# The Geiger Counter

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# Abstract

The Experiment evaluated the functionality of the Geiger counter and calculated the half life of a radioactive source, indium116, to be $3013.6834s \pm 0.0257s$. The limitations of the device’s accuracy were examined and the dead time for the device was calculated to be 0.000592s.

# Introduction and Theory

The experiment aims to evaluate the Geiger Counter (GC) instrument. The Geiger counter records the emission of particles as a result of radioactive decay. It will be used to calculate the rate of radioactive decay and the half-life of a sample of radioactive substance, Indium 116. The activity of a source can be represented by the following equation:

$$\frac{dN}{dt}=-λN$$

Where N is the number of undecayed nuclei in the source and λ is the rate constant. The half life of a source is the time it takes for half the original number of nuclei to decay. It is given by the equation:

$$t\_{\frac{1}{2}}=\frac{ln2}{λ}$$

The change in count rate with time will be recorded over a period of around 2 hours. The slope of the plot of the natural log of the count rate with respect to time will be equal to –$ λ$. The rate calculated for the indium source will be used to find the half-life of indium116.

The GC device consists of a screen which allows the transmission of radioactive emission (alpha, beta or gamma decays) into a chamber filled with low pressure gas, often argon. Radioactive energy (in the form of alpha particles, beta particles or gamma waves) enters the chamber and ionises particles of the argon gas. Electrons freed from the argon atoms in turn move under an electric field in the chamber and ionise more argon atoms. This effect is known as a Townsend discharge and causes a current to flow temporarily through the anode in the chamber. Each of these small flows of current can be correlated to an individual radioactive emission.

The device has a limitation in that after each of these Townsend discharge events, the device has a “dead time” during which it cannot record another event until the inert gas has returned to its neutral state. This means the device cannot record every radioactive decay that occurs in the sample and may cause an error in the values calculated for the decay rate and half-life of a sample. This discrepancy will be particularly prevalent for very active sources, whose rate of emission will be much faster than the device can record accurately.

The experiment will calculate a value for the dead time of the Geiger counter used.

The dead time will be calculated using the two source method. The count rate will be calculated for two sources respectively and then for the combination of the two. Taking $τ$ to be the dead time of the device, m to be the recorded count rate and n to be the true count rate we can say:

Taking the rates of source A alone to be $n\_{1}$ and$ m\_{1}$, the rates of source B to be $n\_{2}$ and$ m\_{2}$, and the rates of the combination of the two to be n and m, the following relation is true:

$$τ^{2}-\frac{2τ}{m}+\frac{m\_{1}+m\_{2}-m}{m\_{1}m\_{2}m}$$

And from the solution of this equation we get a relation giving 2 values for$τ$:

 $τ=\frac{1}{m}\pm \sqrt{\frac{1}{m^{2}}-(\frac{m\_{A}+m\_{B}-m}{m\_{A}m\_{B}m})}$

# Experimental Method

The Geiger counter was set up along with the timer. The background rate for the Geiger counter was calculated by taking a count over the course of two minutes. All subsequent values of count recorded took this background activity into account.

The indium source was placed in the upper tray of the Geiger counter. A 1 minute count was taken every 5 minutes over the course of 100 minutes. The values calculated for the count rate and the natural log of the count rate were plotted as a function of time.

Next the recovery envelope was observed by displaying the amplified output signal of a single current event in the GC on an oscilloscope. By using the variable time cursors on the display of the oscilloscope it was possible to gauge the dead time after a pulse from the Geiger counter. This value was observed and later compared to values obtained using the two source method.

## The two-source method

Two carbon14 sources of beta particles were placed in the Geiger counter which called source A and B, for clarity. The count rate was calculated when source A was exposed and B was covered with a coin, when B was exposed and A covered with a coin, and when both sources were exposed. These count rates,$m\_{A} m\_{B}$ and m, were used to calculate the dead time of the GC using the following equation:

 $τ=\frac{1}{m}\pm \sqrt{\frac{1}{m^{2}}-(\frac{m\_{A}+m\_{B}-m}{m\_{A}m\_{B}m}) }$,

Where in this case, $τ$ is the dead time.

The signal created in the GC is amplified before being recorded. To determine if the configuration electronic components had an effect on the dead time as well as the nature of the gas present in the GC, the two-source measurements were repeated in 3 more scenarios. The above measurements of count rates of exclusively source A, exclusively source B and source A and B combined were repeated 3 times. For the first measurement the system amplifiers gain was set to its minimum and the BIAS was o.6kv. For the second series of measurements both the gain and BIAS were set to minimum (5 and 0.35kV respectively). For the third series of measurements the Gain was set to its maximum, a factor of 1200 and the BIAS was set to 0.35kV. The dead time was calculated for all of the above scenarios.

# Results and Analysis

The background rate for the GC was recorded and found to be 0.70833counts/second.

Taking the background rate into account, the change in count rate was plotted as a function of time for the indium source. The natural log of the count rate was also plotted with time. The rate constant was calculated using Excels regression analysis and found to be $0.00023\pm $8.54E-06.

Using the equation$t\_{\frac{1}{2}}=\frac{ln2}{λ}$, the half-life of the indium source was calculated:

$$t\_{\frac{1}{2}}=\frac{ln2}{0.00023}=3013.6834s$$

The response envelope for the Geiger counter device was observed on the oscilloscope and estimated using the variable cursors to be $28.5\*10^{-6}s$.

The dead time for the GC was calculated from the values attained in the two source part of the experiment. Two values were attained for the dead time using the equation$τ=\frac{1}{m}\pm \sqrt{\frac{1}{m^{2}}-(\frac{m\_{A}+m\_{B}-m}{m\_{A}m\_{B}m})}$. The correct value was found by substituting the attained values for dead time into the equation for the true count rate of the respective sources: $n=\frac{m}{1-mτ} $

The incorrect value was eliminated and the dead time acquired was 0.000592s.

## Error and Uncertainty

The Uncertainty in the half-life for the indium116 sample was calculated using the following relation:

$$∆t\_{\frac{1}{2}}=ln\left(2\right)\frac{∆λ}{λ^{2}}=0.0257s$$

# Results and Conclusions

The half life for the indium source was calculated and found to be$3013.6834s \pm 0.0257s$.

The dead time for the GC device was calculated for the device using the two source method and found to be 0.000592s.

The dead time for the device was minimised when the system amplifiers gain was maximised and the BIAS remained at 0.6kv. This implies that the signal amplification increased the dead time within the electronics of the device, regardless of the argon gas requiring time to return to its normal state.

# The count rate of the indium Source with respect to time.

# The natural log of the Count rate of the indium Source with respect to time.