Radioactivity and Silver Half-Life

Kyle Charbonnet

Lab Partner: Louise Tamondong
TA: Lodico, J.J.
Professor: Wang, G.
Physics 18L, Section 1A
University of California, Los Angeles

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Radioactive material was used to measure the counts of β and γ radiation. The material of main interest is silver with two isotopes, ^{110}Ag and ^{108}Ag. The silver emits radiation when struck by neutrons in a neutron monitor. The rate at which the isotopes emit radiation helps lead to a calculation for the half-life of each isotope. The ^{110}Ag isotope was measured to have a half-life of $24.0 \pm 0.8s$ with a percent error of 2.4% from the accepted value of 24.6s. The ^{108}Ag isotope was measured to have a half-life of $149 \pm 4s$ with a percent error of 2.6% from the accepted value of 145.2s.

I. Introduction/Theory

In 1905, Albert Einstein published his finding that mass can be converted into energy. This interchangeability explains the basis for most radiation. When a nucleus decays into a lighter nucleus, radiation is emitted. This radiation's kinetic energy is made from the mass that is lost in the decay. Some of the lost mass is converted into kinetic energy while the rest is emitted. The radiation can be harmful to humans, but in this experiment precautions were taken to ensure that no harm would occur to participants of the lab.

There are two important types of radiation used in this lab. One is beta radiation, where an electron is emitted along with a very light neutrino. For beta radiation, it is often a neutron that breaks down into an electron, neutrino, and kinetic energy. The other type of radiation is known as gamma radiation. Gamma radiation is made up of photons created from an excited atom.

Each type of radiation has a different range, where the range is a parameter used to describe how far the radiation can penetrate a certain density. The number of particles blocked out of a beam is described by the equation

$$N = N_0 e^{-x/l} \tag{1}$$

where l is the range, x is the thickness of the shielding object, N_0 is the initial number of particles, and N is the number of particles that make it through the barrier. Beta radiation penetrates around $1cm$ of plastic but not as much as gamma radiation [1].

Since radioactivity is inherently based on random events, the radioactive decay expression is

$$N = N_0 e^{-\lambda t} \tag{2}$$

where N is the number of radioactive nuclei at time t and N_0 is the initial number of radioactive nuclei. The rate of decays per second can then be expressed as

$$R(t) = -\frac{dN}{dt} = \lambda N \tag{3}$$

where R(t) is the rate of decay and λ is the decay constant. The decay constant can be used to solve for the mean life $\tau = 1/\lambda$. After one mean life, the number of radioactive nuclei has dropped to $1/e$ of its original value. The mean life is used to calculate the half-life

$$t_{1/2} = \tau ln2 \tag{4}$$

where $t_{1/2}$ is the half-life.

The material used in this lab is Ag which consists of two different isotopes. Therefore, the equation used for $\frac{dN}{dt}$ is

$$-\frac{dN}{dt_d} = \Gamma_1(1-e^{-t_c/\tau_1})e^{-t_d/\tau_1} + \Gamma_2(1-e^{-t_c/\tau_2})e^{-t_d/\tau_2} \tag{5}$$

These equations are capable of solving for the half life of both isotopes in the silver.

II. Experimental Arrangement and Procedure

In order to measure the counts of radiation per second, a Geiger-Muller counter was used and connected to Pasco Lab software to record data. The software was setup to record the number of counts for every 5 second interval. The Geiger-Muller counter was used with a small source of ^{90}Sr to provide beta radiation. The GM counter can be seen in Fig. (1). Prior to starting the lab, the T.A. made it clear that because the sources of radiation were old, pile-up on the GM counter would not become a problem.

The beta radiation source was placed at a height of $0.7 \pm 0.1cm$ from the GM counter. This was as close to the source the GM counter could be without directly touching the thickest filter above the source. The closer the source, the more counts per second and therefore the lower the error in our measurements. Polyethylene filters of various thickness were placed just above the source. Some of the polyethylene filters had glue in the middle and were at an angle downward which might be the cause for some of the error in the lab. The same procedure was done for the gamma source, ^{60}Co, but instead of polyethylene, the filters were lead. We placed the GM counter as close to the center of the source as we could. These two procedures gave the measurements required to calculate the range for beta decay and gamma decay.

The background radiation was measured overnight at our lab table in order to calibrate the GM measurements at the table. Since our table was farther from the neutron source than most other tables, our background radiation was slightly less than the others. In order to calculate the half life of two silver isotopes, the silver was irradiated in a neutron monitor for various times. The silver would be irradiated in a neutron monitor and quickly carried over to the lab table to begin recording data for 5 minutes. Just as in the beta and gamma source procedures, the radiation source was placed as close to the GM counter as possible without touching each other.

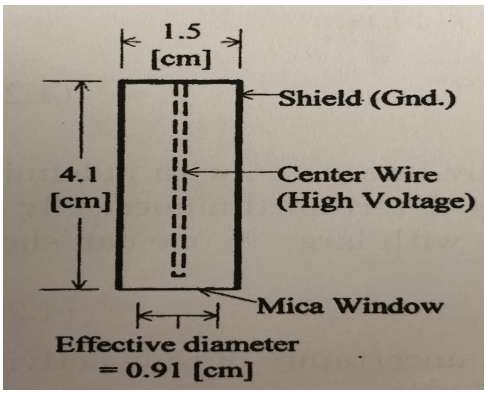

Figure 1: *The radiation source is placed closest to the Mica Window. [1]*

III. Data, Analysis, and Results

Since it was already known that pile-up would not be a problem using these radiation sources, the sources were always placed as close to the Micah Window as possible. The range for the beta source was found by using the polyethylene barriers of various thickness. A graph of the results can be seen in Fig. (2). The natural log of the average counts/sec for 45 seconds was plotted vs the thickness of the barrier. Therefore, using Equation (1), the slope of the best fit line represents $-1/l$ where l is the range. Using the data, the range was calculated to be $0.19 \pm 0.04in$.

The same procedure was done for the gamma radiation source, except instead of polyethylene, the barriers were made of lead. The results are plotted in Fig. (3). The gamma

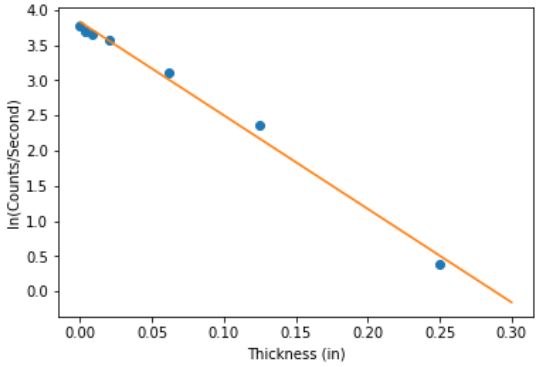

Figure 2: *The natural log of the average counts/sec value for each barrier. Each barrier had a different thickness.*

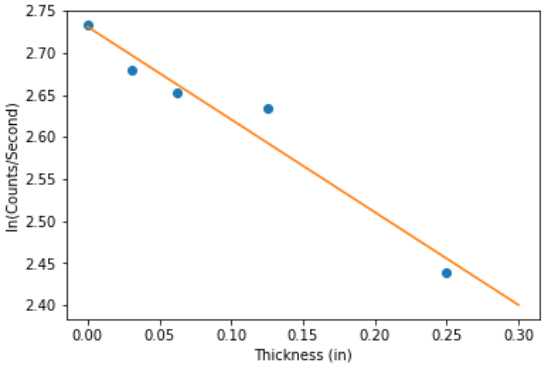

Figure 3: *The same setup as Fig. (2) but instead with a gamma source and lead barriers.*

radiation range is calculated to be $2.30 \pm 0.08in$. This is a reasonable solution because it is much greater than the beta radiation range.

The silver isotopes were irradiated in a neutron monitor for various times before being measured. The silver was irradiated for 10s, 20s, 40s, 60s, 2min, 5min, and 10min and then measured for 5min for each irradiation period. Another trial of irradiation for 10min was performed but this time the silver radiation was measured for 10min.

In Equation (5), τ_1 is assumed to be larger than τ_2. For large t_d the dominating factor is the term with $\tau 1$. Therefore a plot of the natural log of the data, $-dN/dt$, while ignoring the τ_2 term, can be used to find the values of τ_1 and Γ_1. The 10 minute charging time with 10 minutes of measuring provided the best data. In order to use large values of t_d so that the term with τ_2 would be minuscule, the first 20 data points out of 117 were ignored. The plot can be seen in Fig. (4). Using Equation (5), the slope of the line is revealed to be $-1/\tau_1$. Therefore the mean life of the isotope with a longer half-life is $214 \pm 6s$. Since $t_{1/2} = \tau ln(2)s$, the half life for ^{108}Ag is $149 \pm 4s$. The charge rate of the first isotope is found using the y-intercept and Equation (5). It is calculated to be $7.7 \pm 2 nuclei/sec$.

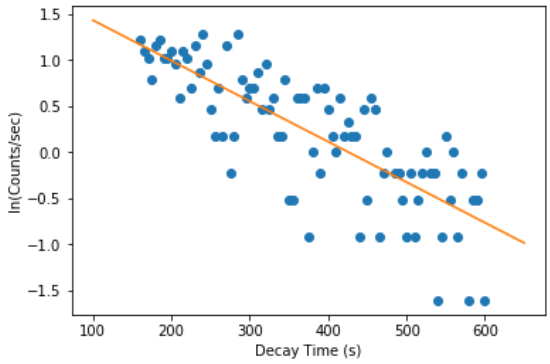

Figure 4: *The large t_d data with 10 minute charging time and 10 minute measuring time.*

For the τ_2 and Γ_2 values, the short t_d data was used. The 10 second charging time with 5 minutes of measuring provided the best data for the short t_d data. In order to use the data with small values for t_d, the last 20 data points were ignored out of 78. It can be viewed in Figure (5). Since τ_1 and Γ_1 are already known, $ln(-\frac{dN}{dt} - \Gamma_1 e^{-t_d/\tau_1})$ can be plotted vs the times. The slope is again $-1/\tau_2$ and the charging time is calculated using the y-intercept. The mean life for the second isotope is $34 \pm 1s$. Therefore, the half-life for ^{110}Ag is calculated to be $24.0 \pm 0.8s$. The charge rate is $56.0 \pm 0.4 nuclei/sec$.

IV. Conclusion

The measured half-life value for ^{108}Ag of $149 \pm 4s$ has a percent error of 2.6% from the accepted value of $145.2s$ [2]. This error is much smaller

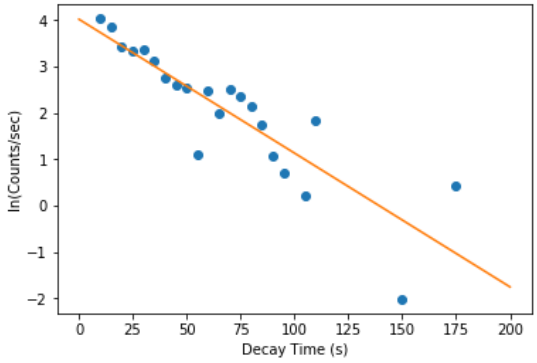

Figure 5: *The short t_d data with 10 second charging time and 5 minute measuring time.*

than expected. However, it can be due to the fact that the data used to get this value was handpicked from a large number of data sets during this lab. Incorporating all of the data would surely lead to a larger value in percent error. Similarly, the measured half-life value for ^{110}Ag of $24.0 \pm 0.8s$ has a small percent error of 2.4% from the accepted value of $24.6s$ [2]. The data for this measurement was also handpicked from a large number of data sets.

This lab went through a very basic way to find the half-life of different isotopes. For possibly more important radioactive material, such as U-238, it is much more complicated to measure due to the possible radiation that is harmful to humans. However, performing these measurements allow us to utilize radiation more effectively and in positive ways such as nuclear energy.

The experiment could have been improved by rolling the neutron monitor out of the room every time measurements were being made. Additionally, the polyethylene barriers could have been cleaned to remove glue that might interfere with the measurements. Also, rolling out the neutron monitor is not an option, the neutron monitor could have been placed just near our table so that the time it takes to move the silver to the table is minimized. The background radiation would be much more important in that case.

References

[1] G. Wang, Physics 18L Lab Manual (2018).

[2] Neutron Activation of Silver sciencedemonstrations.fas.harvard.edu/presentations/neutron-activation-silver