

Determining the half-life of $^{137}\text{Ba}^*$

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(Dated: March 16, 2005)

We measured the half-life of sample of $^{137}\text{Ba}^*$ dissolved in an eluting solution of .0.9% NaCl in 0.04 M HCl. Using a Geiger-Muller counter to measure the decay rate of the sample, we made a single trial, taking 60 measurements over a period of 10 minutes. Using a nonlinear weighted least-squares fit of the background-corrected data, we experimentally determined the half-life of the sample to be 167.0 ± 9.99 seconds, a difference of 9.062 percent from the accepted value of 153.1 seconds.

I. INTRODUCTION

In a radioactive substance, the rate of decay is proportional to the amount of that substance present at any given time. By measuring the rate of decay of a sample of that substance over time, the half-life of the substance can be determined experimentally.

At any given time, the amount of a radioactive substance present in a sample is given by

$$R(t) = e^{-\lambda t} R_0. \quad (1)$$

Here, $R(t)$ is the rate of decay of the substance at time t , R_0 is the decay rate at an arbitrary zero point in time, t is the amount of time elapsed since time zero, λ is the decay constant of the substance, and t is the amount of time elapsed since t_0 .

τ , the half-life of the substance, can be determined by

$$\tau = \frac{\ln(2)}{\lambda} \quad (2)$$

where λ is the decay constant of the substance.

II. PROCEDURE

An eluting solution of 0.9% NaCl in 0.04 M HCl was injected into an isotope generator [1] containing ^{137}Cs in order to obtain our sample of $^{137}\text{Ba}^*$. Approximately six drops of a solution containing the $^{137}\text{Ba}^*$ were produced in this fashion. The sample was placed under a Geiger-Muller tube[2], and a counter[3] was set to take counts over a period of 6 seconds. At 10-second intervals, the value on the counter was recorded, then it was reset to zero and set to count for another 6 seconds. Data were recorded in this way for a total of 10 minutes, in only one trial. The sample was then removed and disposed of, and

the background radiation present was measured using 10 six-second counts.

A plot of our data shows an exponential decay.

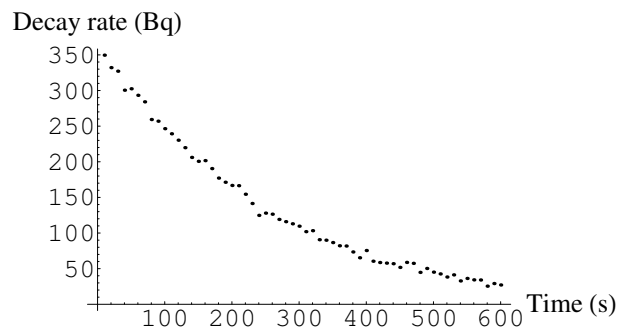


FIG. 1: Our measured decay rates

III. CALCULATIONS

We found the mean background radiation level to be 1.2 ± 0.1 Bq. This was subtracted from each of our data points.

In order to determine τ , we must first determine λ . This can be determined experimentally by using a weighted least-squares fit of the data to Equation (1). Each data point is weighted by a factor of $\frac{1}{\sigma}$. Radioactive decay is a Poisson process[4], so if we had merely measured decay rate, σ would be simply $\sqrt{R(t)}$, where $R(t)$ is the measured decay rate at a given time. However, as we are correcting for background noise, the uncertainty in measurement of that noise must be factored in to σ as well. σ_r , the total uncertainty for each data point, is then given by[5]

$$\sigma_r = \sqrt{\sigma_m^2 + \sigma_n^2} \quad (3)$$

where σ_m is the uncertainty in our measured (i.e. not background corrected) decay rate, and σ_n is the uncertainty in our measured background noise.

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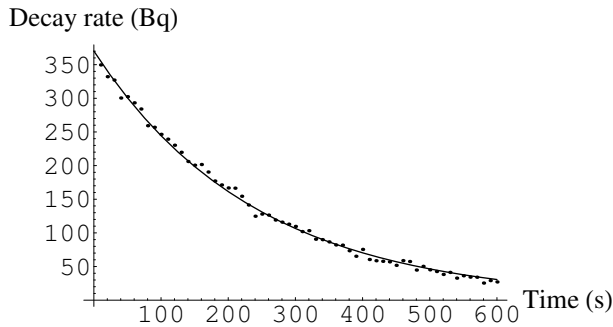


FIG. 2: Least-squares fit of our data

It is worth noting that λ can also be determined by taking the natural logarithm of both sides of Equation (1). However, this will give an anisotropic value for σ_m and skew the weighted least-squares fit.[5]

IV. RESULTS AND SOURCES OF SYSTEMATIC ERROR

The accepted value for the half-life of $^{137}\text{Ba}^*$ is 2.552 minutes.[6] I found τ to be 167.0 ± 9.99 seconds, a difference of 9.062 percent.

Using the isotope generator that was used to generate

our sample of $^{137}\text{Ba}^*$, there is the possibility that some ^{137}Cs will be dissolved in the eluting solution as well as $^{137}\text{Ba}^*$. This would have the effect of increasing the measured count rate, and skewing our result for τ higher than the actual value. As this was brought to our attention after the experiment had been completed, we did not test for this contamination, and it is possible that our results are accordingly skewed.

Our timing was also inexact. The stopwatch that we used was in no way linked to the G-M counter, and this may have introduced a "jitter" into our measurements. While the effect of this jitter is minimized by using a least-squares fit, its potential contribution to the systematic error should be noted.

Of the two aforementioned potential sources of error, I feel that the possible presence of ^{137}Cs in our sample is the largest contributor to the total systematic error.

Acknowledgments

I would like to thank Dr. Jon Hakkila of the Department of Physics & Astronomy at the College of Charleston for his assistance in creating a weighted least-squares fit of our data, for reminding me that radioactive decay is well-modeled by Poisson statistics, and for providing a formula for our error in measurement that takes the background noise into account.

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- [1] The isotope generator was manufactured by Such-and-Such Company of Sheboygan, WI, and dated July 2003
 [2] The G-M tube was operated at 900 V.
 [3] The counter used was a Model 550 Scaler-Timer manufactured by The Nucleus, Inc., of Oak Ridge, TN.
 [4] Weisstein, Eric W. "Poisson Process." From

- MathWorld—A Wolfram Web Resource.
<http://mathworld.wolfram.com/PoissonProcess.html>
 [5] Hakkila, Jon. Personal conversation, 4 March 2005.
 [6] Table of Nuclides [Web page];
<http://atom.kaeri.re.kr/ton/> [Accessed February 2005]