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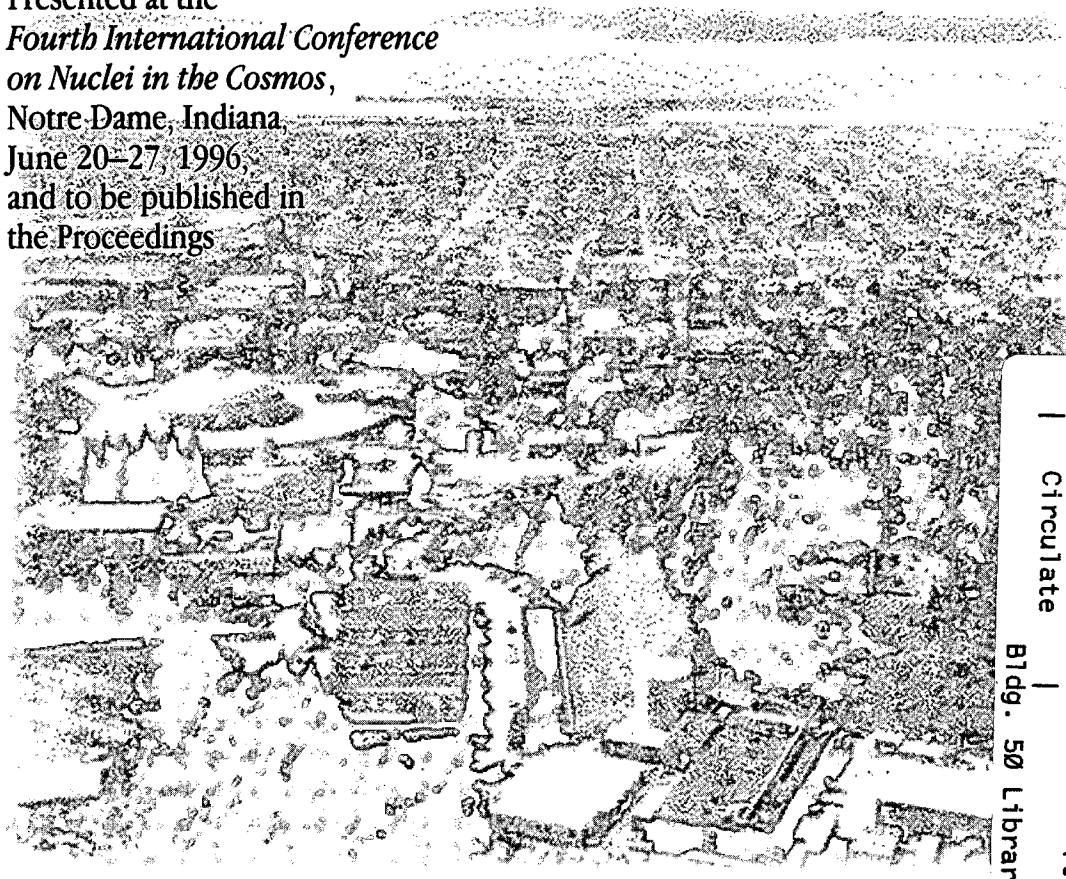

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On the Half-Life of ^{44}Ti

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On the Half-Life of ^{44}Ti

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One of the few long-lived gamma-ray emitting radioisotopes expected to be produced in substantial quantities during a supernova explosion is ^{44}Ti. The relevant portions of the decay schemes of ^{44}Ti and its daughter ^{44}Sc are shown in Figure 1. ^{44}Ti decays to ^{44}Sc emitting γ rays of 68 and 78 keV. ^{44}Sc subsequently decays with a 3.93-hour half life to ^{44}Ca emitting an 1157-keV γ ray. This characteristic 1157-keV γ ray from the decay of ^{44}Ti has recently been observed from the supernova remnant Cas A [1].

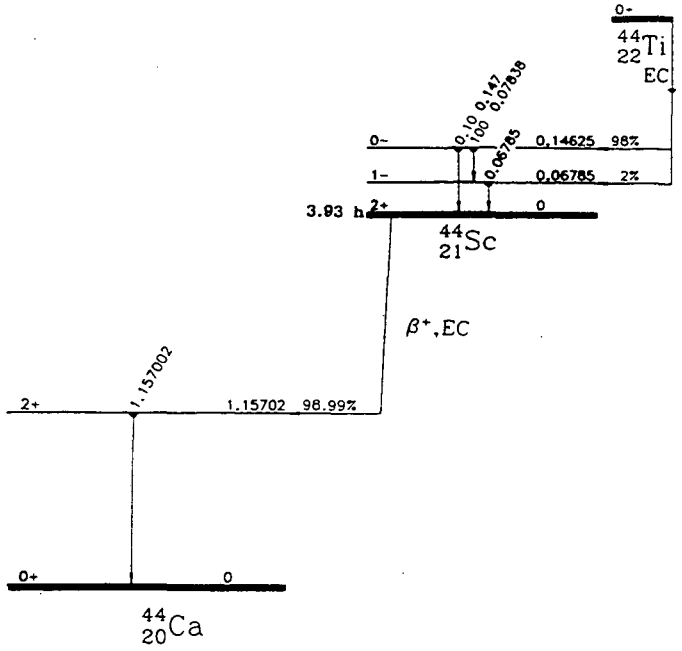

Figure 1. Relevant portions of the decay schemes of ^{44}Ti and ^{44}Sc [2]. All energies are in MeV.

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In order to compare the predicted γ-ray flux to that actually observed from this remnant, one must know the half-life of ^{44}Ti. However, published values for this quantity range from 46.4 to 66.6 years [3-7]. Given that the Cas A supernova is believed to have occurred approximately 300 years ago, this translates to an uncertainty by a factor of 4 in the amount of ^{44}Ti ejected by this supernova. Thus, in order to provide an accurate and reliable value for this important quantity, we have performed a new experiment to determine the half-life of ^{44}Ti.

We produced ^{44}Ti via the ^{45}Sc(p,2n) reaction using 40 MeV protons from the Lawrence Berkeley National Laboratory's 88-Inch Cyclotron. This energy was chosen to be just above the maximum of the excitation function for this reaction as reported by McGee *et al.* [8]. However, in the course of preparing this source, we produced far less ^{44}Ti than expected. We therefore remeasured the excitation function for this reaction and found that it peaks at much lower energy and has a significantly smaller maximum cross section than previously reported [9]. To produce the source for the present half-life measurement, a 99.9% pure metallic scandium target 37.8mg/cm^2 thick was irradiated for approximately 24 hours with 1 microampere of beam. After allowing the short-lived activities to decay away, approximately 0.01 μCurie of ^{44}Ti was chemically separated from the target, mixed together with 0.04 μCurie of ^{22}Na and 0.05 μCurie ^{137}Cs, then dried and sealed. This mixed source and a separate 1 μCurie source of ^{241}Am were then rigidly mounted to a shielded 110-cm^3 high-purity germanium detector for γ-ray counting. Gamma-ray spectra of 4096 channels were collected in 24-hour intervals and recorded to magnetic disc using a dedicated ORTEC ACE data acquisition system on a PC. In this mode, we accumulated approximately two year's worth of data. A typical spectrum obtained in one day of counting this mixed source is shown in Figure 2.

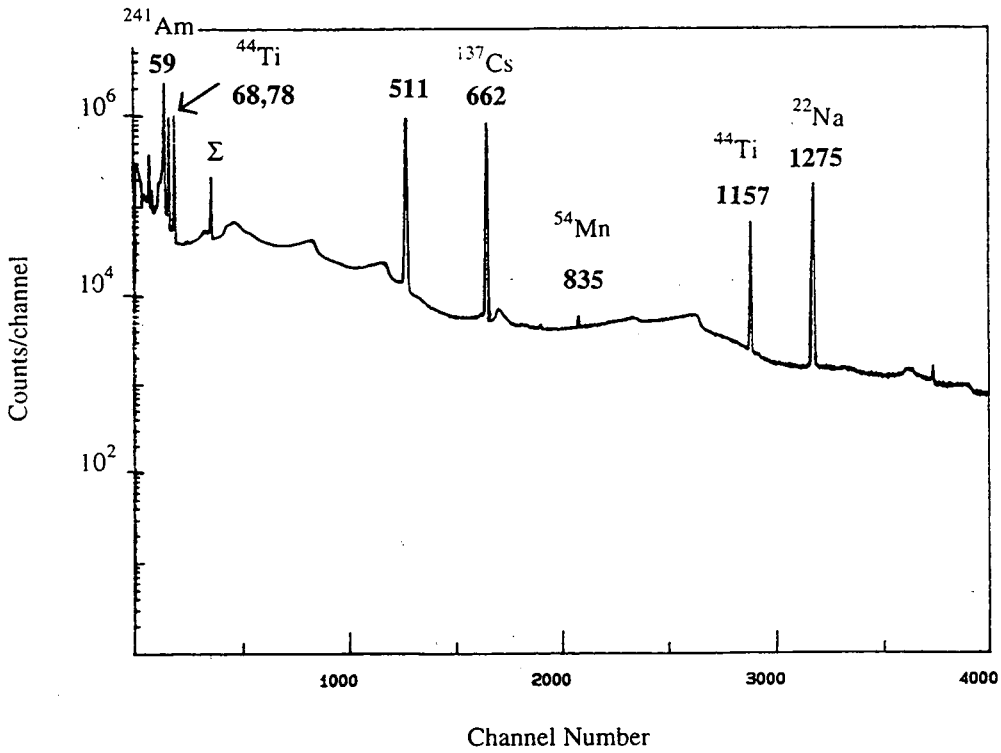

Figure 2. γ-ray spectrum observed in 1-day of counting our mixed source. All energies are in keV.

In the present experiment, we attempted to use all three ^{44}Ti γ-ray lines to determine its half life. However, analysis of the ^{241}Am and ^{137}Cs lines produced an incorrect value for the half life of each of these isotopes. On the other hand, the analysis of the ^{22}Na line produced a result that agreed to within 0.5% of the known value of 2.603 years. Also, a small ^{54}Mn contaminant line at 835 keV yielded a half life that agreed to within 1% of its known value. Thus, we decided to concentrate our effort on the analysis of the 1157-keV line. In order to reduce systematic effects such as the possibility of a change in the source-detector distance or a change in the detection efficiency, we compared the area of the 1157-keV ^{44}Ti line to that of the nearby 1275-keV line from the ^{22}Na standard. The ratio of these peak areas was plotted versus time and then fitted to an exponential whose argument was the difference in decay rates between ^{44}Ti and ^{22}Na. The results of this procedure as applied to somewhat less than half of our total data set are shown in Figure 3. Each plotted point represents the sum of 10 days of data, and the actual error bars are ten times smaller than shown here. The chi-squared per degree of freedom for the fit is 1.1. The half life of ^{44}Ti that we deduce from this experiment is 63±3 years.

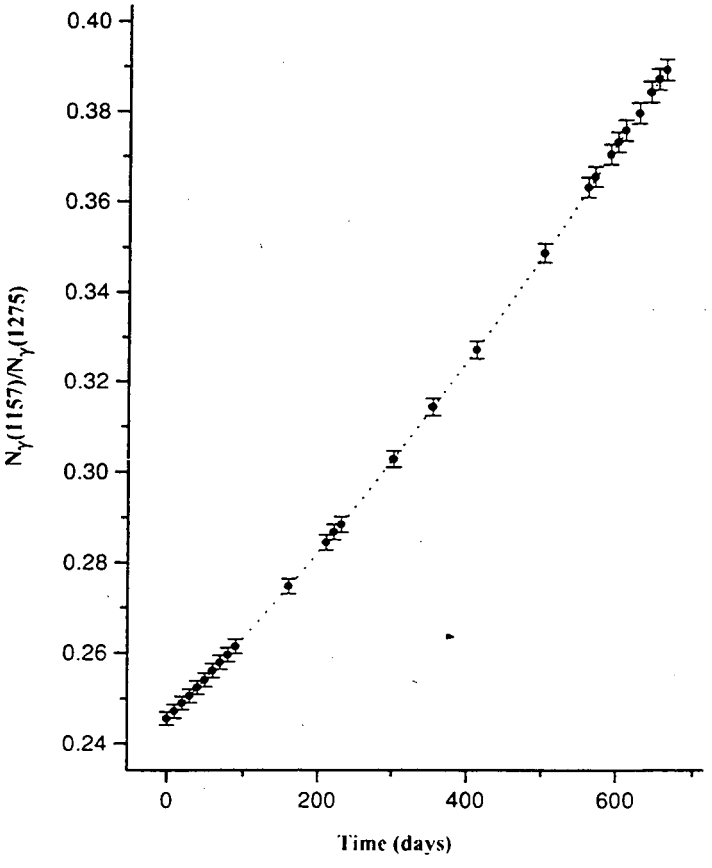

Figure 3. Ratio of peak areas of 1157/1275 keV γ rays versus time. The dotted curve is a least-squares fit in which the ^{22}Na half life was fixed at its known value and the ^{44}Ti half life varied as a free parameter.

In Figure 4, we summarize the results of all the reported values for the half life of ^{44}Ti. Our result strongly disagrees with the early half-life measurements[3-5], but agrees well with the more recently published values [6,7].

As discussed above, in the present experiment we were not able to use the low energy ^{44}Ti lines to determine a half life. In order to address this issue, we have begun a second experiment in which a new mixed source of ^{44}Ti and ^{207}Bi has been prepared. In this measurement, we will compare the yields of the 68- and 78-keV lines from ^{44}Ti to the Pb K x-rays produced by the electron-capture decay of ^{207}Bi, and the 1157-kev ^{44}Ti line will be compared to the 1064-keV line from ^{207}Bi decay. This experiment has been running for approximately 2 months and we hope to have a result within the next year.

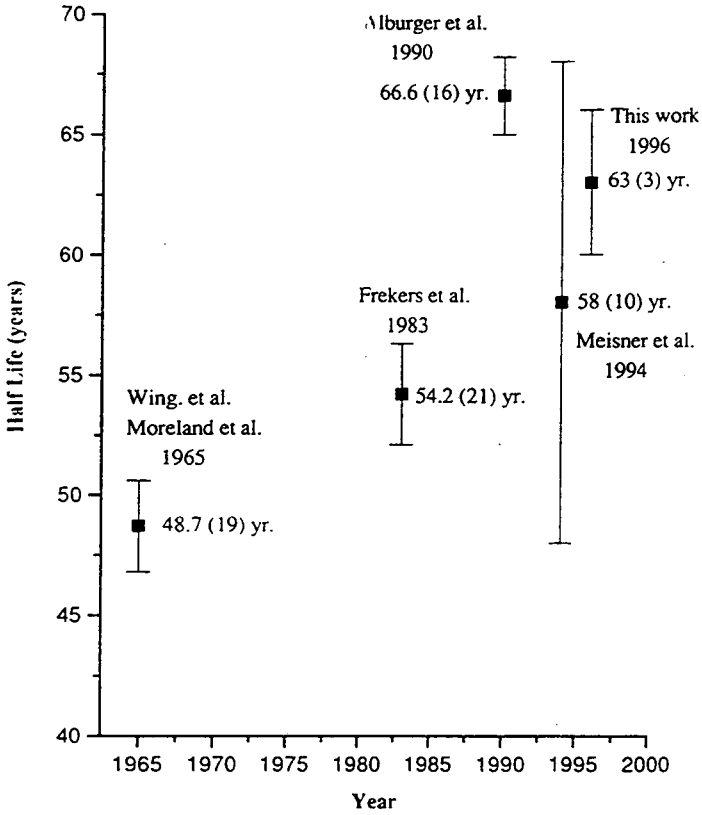

Figure 4. Summary of the measurements of the ^{44}Ti half life.

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