
PHYSICS 252 EXPERIMENT NO. 10

RADIOACTIVE DECAYS

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 subsequently 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.

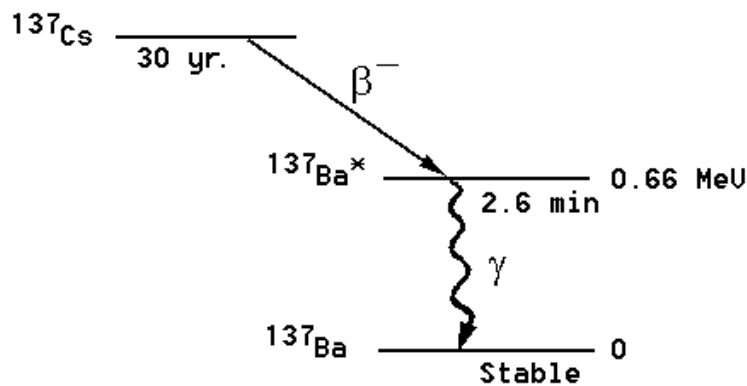


Figure 1: The ^{137}Cs decay chain.

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

$$dN(t)/dt = -\lambda N(t) ,$$

where the proportionality factor λ is defined as the decay constant. Integration of above expression leads to

$$N(t) = N_0 \exp(-\lambda t) ,$$

where N_0 is the number of excited nuclei present at $t = 0$. The *half-life* $t_{1/2}$ is defined as the time it takes for the activity to be reduced by *half*; thus, at $t = t_{1/2}$, $N = N_0/2$. Derive the relationship between λ and $t_{1/2}$. Show that at any time $t + t_{1/2}$, there will remain only one-half of the excited nuclei that were present 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 (400-600 V usually). Measure the room background for about 10 minutes. You will need this information later to correct your counting measurements of $^{137}\text{Ba}^*$.
2. Use a *freshly* prepared (!) sample of $^{137}\text{Ba}^*$, 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.

Analysis

Correct your data for the background and plot the logarithm of the corrected count rate versus the time t . You should obtain a straight line. Don't forget to put proper errorbars on your data points. From the slope of the straight line you can obtain the half-life and the decay constant (including the errors). Compare with the accepted values.

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