Half-Life of ^{44}Ti

E. B. Norman, E. Browne, Y. D. Chan, I. D. Goldman†, R.-M. Larimer, K. T. Lesko, M. Nelson, F. E. Wietfeldt, and I. Zlimen

The long-lived radioisotope ^{44}Ti is of considerable interest in astrophysics. It is one of the few long-lived γ-ray emitting nuclides expected to be produced in substantial amounts during a supernova explosion. ^{44}Ti decays to ^{44}Sc emitting γ rays of 68 and 78 keV. ^{44}Sc subsequently decays to ^{44}Ca emitting an 1157-keV γ ray. This γ ray was observed from the young supernova remnant Cassiopeia A (Cas A). More recent studies of Cas A have provided indications of the 68- and 78-keV γ rays from ^{44}Ti as well. ^{44}Ti can also be produced in meteorites through cosmic-ray interactions, thus providing information on solar activity from the cosmic-ray exposure of such objects. Furthermore, the solar system abundance of ^{44}Ca is believed to have originated from the nucleosynthesis of ^{44}Ti and the subsequent decays.

In order to deduce the mass of ^{44}Ti ejected in the explosion using the γ-ray flux measured from a supernova remnant, one needs to know its age and distance as well as the half-life of ^{44}Ti. For Cas A, there are reasonably good historical records from the first British astronomer royal, Sir John Flamsteed, who observed this supernova in about 1680; its distance has been estimated to be 3 kpc. However, published values for the half-life of ^{44}Ti range from 39.0 to 66.6 years. This half-life range produces an uncertainty of a factor of 6 in the amount of ^{44}Ti ejected by the Cas A supernova. This uncertainty is much larger than that from theoretical estimates of the amount of ^{44}Ti produced in such a supernova event. Because of the need for an accurate and reliable value of this important quantity, we performed two experiments to determine the half-life of ^{44}Ti.

In these experiments we measured the half-life of ^{44}Ti relative to that of ^{22}Na and ^{207}Bi, respectively [1,2]. By comparing the numbers of 1157-keV γ rays from ^{44}Ti to those of 1274-keV γ rays from ^{22}Na observed from a mixed source over a period of approximately 2 years, we determined the half-life of ^{44}Ti to be 61.5±1.0 years. From an approximately 1-year long study of another mixed source, where we compared the numbers of 1157-keV γ-rays from ^{44}Ti to those of 1064-keV γ rays from ^{207}Bi, we determined the ^{44}Ti half-life to be 62±5 years. The longer half life of ^{44}Ti deduced from the our experiment implies that the amount of ^{44}Ti required to account for the observed γ-ray flux from the Cas A supernova remnant is smaller than previously suggested. This smaller amount is easier to explain in the context of recent models of supernova nucleosynthesis [3].

In the course of performing the second experiment, we discovered a set of discrepant values for the half-life of ^{207}Bi. Thus we have just begun a third and final experiment which utilizes a mixed source of ^{44}Ti / ^{207}Bi / ^{137}Cs / ^{133}Ba. In order to accurately determine the half-life of ^{207}Bi, we will compare the rate of the ^{207}Bi 569-keV γ-ray to that of the nearby 662-keV line from ^{137}Cs. We will then determine the half-life of ^{44}Ti by comparing the rate of the 1157-keV ^{44}Ti line to that of the ^{207}Bi line at 1064 keV. This new measurement will take at least one year.

Footnotes and References

† Universidade de Sao Paulo, Sao Paulo, Brazil

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