PHY 252 Lab 9: Radioactive decay

Fall 2009

1 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}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}Ba* and the ground state.

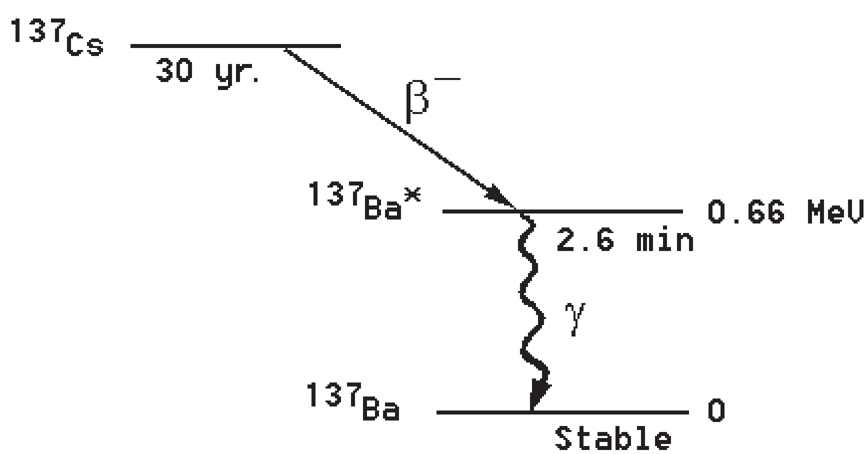

Figure 1: The ^{137}Cs decay chain.

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

$$\frac{dN(t)}{dt} = -\lambda N(t), \tag{1}$$

where λ is defined as the decay constant. Integration of Eq. 1 leads to

$$N(t) = N_0 \exp[-\lambda t], \tag{2}$$

where N_0 is the number of excited nuclei present at $t = 0$. The *half-life* $t_{\frac{1}{2}}$ is defined as the time it takes for the activity to be reduced by *half*, so at $t = t_{\frac{1}{2}}$, $N = N_0/2$. Derive the relationship between λ and $t_{\frac{1}{2}}$. 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 !

2 Measurement

1. Locate the plateau of the Geiger-Müller tube and adjust the high voltage to a value in the plateau region (400–600 V usually). Measure the room background for about 10 minutes. You will need this information later to correct your measurements of $^{137}\mathrm{Ba}^*$.

2. Use a *freshly* prepared (!) sample of $^{137}\mathrm{Ba}^*$, place it under the Geiger counter, and measure the decay rate ΔN in some suitable time interval Δt as a function of the elapsed time. Continue until the count rate is comparable with the background rate over the same time interval.

3 Analysis

You must first subtract the background, no-sample count rate from your measurements. Next, if you take the natural logarithm of both sides of Eq. 2, you obtain

$$\ln[N(t)] = -\lambda t + \ln(N_0) \tag{3}$$

so that a plot of $\ln[N(t)]$ versus t lets you determine N_0 from the y-intercept and λ from the slope. Don't forget to include errorbars!