# Radioactive Half life

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Lab Section: ________________

Instructor: __________________

GRADE: ______________________

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PHYSICS DEPARTMENT  
JAMES MADISON UNIVERSITY

Revision Spring 2002
PHYSICS 135
LAB INSTRUCTIONS

RADIOACTIVE HALF LIFE

Purpose: To measure the radioactive half-life of Indium-116.

Background: In the process of radioactive decay, Indium-116 emits a beta particle to form Tin-116. The rate, $R$, at time $t$, from a sample of a radioactive isotope is given by the formula:

1. \[ R = R_0 e^{-\lambda t} , \]

where the decay constant, $\lambda$, is a characteristic of the particular isotope in the sample and $R_0$ the rate count at $t = 0$. Note -- in this case $\lambda$ is not a wavelength; it is measured in reciprocal time units.

The In-116 sample is prepared by bombarding a foil of In-115 with neutrons.

It can be shown that the constant, $\lambda$, is given by the formula:

2. \[ \lambda = \ln(R_0/R_t)/t , \]

and that when \((R_t/R_0) = 1/2\), then

3. \[ t_{1/2} = 0.693/\lambda . \]

The time interval, $t_{1/2}$, is termed the half life of the isotope found in a particular sample; for In-116, $t_{1/2} = 54$ minutes.

A plot of $R$ vs. $t$ on a linear graph will correspond to the curve shown in figure 1. A plot of natural logarithm $\ln(R)$ vs. $t$ should give a straight line curve, where $l$ is the slope and $R_0$, the vertical intercept. Figure 2 is an example of a $\ln(R)$ vs $t$ plot.

The process of radioactive decay is random. The functions discussed above only describe the average behavior. To deepen our understanding of the randomness of the process we will model radioactive decay by rolling dice. Our initial sample of nuclei will consist of 100 dice. Rolling the dice constitutes a step forward in time. On each roll (time step) a certain number of dice (radioactive nuclei) will decay. In addition to the radioactive decay, our apparatus will be sensitive to other processes. These other processes will be referred to as background. The background events are also from random processes. It may help to complete section IV before answering some of the questions.

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Half Life79
Figure 1: Rate dependence of radioactive decay

Figure 2: natural logarithm of the rate vs time
The Geiger-Muller Tube and Scaler. In this experiment a Geiger-Muller (G-M) tube is used to detect the radiation emitted by a radioactive source. The G-M tube consists of a hollow metal cylinder with a wire down the center as shown in figure 1. The wire is held in the center of the tube cylinder by insulating glass or plastic which also covers the entire tube except for the mica end-window. This center wire is connected to the positive side of a power supply and the outer metal cylinder to the negative side. The tube is filled with a mixture of neon, argon and other gases.

When a charged particle, such as $\alpha$ $\beta$-particle, or a quantum of $\gamma$-ray energy enters the tube through the mica window, the radiation ionizes the gas mixture, causing an electrical pulse between the positive wire and negative metal case. This pulse, as a momentary current through the power supply, is registered by the scaler or can be counted by a computer.

The scaler with a timer is an electronics counter designed to read in counts per unit time. The model used for this lab (The Nucleus, Model 500) has an LED display readout and will give a count up 99,999.

In this lab we will use the ULI interface and the computers to record the data. The program LoggerPro will count the number of events (radioactive decays) that occur for a preset time interval. The number of counts divided by the time interval gives the average rate $R$ at that time. The program continues to sample time intervals and a plot of $R$ versus time $t$ is generated. The plot should appear similar to figure 1 but for a shorter time range.

Equipment: The Nucleus (Model 500) Scaler/Timer connected to a Geiger-Miller Tube, Tube Holder, Ringstand Platform for Source, In-116 Foil Source, Source Holder, AMF Digital Timer, 100 dice, Computer and ULI interface (scaler is cabled to digital input 1).

Part I. Scaler Operation.

1. The G-M tube should be already adjusted for operation. The power should be on. The count button can be pressed. The scaler counts pulses for the interval determined by the setting of the toggle switch (time interval) and the dial setting (2 minutes). At the end of the interval the stop light/button is lit. To count pulses for a new interval push the reset button and then push the count button. Without a source of radiation the G-M tube should still register events. DO NOT MANIPULATE THE HIGH VOLTAGE KNOBS YOURSELF. AN EXCESSIVE VOLTAGE CAN DESTROY THE G-M TUBE.

2. The instructor will provide each group with an In-116 foil source taken from a neutron irradiation device. The foil will be carried on a planchette holder; YOU SHOULD NOT HANDLE THE FOIL
3. Determine that the scaler is adjusted to show sensitivity to the In-116 source. To do this, a) set the scaler/timer to 1.0 minute, b) push the COUNT button in, c) and while observing the scaler readout numbers, place the In-116 source, IN ITS HOLDER, on the platform about 3.0 cm from the G-M tube end window; d) if by doing so, the readout rate is made to increase by a significant amount, good evidence is provided that the system is indeed sensitive to the In-116 source.

4. Remove the In-116 source from the platform at least 2 feet from the G-M tube end window. Push the RESET button and set the scaler timer at 2.0 minutes; the readout should now read zero. Push the COUNT button and observe the count reading when the scaler automatically shuts off at 2.0 minutes. This should be regarded as the background count. *Record this value in the data table as "background."* Divide this value by two and *record the result with the data table as "background rate in counts per minute (cpm)."* Put the G-M scaler into free running mode by setting the time interval to manual. Press the count button. The scaler will count continuously. Now run the Logger Pro (load radiation_1m_5m_dur) counter program on the computer. See if you get it to record data. When it seems to be working. Measure the background using the event counter program for five minutes. What is the background rate as measured by the event counter. How do the individual points compare? Does the event counter measurement agree with scaler measurement?

**Part II. Count Rate Measurements Over Time.**

1. Place the In-116 source, IN ITS HOLDER, about 3.0 cm from the G-M tube end window; this distance should not be altered for the duration of the experiment.

2. Set the event counter to record one minute intervals. Adjust the length of the measurement to be about 1 hour (or load radiation_1m_1h_dur). Start the event counter program an examine the first few data points to insure that the system is operating correctly. Once you are sure that the program is running correctly you may move on to section IV and return when the measurement is finished.

3. When the event counter has recorded for about one hour save the data to disk.

4. Move the data to the Excel spread sheet.

5. Remove the radioactive source and measure the background for 5 minutes.

6. Calculate the background rate and compare it to the earlier measurements. Save this data to disk.

**Part III. Finding the Half-Life.**

In order to determine the half life we need to subtract the background rate from the measured rate. This gives the decay rate of the source.

1. Estimate the background rates by examining the rates before and after the measurement.

2. Copy data to an excel spreadsheet. Create a data column that contains the raw data minus your best estimate of the background rate. This column represents the actual decay rate of the source. Create a
new column, which is the natural logarithm of this rate. Plot this versus time.

3. Use DATAFIT to fit the data to the theoretical function and find the lifetime of your source. Be sure that you are consistent in your use of units.

4. Plot the fit on the graph with the data by generate a column of values based on the found parameters.

Part IV  Random Processes

1. Put 100 dice into a cup. Each die now represents a radioactive nucleus that has not decayed.

2. Choose a number between 1 and 6. This number represents a radioactive decay. Whenever a die has this value you will assume that it has decayed and you will remove it from your sample.

3. Roll the dice. Collect all the decayed nuclei into a pile. The number of decays in the first interval is equal to the number of dice in this pile. Enter this number in the table.

4. Roll the remaining dice. Remove and count the decayed nuclei. Enter this number in the table.

5. Continue rolling until all the dice are gone (all nuclei decayed). Be sure to enter a zero into the table for any roll where there was no decay. Should you decide to use the logarithm of the data in an analysis you will need to exclude these zeros. If you fit the data to an exponential the zeros will not cause problems.

6. Enter the numbers in the table into a spreadsheet. Remember each roll represents a time step. For simplicity let us assume that this time step is 1 minute. The number that decayed in each roll represents the number of decays per minute. You can then plot the rate R versus time for our model and compute the decay constant and the half life as described in section III.

7. To model the background process again roll 100 die and count the number of decays. Repeat this several times placing all 100 dice into the cup on each roll.

8. Use Excel to plot background rate versus time.

| Measure background. Plot data. Find average rate. |
| Measure radioactive source. Plot data. |
| Fit data. Plot fit function. |
| Find lifetime and compare |
| Plot dice data. |
| Fit dice data and find lifetime. |
| Model background with dice. Plot data. |