# The Geiger Counter

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## Abstract

This experiment was carried out with the aims of finding the dead-time of the Geiger counter and the half-life of neutron irradiated indium.

The dead-time of the counter was found to be 480±4μs and the half-life of the neutron irradiated indium was found to be 3250±90s and both are around the commonly accepted values.


## Method and Theory

The Geiger counter relies on gas ionization and the Townsend Avalanche effect.

When ionizing radiation is incident on the Geiger counter, it passes through the glass of the detector into the gas inside, ionizing it. A large voltage over the gas pulls the positive and negative ions to the cathode and anode respectively. While being accelerated to a terminal, the ionized gas particles will ionize more gas on the way causing an avalanche of ionized particles to be created. This phenomenon causes a current to pass through the circuit and a "count" is recorded each time this happens.

However, due to the nature of the counter, clouds of ionized gas build up around the anode and cathode preventing further ions from reaching the terminals until the gas becomes sufficiently de-ionized for the process to begin again. The time required for this equalization is called the "dead-time". No counts can be recorded during this time.

By recording the number of counts per second, it is possible to find the rate of decay or activity of a source, and hence its half-life. (by finding when the rate is equal to half the rate of a previous point in time, or more accurately by fitting a rate versus time graph to an appropriate exponential graph and extracting the necessary data from there.)

As a note, the Geiger counter isn't very good at detecting what energies are incident on the counter, only the volume of total radiation.

## Experimental Method

### Background Radiation

To take into account continuous error due to background radiation, a count was taken until it reached 100 (for nice errors) and the time it took recorded. The rate found here would be taken away from succeeding measurements.

### Dead-Time

Measuring the dead-time was first attempted. To do this, two sources of carbon-14 were used, which decay to nitrogen-14 by beta decay, which is ionizing.

A count of one source was taken by putting it in the chamber of the Geiger-Counter and recording its count for 500 seconds. The same procedure was then performed with the other source. Once again the procedure was repeated, except with both sources present.

The sum of the rates of the individual sources should equal the rate of the two sources exposed simultaneously. However, this is not the case due to the dead-time of the apparatus. Given some algebra, the true count η of a source can be expressed as $\eta = \frac{m}{1-m\tau}$, where $m$ is the recorded count rate and τ is the dead-time of the counter. So since the rate of both sources exposed should equal the sum of each individual source, $\frac{m_1}{1-m_1\tau} + \frac{m_2}{1-m_2\tau} = \frac{m}{1-m\,\tau}$.

Rearranging for the dead-time, τ, can be found that $\tau = \frac{1}{m} \pm \sqrt{\frac{1}{m^2} - \frac{m_1+m_2-m}{m_1 m_2 m}}$, where $m_1$ is the rate of the first source, $m_2$ is the rate of the second source and $m$ is the rate of both sources exposed at the same time.

One of the values for τ found from this formula was, as expected, clearly wrong by substitution back into the equations given. The other value was accepted as the dead-time.

## Half-Life of Indium

Indium, a gamma emitter when activated by a neutron source, was used for this experiment.

A one minute count of the source was taken every 5 minutes, ie a count was taken over one minute and the apparatus was left for four. This was repeated for two *long* hours. The results were graphed.

Indium was used because of its short half-life.

## Results, Analysis and Errors

## Background Radiation

Count = 100
Count Error = $\sqrt{100}$ = 10
Time = 191 s

Count Rate = 0.52356 ± 0.05
≅ 0.52 ± 0.05 $s^{-1}$

## Dead-Time

$m_1$:
Count = 243,852
Count Error = 493.81
Time = 500 s

Count Rate – Background Rate = 487 ± 1 $s^{-1}$

$m_2$:
Count = 255,800
Count Error = 505.7667
Time = 500 s

Count Rate – Background Rate = 511 ± 1 $s^{-1}$

$m$:
Count = 403,034
Count Error = 634.8495
Time = 500 s

Count Rate – Background Rate = 805 ± 1

τ :

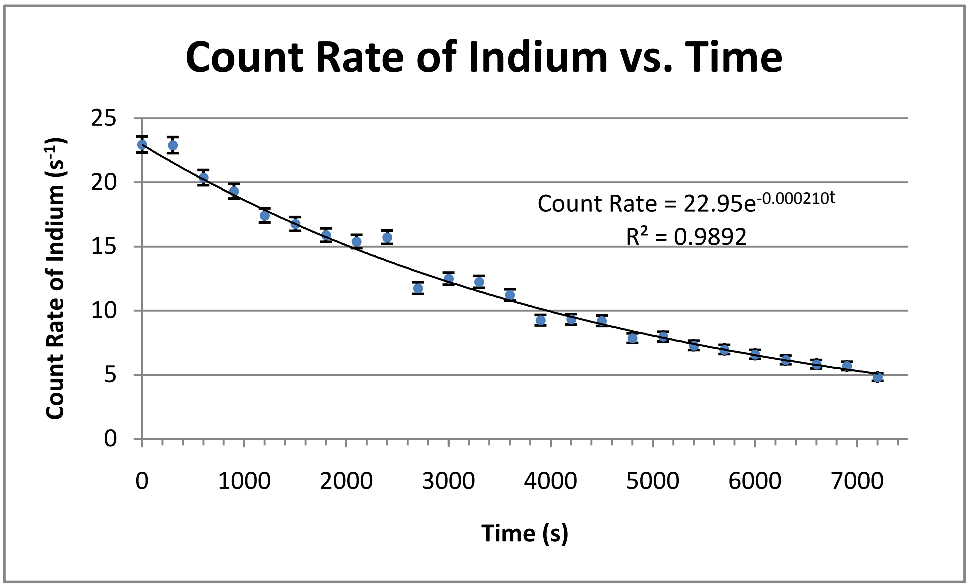
$\tau = \frac{1}{m} \pm \sqrt{\frac{1}{m^2} - \frac{m_1 + m_2 - m}{m_1 m_2 m}}$

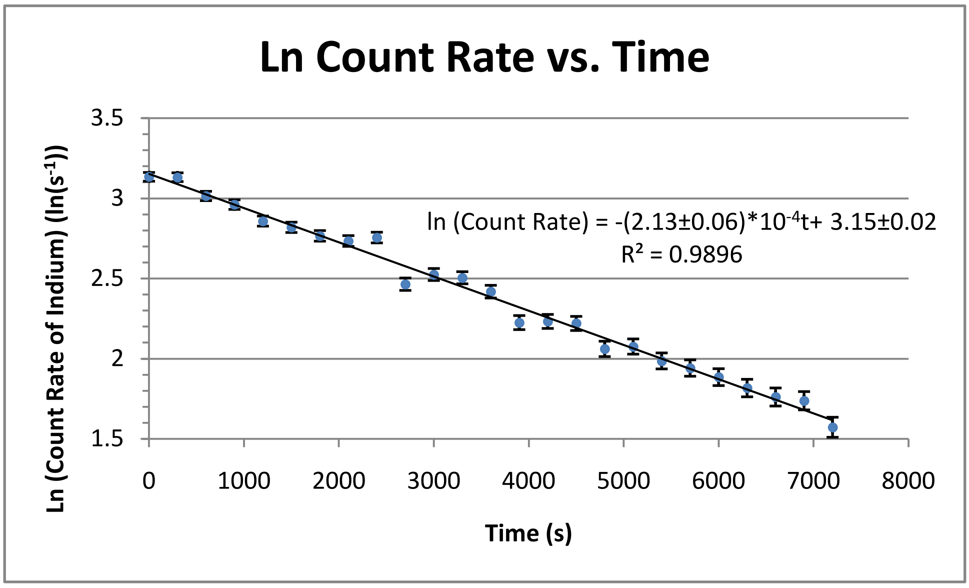
$\Rightarrow \tau = 2003.364\mu s$ or $480.83\mu s$

Substituting τ back into $\frac{m_1}{1-m_1\tau} + \frac{m_2}{1-m_2\tau} = \frac{m}{1-m\,\tau}$
τ = 480μs satisfies the equation.
Errors were worked out in Mathematica

τ = 480±4μs

## Half life of Indium



As can be seen, there is a logarithmic relation between the count rate and the time passed. Solving $e^{-a\,t_{\frac{1}{2}}} = \frac{1}{2}$, we get $t_{\frac{1}{2}} = \frac{\ln 2}{a}$ and $\Delta t_{\frac{1}{2}} = \frac{\ln 2}{a^2}\delta a$ . Linearising the equation gives $\ln R = -at + c$. So for indium, from the data given, $t_{\frac{1}{2}} = \frac{\ln 2}{0.000213} = 3254 \pm 90$ s .

## Discussion and Conclusions

The value for the dead-time of the Geiger counter is of the order 100μs, which is the value expected of a Geiger counter, so this value is likely accurate. The value measured was 480±4μs.

The value found for the half-life of indium seems to adhere to the gathered experimental data at all points, so at least it's sensible. One source was found online quoting the half-life of neutron irradiated indium to be 54.2 minutes, ie 3252 seconds. The value measured in this experiment was 3250±90s. This is very close to the quoted value.

## Resources

http://www.csun.edu/~hcchm003/322l/322lmnaa.pdf