BRIEF REPORTS

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Measurement of the half-life of ^{56}Co

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Gamma rays from a mixed source of ^{56}Co+^{46}Sc were measured in a Ge(Li) detector. The ^{56}Co/^{46}Sc peak intensity ratios I_{847}/I_{889} were determined by careful analysis of line shapes and underlying backgrounds. Based on the known ^{46}Sc adopted half-life value of 83.810(10) d, the fit to the intensity ratios corrected for ^{46}Sc decay from 107 runs over an elapsed time of 172 days gave a half-life value of 77.29(3) d for ^{56}Co.

I. INTRODUCTION

Because of its relevance to the light decay rate of supernova 1987A there have been several recent determinations[1–3] of the ^{56}Co half-life, not only to improve on the accuracy but to resolve some earlier discrepancies in values. The history of measurements to date is given in Ref. 3. Of the three recent values for the ^{56}Co half-life, 77.28(4) d (Ref. 1), 77.08(8) d (Ref. 2), and 77.30(9) d (Ref. 3), those of Refs. 1 and 3 are in good agreement, while those of Refs. 1 and 2 differ by nearly twice the sum of their respective assigned uncertainties. In most of the recent work the decay of ^{56}Co was determined relative to radiations from long-lived reference standards, using a high-pressure ionization chamber in the case of Ref. 1 and Ge(Li) detectors in the cases of Refs. 2 and 3.

As discussed in Ref. 3 we believe that perhaps the most reliable method for measuring the ^{56}Co half-life is to compare its γ rays in a Ge(Li) detector with those from a source having nearly the same, but accurately known, half-life. The shape of the pulse-height spectrum then changes very little with decay, thereby reducing the possible systematic effects in the subtraction of backgrounds under the relevant peaks; i.e., the parameters in the background fits will be nearly the same for all spectra and will change very slowly with decay.

Following the suggestion of Ref. 3 we selected ^{46}Sc to serve as a reference source. It decays with a half-life having an adopted value[4] of 83.810(10) d and emits γ rays of 889 and 1121 keV with equal intensity. The 889-keV γ ray was selected for comparison with the 847-keV γ ray of ^{56}Co.

II. EXPERIMENTAL PROCEDURES AND RESULTS

A source of ^{46}Sc was available that had been produced in the High Flux Beam Reactor at Brookhaven National Laboratory (BNL) using the ^{45}Sc$(n,\gamma)^{46}$Sc reaction. This was combined with a ^{56}Co sample which had been formed in the ^{56}Fe$(p,n)^{56}$Co reaction using 25-MeV protons from the BNL 60-inch cyclotron. The two sources were cut and then clamped in a holder such that the initial intensity of the ^{56}Co 847-keV peak was slightly greater than that of the ^{46}Sc 889-keV peak. The combined source was placed on the axis of a Ge(Li) detector at $d=13$ cm and the initial total counting rate was 7100/sec. During the entire 5.7 months of running neither the detector nor source was moved.

Figure 1 (top and middle parts) shows a portion of one of the early spectra (taken at $t=11$ d) in the region of the 847- and 889-keV peaks where in the top part of the figure the ordinate is expanded by a factor of 70. The first step in the analysis was to shift each spectrum, using the program[5] PAINT, so that the 847- and 889-keV lines were at standard peak positions. It was verified that only a shift in offset but no gain shift was necessary in the region of interest. Two runs were rejected because of peak shifts during the runs. Of all remaining 107 runs the peak positions after shifting were both constant to better than 0.3 channels. The summed spectra after shifting are shown in the bottom part of Fig. 1. Each peak was then fitted using the program LEONE (Ref. 6) which fits a Gaussian to the peak with exponential high-energy and low-energy tails. The background, as indicated in the top part of Fig. 1, consists of a step function under the peak superimposed on a polynomial function. For the regions of interest, the peak and background parameters were fitted simultaneously. In the fits, the region of the new 853-keV γ-ray peak[7] of ^{56}Co had to be avoided in the 847-keV peak analysis and the region of the ^{56}Co 897-keV peak had to be avoided in the 889-keV peak analysis. Both of these weak peaks are visible in most of the individual spectra as can be seen in the top part of Fig. 1.

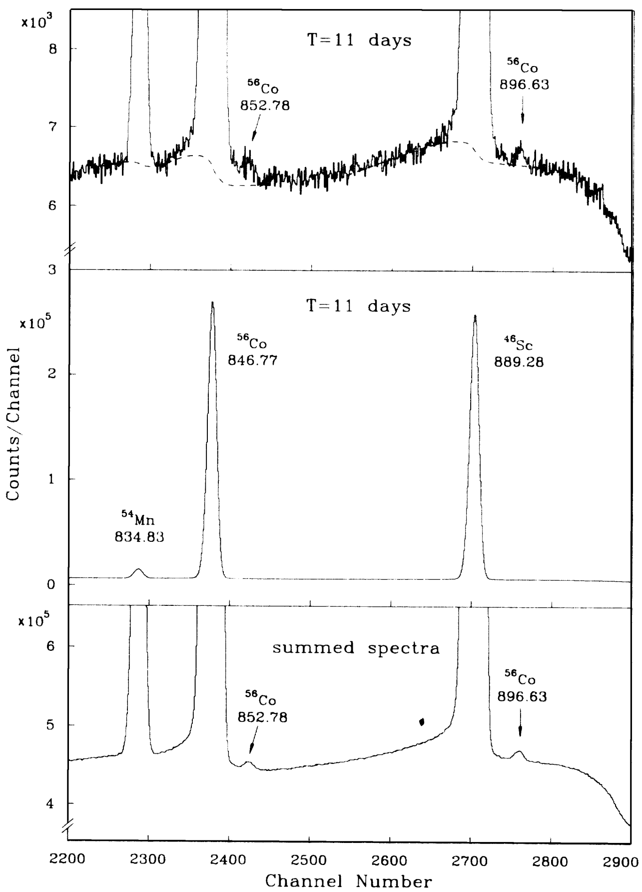

FIG. 1. Top and middle parts: Pulse-height spectra from one of the first Ge(Li) 6-h runs on a mixed $^{56}Co+^{46}Sc$ source in the region of the ^{56}Co 847-keV line and the ^{46}Sc 889-keV reference line. The top part illustrates the fitting of the background as discussed in the text. The bottom part shows the sum of all individual runs after shifting to standard peak positions.

However, their exact positions were determined from the summed spectra (bottom part of Fig. 1). Because of the normalized peak positions, the same parameters and regions of fit could be used for all of the spectra.

No additional background line was found in the region shown in Fig. 1 and beyond (i.e., between 830 and 920 keV). The 2σ detection limit rules out transitions with $I_{rel} > 0.004\%$ $I(^{56}Co$, 847 keV) and $I_{rel} > 0.004\%$ $I(^{46}Sc$, 889 keV).

Initially, the runs were of 6-h duration. For the very first run the net peak intensities were 3.59×10^6 counts for the 847-keV line and 3.48×10^6 counts for the 889-keV peak and thus the statistical uncertainty in the 847/889 intensity ratio was 0.078%. Towards the end of the experiment the runs were increased to 8 h.

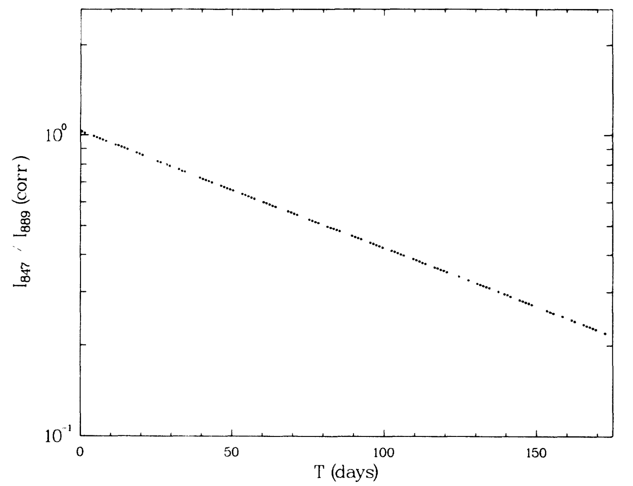

FIG. 2. Decay of the ratio I_{847}/I_{889} corrected for the decay of ^{46}Sc [half-life 83.810(10) d]. A total of 107 runs were analyzed over an elapsed time of 2.2 half-lives of ^{56}Co. Statistical error bars are comparable with the sizes of the data points.

Runs were made at the rate of 4 or 5 per week over a period of 172 days. The I_{847}/I_{889} ratios, after correction for the decay of ^{46}Sc, are shown in Fig. 2 for the 107 acceptable runs that were made. A fit to all of the points gave a half-life of 77.29(2) d for the half-life of ^{56}Co. Separate fits to data points for the first and second halves of the series gave 77.34(5) d and 77.22(6) d where the uncertainties are statistical only and include the uncertainty in the ^{46}Sc half-life. Analyses using various background parameters suggested that systematic uncertainties could be present that are comparable to the statistical uncertainties. We therefore combine the statistical and estimated systematic uncertainties and adopt $t_{1/2}=77.29(3)$ d for the half-life of ^{56}Co. This value agrees very well with the results of Refs. 1 and 3 but is outside the sum of uncertainties when compared with the result of Ref. 2. The weighted average of the four values of Refs. 1 to 3 and the present result, is $t_{1/2}=77.27(3)$ d.

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