fairly smooth Poisson distribution of counts. Flipped Surce!
4. Again, using the ^{137}Cs source, collect a number of counts at various source tray positions to demonstrate count reduction with distance. 5 counts each position Farther away → Variance is smaller

Questions:

1. Using the data of #3 above, calculate the mean, standard deviation, and variance of your experimental data.
2. Describe what the values of mean, standard deviation, and variance tell you about the data that you've collected. Describe how you might use a Chi-Square test to judge the validity of your data.
3. Using the data from #4 above, does the variance in the data change with detector-to-source distance? Would you expect it to?

II. Gas-Flow Proportional Counting

The proportional counter is a gas-filled detector that was introduced in the late 1940's. It is similar to the Geiger-Mueller tubes because it is almost always operated in pulse mode and relies on gas multiplication. In order to better prepare for this lab, re-read **Knoll pp. 160-161, 184-186.** This will give you a better understanding of some of the experiments that will be done. Search the web as well for journals and other additional information to familiarize yourself with this lab before you begin.

Purpose:

- To familiarize students with the operation of a gas-flow proportional counter;
- To determine the operating plateau for the detector (both alpha and beta); and
- To calculate the system dead time.

Procedures:

Setup

1. Setup and connect the gas-flow proportional counter apparatus (similar to the GM, except that you'll use a preamp (Ortec model 142) instead of the homemade signal splitter).

2. When using a preamplifier, notice that the pulse to the amplifier is now positive; since the preamp inverts the pulse.
3. Always be sure that the HV power supply is set to zero volts (fully CCW) before turning on HV power.
4. Ensure that your bubbler has enough water to cover the gas outlet tubing (to indicate gas flow). Add water to the bubbler, if necessary.
5. Ensure that the gas line is connected to the detector chamber. Ensure that gas valves at other stations in the lab, that are not being used, are closed.
6. To open the gas bottle in the back of the room: (a) turn the blue knob so that it is in-line with the tubing; (b) turn the regulator valve (t-handle) most of the way out counter-clockwise; (c) open the bottle with ½ turn counter-clockwise of the large valve (the pressure in the bottle should indicate ~2000 psi); (d) turn the regulator t-handle clockwise until the indicator shows about 6-8 psi; (e) check the regulator on the lab bench to ensure a pressure of about 5 psi; (f) open the valve at your detector to ensure gas flow and recheck pressure indications on the gas bottle.
7. Purge the counting chamber for about 1 minute at a flow rate of about 5 bubbles/sec. - don't want oxygen in
8. Reduce the gas flow rate in your detector to about 1-2 bubbles/sec for data collection.

90% argon
10% CH_4
P10 gas

Determining the Operating Plateau for the Gas Flow Proportional Counter

Alpha Plateau

Po210 0.1 uc: Jan16 138d

1. Place an alpha source on the tray and slide it under the gas flow proportional counter's thin window (BE CAREFUL NOT TO TOUCH THE **VERY THIN** WINDOW). - Gain was Third
2. Starting with an applied voltage of 0 Volts, record the count rate vs. applied voltage to develop the alpha plateau of the counting curve. Occasionally throughout the lab, you should **CAREFULLY** slide the source tray out (thus removing the source from in front of the detector window) to be sure that your counts are due to radioactive decay and not some artifact of the instrumentation.
3. Continue to increase the bias in ~20 V increments while recording count rate, but do not exceed 1000 Volts.
4. Reduce the applied voltage to zero and remove the alpha source.

Beta Plateau

1. **CAREFULLY** place a beta source under the chamber's thin window.
2. Turn the high voltage up to about 800 Volts and wait a moment for the system to stabilize. 750V
3. Determine the count rate at your starting voltage and at voltage settings beyond (**DO NOT** exceed 1800 Volts) to produce the beta plateau of your counting curve.
4. Reduce the applied voltage to zero and remove the beta source.

Questions:

1. With the data you've recorded, graph a single alpha/beta counting curve.
2. What shape would you expect this curve to take?

3. Determine your operating voltage for alpha detection and the operating voltage for alpha/beta detection.
4. Determine the slope (as a percentage) of each plateau.

Beta - 1200V
1 - 37066
w/both - 84621
2 - 50565
Bkg - 27

Alpha - 500V 30sec. count
1 - 1231
w/both - 2432
2 - 1242
Bkgd - 0

Operating Characteristics

1. As you did for the GM detector, use the two-source method to determine the dead time of the gas-flow proportional counting system at both the alpha and beta operating voltages.
2. Collect an appropriate background count at each operating voltage.
3. Use the oscilloscope to examine pulse shapes form the detector and preamplifier as you did in Lab 1. Report your findings.
4. Shut the system down and make sure that the counting gas is turned off properly at the bottle in the back of the lab: (a) open the bubbler valve at your detector; (b) turn the gas bottle valve (large knob) clockwise to close the bottle; (c) allow the pressure to reduce; (d) turn the regulator t-handle counter-clockwise a few turns; (e) close the bubbler valve; (f) the bottle should indicate zero pressure; (g) close the bubbler valve at the detector.

Questions:

1. Calculate the dead time for this counter.
2. Why is there a need to purge the gas-flow counter prior to beginning the experiment? What kind of counting gas is used; why? Why does the flow rate matter? — P10 gas 90% argon
3. How do the pulse shapes of the proportional counter differ from those of the GM?
4. What is the counting gas that we use for this lab? What components does it contain? What is the purpose of each of those components? What happens if the counting gas flows too slowly? Too rapidly?

to remove Oxygen out of the detector gas filled

counting gas

P10 gas; 90% argon 10% methane CH_4

2.) → Flow is too fast rate → gonna cause vibration of wire = No good signal

3.) Look @ signa

- GM is sealed — leak will be problem - quenching gas can be destroyed
- Proportional - gas flow throughout measurement - Small leak will not be a problem

$CPS \propto \frac{1}{r^2}$ $\frac{A}{4\pi r^2}$

Deadtime
excel

$$\tau = \frac{X(1-\sqrt{1-Z})}{Y}$$

$X = m_1 m_2 - m_b m_{12}$

$Y = m_1 m_2 (m_{12} + m_b) - m_b m_{12} (m_1 + m_2)$

$$Z = \frac{Y(m_1 + m_2 - m_{12} - m_b)}{X^2}$$

GH

m_1 = [illegible]

m_2 [illegible]

m_{12} [illegible]

m_b = [illegible]4

X = [illegible]

Deadtime = [illegible] sec

$= 1.84 \times 10^{-4}$ cps

Gas Counting Systems
Laboratory Questions

Ionization Chambers

1. Name three of the four types of collisions that will normally take place between free electrons, ion, and neutral gas molecules and are important in understanding the behavior of gas filled detectors. Draw the collisions.

2. The ion chamber you will be working with has a capacitance of 300 pF. It is originally charged at 990 V and then it was exposed to a gamma-ray flux for 20 minutes. When the time was up, another voltage measurement was taken. The second voltage reading was 745 V. Calculate the average charge that would have been measured over the exposure period under these conditions.

3. An air-filled ion chamber is operated at a pressure of 5 atm and a temperature of 125 degrees C. If its active volume is 3,000 cm^3, find the saturated ion current corresponding to a gamma-ray exposure rate of 92 pC/kg s.

Proportional Counters

4. How are gas multiplication and the Townsend avalanche related?

5. Describe the process that gives rise to an "x-ray escape peak".

6. If W = 34 eV/ion pair, the Fano factor is 0.17 for Neon, and 1.17 MeV is deposited in the detector, find the relative standard deviation of the pulse amplitude distribution.

7. A windowless flow proportional counter is used to detect 5 MeV alpha particles that are completely stopped in the fill gas. The anode radius of the tube is 0.008 cm and the cathode radius of the tube is 7.00 cm. The tube is filled with 90% Xe and 10% CH_4 at 1 atm. Using the data from Tables 6.1 and 6.2 and assuming C= 300 pF, estimate the amplitude of the voltage pulses from the counter for an applied voltage of 2800 V.

Geiger-Mueller

8. How does a Townsend avalanche extend to a Geiger discharge?

9. What is quench gas? What is the purpose of quench gas in a GM? Why is it different from the quench gas in a proportional counter?