Determining ^{137}Cs Contamination: Calibration Using a Counting Technique to Identify a Ba Isotope by its Half-Life

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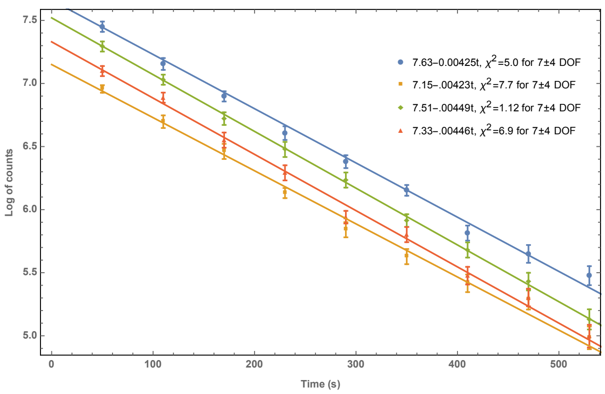

FIG. 1: The logarithm of the number of counts in 50 seconds every minute for 4 separate runs.

ANALYSIS

In real time, we used Mathematica to plot our data for each run (after subtracting the background count) and computed a least-squares fit [1] of the logarithm of the number of counts n to a linear fit of the form

$$\log(n) = b + at, \tag{1}$$

where t is time in seconds, and a and b are fit parameters. Note b is dimensionless. See Fig. 1. We measured the background rate to be 0.30 ± 0.01 counts/s. We accounted for timing error by estimating that we were accurate to within 0.25 seconds. We then estimated an "instantaneous rate" for each time by taking the measured count and dividing it by the collection time interval (50 seconds). Finally we obtained an estimate for the uncertainty in the count due to timing error by multiplying this rate by 0.25 seconds.

There are several possible systematic errors. One is the efficiency of the Geiger counter. If the Geiger counter misses, say 3% of the counts due to not triggering, we will be undercounting, and subsequently our estimate for the fit parameters a and b will be affected. Another possible error is due to the dead time of the Geiger counter, i.e. the time it takes the counter to reset itself after recording a count. This error is more important for larger count rates. We estimate this error to be small compared to the other errors. Another error is fluctuations of the high voltage necessary to operate the Geiger counter. We compensated for this by plateauing the count rate as a function of the voltage before taking data, and thus expect this effect to also be small. In total we estimate, that the total error due to these effects is a 3% error in each measured count. In absence of any evidence to argue otherwise, we combine the statistical errors and the systematic errors in quadrature. For estimates of the fit parameters see Table I.

TABLE I: Fit parameters for the four runs. Note $\tilde{\chi}^2$ is χ^2 divided by the number of DOF.

$a(s^{-1})$	b (dimensionless)	$\tilde{\chi}^2$
-0.00425 ± 0.00017	7.63 ± 0.03	0.71 for 7 ± 4 DOF
-0.00423 ± 0.00012	7.15 ± 0.03	1.10 for 7 ± 4 DOF
-0.00449 ± 0.00012	7.51 ± 0.03	0.16 for 7 ± 4 DOF
-0.00446 ± 0.00012	7.33 ± 0.03	0.99 for 7 ± 4 DOF

The half-life $t_{1/2}$ is given in terms of the fit parameter a by

$$t_{1/2} = \frac{\log 2}{a}. \tag{2}$$

Using this, we find $t_{1/2}$ for our four runs to be:

$$2.72 \pm 0.11,\ 2.73 \pm 0.08,\ 2.58 \pm 0.07,\ 2.59 \pm 0.07 \text{ min.}$$

Taking the weighted average of these results, we find that our best estimate of the half-life is

$$t_{1/2} = 2.64 \pm 0.04 \text{ min.} \tag{3}$$

The accepted value of the half-life is 2.55 min [2]. In terms of our standard deviation, the deviation of our result is

$$\frac{2.64 - 2.55}{0.04} = 2.25 \text{ standard deviations.} \tag{4}$$

CONCLUSIONS

We measured the half-life of ^{137}Ba to be 2.64 ± 0.04 min. Our results are not in great agreement with the accepted value, being a bit more than 2 standard deviations from the accepted value. It is highly likely we neglected some sources of systematic error, given that all our trials resulted in a value for the half-life greater than the accepted value.

[1] A. Sandvik, "Py502, line fit," (2017), http://physics.bu.edu/py502/linefit/linefit.html.

[2] A. Melissinos and J. Napolitano, *Experiments in Modern Physics*, 2nd ed. (Academic Press, 2003).