Experiment 4: Measuring Radiation with a Detector

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ABSTRACT

Radiation is moving energy emitted from a particle or atom for a particular reason usually because of excess energy in the system before reaching equilibrium. Radiation is usually emitted because the decay of a nucleus's bond with itself causing the release of energy or matter typically both. While radiation can be found everywhere, in our experiment we analyzed several materials particularly we analyzed Beta, Gamma, and Neutron radiation. Initially we just measured the Beta and Gamma radiation that would be released by Strontium and Cobalt.In essence this experiment sought to bombard natural silver atoms with neutrons so that they would transform in the nucleus and then remove them from their chambers such that they can decay back into their original states pre neutron bombardment and we then measured the subsequent radiation that was released by the silver. This experiment showed the decay properties of many samples of radiating sources, we were able to calculate the decay constants and the error inevitably was high in this experiment, but we were able to keep things within the bounds of scientific certainty.

I. INTRODUCTION AND THEORY

The initial foundation for the quantification and discovery of radiation began with Einsteins famous mass to energy equation.

$$E = mc^2 \qquad [1]$$

Radiation is released electromagnetic waves or mass such as neutrons or neutrinos, following the destruction of a nucleus to a lighter form. Radioactive materials because of the decay are able to retain conservation of energy which originally though was being violated.

The exposure to radiation was a major concern during the laboratory as such we constructed a series of methods to reduce exposure as well as get a better understanding of the nature of radiation. Radiation itself is found everywhere. Radioactive isotopes are found in all parts of nature, but it can be also produced artificially, in nuclear reactors and particle accelerators.

There are four types of radiation known at the moment. The weakest source being Alpha radiation. These are helium nuclei emitted by a radioactive source. Alpha particles follow a monochromatic energy spectrum and completes the energy and momentum conservation that needs to follow a particle. The next source of radiation is Beta radiation, which is emitted electrons or positron. The actual end state of a beta radiation decay is that of three particles a reluctant nucleus, electron or positron, and a associated neutrino or anti-neutrino depending on the electron, this was proposed and resulted by Wolfgang Pauli. Neutrino particles are immensely small mass particles with spin 1/2. The most dangerous source of radiation is Gamma radiation, these are high energy monochromatic electromagnetic waves. Gamma rays are of spin 1, but carry energy and momentum despite no mass. The last source of radiation that is emitted by decaying particles is Neutron radiation. Neutrons contain very little net charge, this allow it to penetrate many materials directly as no electromagnetic interactions would slow it down. These neutrons can embed themselves into other material or cause other atomic interactions to occur it depends on the interaction that is being observed.

While understanding what radiation is, helps us discover more properties of the particles that we want to observe, in order to remain self ourselves while observing these situations. The biggest factor to reducing exposure to radiation is distance, as the decay of energy over a distance typically occurs. The next big source of radiation exposure is the time actually spent interacting with radiation as that increases the exposure overall. The last stage in providing effective protection against radiation is the shielding, for alpha particles clothes and small covering is effective, for Beta rays plastics and slightly dense material are the perfect deterrent, Gamma rays themeselves require dense high atomic material, though neutron radiation since it is neutral needs light and highly electrified materials such as water.

In our experiment we observed the decay of many isotopes particularly our research was focused on that of silver. In the experiment we irradiated several sources of

$${}^{107}_{47}\mathrm{Ag} + n \rightarrow {}^{108}_{47}\mathrm{Ag} \qquad [2]$$

$${}^{109}_{47}\mathrm{Ag} + n \rightarrow {}^{110}_{47}\mathrm{Ag} \qquad [3]$$

These equations show the neutron interaction with the silver, and the creation of the subsequent isotopes. Both isotopes decay and release Beta and Gamma radiation as a result of the half life of the Silver isotopes.

$$^{108}_{47}\mathrm{Ag} \rightarrow {}^{110}_{48}\mathrm{Cd} \cdot + e^- + v, 1.8MeV\beta^-(2.42min) \qquad [4]$$

$$^{110}_{47}\mathrm{Ag} \rightarrow {}^{110}_{48}\mathrm{Cd} \cdot + e^- + v, short(seconds) \qquad [4]$$

This equation shows the respective decays of the silver isotopes, what occurs is the generation of cadmium and the radiation of an electron and a neutrino as well as beta primarily beta radiation from equation 4.

From these observations of how the silver atom will react we can then construct a decay equation set from which we calculate our final results. Considering a decay constant λ and a unit N to represent the sample of nuclei we observed we have the equations

$$dN \propto Ndt \qquad [5]$$

$$dN = -\lambda Ndt \qquad [6]$$

What equation 5 is trying to convey is that the net amount of N can be found with the net particle dN per dt that elapses during the measurement. Then equation 6 shows the decay in the amount of particles that will be found over time due to the fact this is a decaying radiation experiment. The equation then translates thusly,

$$\frac{dN}{N} = -\lambda dt \qquad [7]$$

$$ln(N) = -\lambda t + C \qquad [8]$$

$$N = e^{-\lambda t + C} = e^C e^{-\lambda t} \qquad [9]$$

What the above equations are showing is that the net particles that will be found in the system during specific points. What occurs is the separation of variables and then integration of both sides. To remove the logarithmic factor we express the equation with Euler constants. That is when we get our final yield of a exponential decay with the rate of the decay constant multiplied by time as well as the initial factor that is present. We can then substitute N_0 for e^C and get the final resulting equation for the number of radioactive nuclei.

$$N = N_0 e^{-\lambda t} \qquad [10]$$

This equation will be one of the graphed quantities later shown for our lab. To get more quantities we then look at the decay rate which cna be derived as follows

$$R(t) = \frac{dN}{dt} = \lambda N = \lambda N_0 e^{-\lambda t} = R_0 e^{-\lambda t} \qquad [11]$$

This is the decay equation where $R_0 = \lambda N_0$, where the mean life time is the reciprocal of the time decay constant

$$t = \frac{1}{\lambda} \qquad [12]$$

$$t_{1/2} = \frac{ln(2)}{\lambda} = t(ln(2)) = 0.693t \qquad [13]$$

This is the mean lifetime of the half-life of the isotope, though considering the fact that the rate decreases as the amount of particles N decrease causing the decay equation we require a half way point equation which then takes over the mean half life. The last equation we use for the single radioactive system is the logarithm of the decay constant which just shows the slope of how the system will decay.

$$N = N_1 e^{-t_d/t_1} + N_2 e^{-t_d/t_2} \qquad [14]$$

What this equation shows is the main part of our experimental dissection. Particularly we are observing two isotopes decay at the same time, one of the isotopes decays at a larger rate than the other but both provide the populations of the atoms available

$$N = \lceil_1(1 - e^{-t_d/t_1})e^{-t_d/t_1} + \lceil_2(1 - e^{-t_d/t_2})e^{-t_d/t_2} \qquad [15]$$

$$N = \lceil_1 t_1(1 - e^{-t_d/t_1})e^{-t_d/t_1} + \lceil_2 t_2(1 - e^{-t_d/t_2})e^{-t_d/t_2} \qquad [16]$$

This shows $N_1 and N_2$ which are the initial populations for the individual isotopes that we observed after bombarding silver isotopes with neutrons and their subsequent decay rates.

We are able to calculate error in this system with the statistical processes first we start with the standard deviation of the Gaussian function

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-v)^2/2\sigma^2} \qquad [17]$$

What this equation shows is the standard deviation from the received population of isotopes recorded. Then after receiving the standard deviation we then calculate the overall change, this yields the error of our results, we then begin operations for the experiment

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-v)^2/2\sigma^2} \qquad [17]$$

II. EXPERIMENTAL ARRANGEMENT AND PROCEDURE

The main way we conducted this experiment was via the Geiger-Mueller counter (G-M counter). The G-M counter works by capturing incoming radiation and then using the separating potentials of the circuitry to feed the counter the specific values of radiation feed to it. In order to avoid an error called pile up, which is when the G-M counters max count is reached in a single instance so parts of the data would be incomprehensible as it would not display the full range that is occurring. To sufficiently conduct the experiment of finding the decay rates of neutron soaked silver atoms, we had to bring in firstly the G-M interface and a stand to angle it properly for best absorption, as well as a computer to receive the inputs which was done with the CAPSTONE program.

To test the accuracy of our G-M counter we first tested two measured sources of radiation, one of beta and the other of gamma, they were provided by Cobalt-60 and Strontium-90 respectively. To conduct the test on G-M counter, we measured first the Cobalt-60 and moved it about 9.5mm for each measurement and to add variety to the data we started applying filters to both sources of radiation. For the beta we used polyethylene absorbers ranging from .01-.6cm in thickness. For the gamma radiation we used lead filters to block the radiation and measured at different distances as well.

The main part of our experiment involved silver samples on polyethylene rods, a neutron source to irradiate the samples, and some stop watches. Before we began measuring for the decay rates of the silver we spent about 21 hours gathering cosmic rays in the environment we working in, factoring this into our results. We then began our experiment. We placed the G-M counter parallel to a cradle which we then placed polyethylene rods holding silver samples, placing the silver samples towards the G-M counter. We did this process about eight times of different irradiation levels and time measurements

Figure 1: This is an approximate look at how we measured our initial radiation samples, a greater factor is that it shows the Geiger-Muller counter.

III. DATA, ANALYSIS, AND RESULTS

Our initial observation was that of the background, we only got a max count at around .1 counts per 5 sec. We then began to look at the beta decay without any covering.

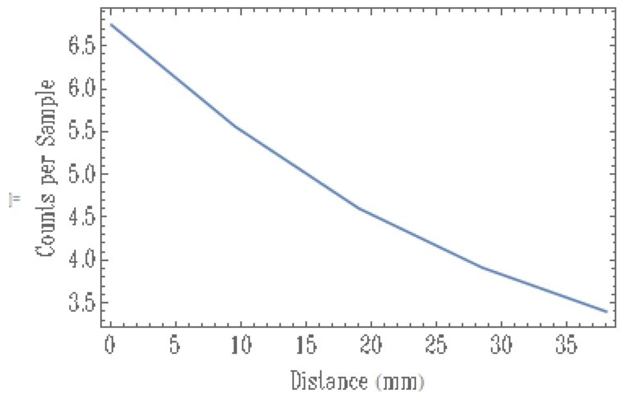

Figure 2: This is the results of our initial observation, it did not exceed the max count of the G-M counter and helped us get a gauge of how the data would turn out.

What we found was the decay was following what we would expect to a high certainty. The range of observation we got was from 0 to 12 centimeters. We then began to measure the gamma radiation

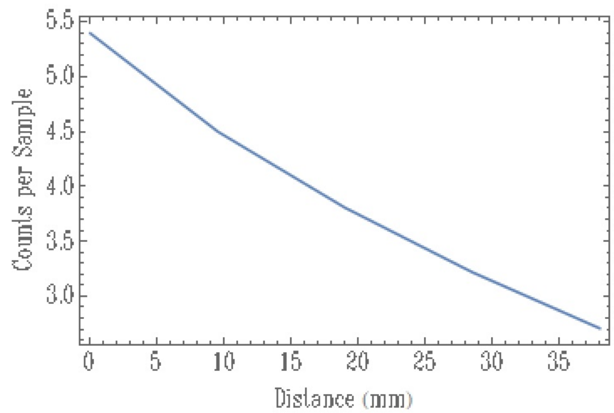

Figure 3: This shows the gamma radiation sample without covering, it follows what we should get for the gamma source that has aged and decayed at a distance properly .

We then began our main observations of the decaying rods. We calculated the back round data for cosmic rays that would infect our results we found for two minute intervals an average of 40 counts. We then looked at how the silver would decay. In order to isolate the particular isotopes we would irradiate at different rates and measure at different time intervals. So to isolate the Ag-110 sample we had low radiation rate and measured for long intervals. The results were as follows,

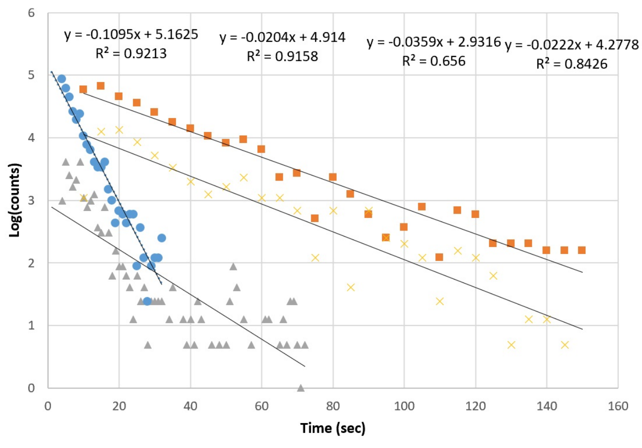

Figure 6: This shows the decay rate and the equation for best fit slope gives the decay rate and the y-intercept can be seen as the half life of the system, we are looking at the decay of Ag-110 specifically we looked at the 10,20,40,60 seconds irradiation, also their decay, half life, and error left to right respectively and recording for this sample .

What the above shows is that, the decaying Ag-110 occurs at a rate of .2 per second and the half-life was close to 2 to 5 seconds. Then to get more accurate results due to the fact we are dealing with two not one isotopes we have to implement equation 14 which displays the actual decay that is occurring. We took measurements of many times for a single 10 minute cycle we get the following.

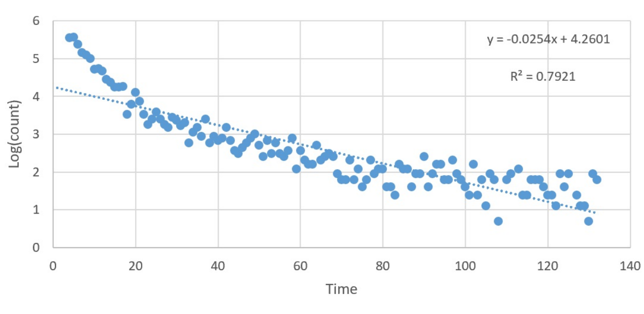

Figure 5: This shows the decay rate and the equation for best fit slope gives the decay rate and the y-intercept can be seen as the half life of the system, we are looking at the decay of Ag-108 specifically we looked at the 10 minute irradiation and recording for this sample .

The results for this were not highly accurate, so we tested at various time intervals to average our results, which is our final results for this laboratory. The results of which were not the most accurate with near 20% for most of the taken measurements.

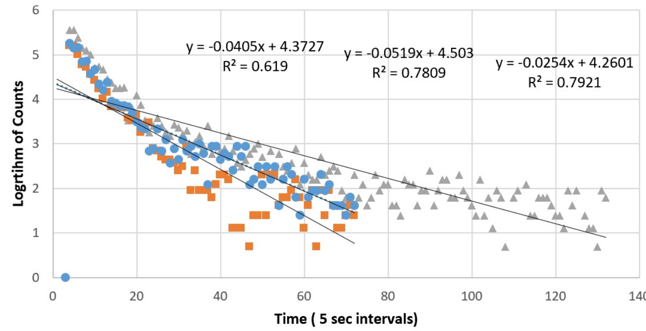

Figure 6: This shows the decay rate and the equation for best fit slope gives the decay rate and the y-intercept can be seen as the half life of the system, we are looking at the decay of Ag-108 specifically we looked at the 10,5, and 2 minute irradiation and recording for this sample .

The results of this measurement was the decay rate was ranging from .2 to .4 and the intercept for them ranged from 4.2 to 4.5.

IV. CONCLUSION

What this experiment sought to do was calculate the decay rate for silver that was irradiated by neutrons. We were miraculously able to get results that lay within reasonable measure. We got error as high as 34% error for our initial results but factoring in the statistical uncertainty we calculated such as the back round cosmic rays of 40 counts per 2 minutes, we were able to reduce our error significantly close to 5% for more certain measurements particularly those of shorter exposure for Ag-110 and longer exposure for Ag-108. Inevitably due to the crude environment we were working in as well as the unsophisticated or up to date equipment and sources of radiation, the error and accuracy of this experiment was difficult to maintain. In this laboratory the most important observations we made was how the decay fluctuates with time, its exposure to radiation and the time we spent measuring it. The erro was due to numerous factors, the low quality of the equipment, as it was old which causes the lowered decay rate of the radiation we used to test our Geigher-Muller counter, so much so that we could never achieve the max count for the counter which was one of the goals of this experiment. In the end we still were able to achieve results within the bounds of reason with background calculated giving us more accurate results.