

PHY 252 Lab 9: Radioactive Decays

Spring 2007

Introduction

In this experiment we will measure the half-life of an excited state of the ^{137}Ba nucleus. Samples are prepared from a radioactive isotope of ^{137}Cs . This isotope has too many neutrons to be stable; it decays by β -decay into $^{137}\text{Ba}^*$. This daughter nucleus is produced in an excited state, indicated by the asterisk (*). The excited state successively decays into the ground state of ^{137}Ba with a half-life of the excited state of 2.6 min. The decay of the excited state is detected by measuring the emitted γ -rays of 0.66 MeV. This energy corresponds exactly to the energy difference between the excited state in $^{137}\text{Ba}^*$ and the ground state.

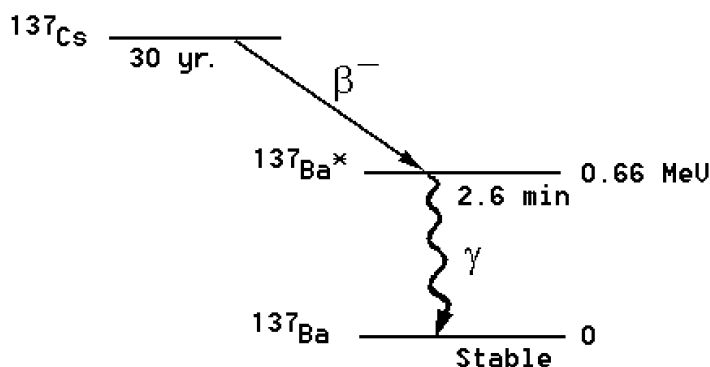


Figure 1. The ^{137}Cs decay chain.

The γ -ray emission rate is $R(t) = -dN(t)/dt$, where $N(t)$ is the number of $^{137}\text{Ba}^*$ nuclei present at time t . The emission rate is proportional to $N(t)$ itself:

$$\frac{dN(t)}{dt} = -\mathbf{I} N(t), \quad (1)$$

where \mathbf{I} is the decay constant. Integration of Equation (1) gives

$$N(t) = N_0 \exp(-\mathbf{I}t), \quad (2)$$

where N_0 is the number of excited nuclei present at time $t = 0$. The *half-life* time $t_{\frac{1}{2}}$ is defined as the time it takes for the activity to be reduced by $\frac{1}{2}$, so that at $t = t_{\frac{1}{2}}$, $N = N_0/2$. Derive the relationship between \mathbf{I} and $t_{\frac{1}{2}}$. Also, show that at any time $t + t_{\frac{1}{2}}$, there will remain only one-half of the excited nuclei that were there at time t .

Measurement

1. Locate the plateau of the Geiger-Müller tube and adjust the high voltage to a value in the plateau region (use your Lab 8 experience). Measure the room background counts for about 10 minutes. You will need this information later to correct your measurements of $^{137}\text{Ba}^*$.
2. Use a *freshly* prepared (!) sample of $^{137}\text{Ba}^*$, place it under the Geiger counter. You want to approximate the measurement of the decay rate $R(t) = -dN(t)/dt$ by measuring the number of counts ΔN for some suitable time interval Δt . Measure $\Delta N / \Delta t$ as a function of the elapsed time. Continue until the count rate is similar to the background rate, when no accurate measurement is possible.

Analysis

Correct your data for the background and plot the logarithm of the corrected count rate versus time. Fit your results with a straight line. Don't forget to put proper error bars on your data points. From the slope of the straight line you can obtain λ and the half-life (including their uncertainties).