Measurement of the half-life of ^{8}Li

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We present results of a measurement of the beta-decay half-life of ^{8}Li using an ^{8}Li radioactive ion beam implanted in a Si detector. The half-life is found to be 840.3±0.9 ms.

I. INTRODUCTION

Measurement of the half-lives of beta-decaying nuclides can, in some cases, provide information both about details of nuclear structure and, more importantly, of fundamental aspects of the interactions involved. An example of such information is provided by ^{8}Li, which has been used by Wilkinson and Alburger[1] to search for the possible existence of second class currents. Clearly the accuracy with which one can determine any half-life thus defines the accuracy with which such basic questions can be answered, or the limits that can be placed on such effects.

In this Brief Report we present results of a new measurement of the half-life of ^{8}Li using a radioactive beam of ^{8}Li ions. While the limit we impose on that half-life is somewhat better than those of previous measurements, our technique is sufficiently different, so that is is of interest not only as a check on previous results, but also as an illustration of a way to determine other half-lives with higher precision than has previously been attained.

II. EXPERIMENTAL DETAILS

The experiment involved use of of the Lawrence Livermore National Laboratory–Ohio State University (LLNL-OSU) radioactive ion-beam (RIB) facility, described in previous publications.[2] We generated ^{8}Li ions from an 18 MeV ^{7}Li beam from the LLNL FN tandem van de Graaff accelerator incident on a D_2-filled gas cell. The cell was designed with internal collimation so that ^{7}Li ions scattered from the entrance window could not be emitted through the exit aperture of the cell. The ^{8}Li ions were produced via the ^{2}H(^{7}Li,^{8}Li)^{1}H reaction.

The ^{8}Li ions that passed out through the exit window of the cell went into a double-triplet magnetic quadrupole spectrometer that was configured to select the ^{8}Li ions from all those exiting the gas cell. Central to the spectrometer's capability to perform this function is a set of slits at the ion optical crossover between the two quadrupole triplets and an electrostatic deflector located just prior to the slits. The beam intensity used in this experiment was about 400 ^{8}Li ions per second; it was purposely kept this low to keep dead-time effects in the data acquisition system small. The ^{8}Li beam from the spectrometer was focused onto a 50 mm^2 50-μm thick Si surface-barrier detector located about three meters downstream from the entrance to the spectrometer. In an earlier attempt to measure the ^{8}Li half-life, we used a CaF_2 scintillator as the detector; it was found to become activated, apparently from the interaction of the ^{8}Li with the F, producing a background decay and an attendant uncertainty in the data analysis.

The ^{8}Li ions which implanted in the Si detector decay to the first excited state of ^{8}Be. While the electrons from that decay deposit some energy in the detector, the dominant signal observed is that from the decay of ^{8}Be* into two alpha particles usually having a total energy of about 2.9 MeV. In our experiment the ^{8}Li ions were implanted sufficiently deep so that most of the energy from the two alphas was deposited in the detector. The energy spectrum seen in our detector is shown in Fig. 1; the broadness of the energy peak and the high-energy tail mainly reflect the very large width of the first excited state in ^{8}Be.[3] Also evident is the low-energy tail due to noise in the detector. Such events were excluded in the analysis.

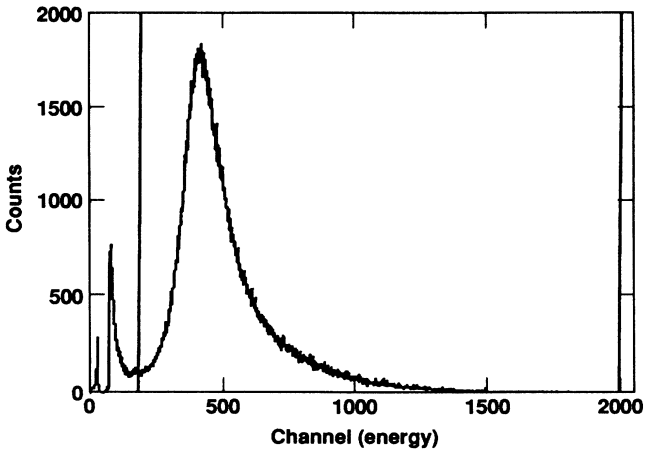

FIG. 1. Energy spectrum from the decay of ^{8}Li implanted in a Si detector. The vertical lines indicate the energy gate used for events included in the time spectrum. Each channel corresponds to 0.0064 second.

Events were taken in a cyclical mode in which the ^{7}Li beam was incident on the gas cell for two seconds, and then was deflected away for ten seconds. Detection of decay events was begun 100 ms after the beam was deflected away and continued until 900 ms before the deflector was turned off. The time after the initiation of a data acquisition cycle at which a ^{8}Li decay event occurred was determined via use of a Hewlett Packard Model 3325A Synthesizer/Function Generator, acting as a precision pulser operating at 5 kHz. At each decay event the number of pulses since the start of the data acquisition cycle was read. The on-line computer then stored the number of events occurring between each pair of pulses, i.e., during each 0.0002 s. The resulting number of events versus the number of pulses emitted after the initiation of the cycle produced the exponential decay curve characteristic of ^{8}Li.

Limitations to the accuracy of this technique can arise from several sources. Clearly the statistical accuracy of the data and the time calibration of the time spectrum will be fundamental limitations. The latter was performed by calibrating the Hewlett-Packard precision pulser to an Efratom Model PTB-100 Precison Time Base/Frequency Standard, which is referred to a ^{87}Rb standard with an uncertainty of $<2\times10^{-9}$. The Hewlett-Packard precision pulser was found to agree with the Efratom Standard with an uncertainty of $<1.2\times10^{-6}$. This uncertainty contributes negligibly to the overall result. The statistical accuracy of the data obtained in half a day of running provided a measurement of the ^{8}Li half-life to a fraction of a ms. However, in addition to these two sources of uncertainty, dead-time effects and possible background contributions to the decay spectrum can contribute to the overall uncertainty; these effects are discussed in the following.

Dead time can have a very significant effect on the overall result since it will depress the part of the decay spectrum which occurs earliest after the beam is deflected, and which is statistically most significant. It will thus tend to produce a larger lifetime than the correct one if correction is not made for the effect. We therefore put a pulser into our spectrum with the beam on to measure the necessary correction, then measured the deviation from flatness in the resulting time spectrum for the pulser events. The effect of dead time immediately after the beam was deflected was found to be about 3%. The pulser spectrum was fitted with the function

$$\text{Yield}=\text{Yield}_0[1-\exp(-\lambda t)] .$$

The measured curve for ^{8}Li was then divided by this function to produce the dead-time-corrected curve. The event rates between the pulser run and the data acquisition run were the same to less than ±5%, which, since the dead-time correction results in a half-life correction of about 6 ms, introduces an uncertainty in the half-life of ±0.3 ms.

The dead-time corrected data for ^{8}Li decay are shown in Fig. 2. In that figure the axis labeled "Counts" is actually the number of events per each 32 pulser pulses, or 0.0064 s. The data were fit with an exponential decay curve assuming that all the events seen by the detector were only from the decay of ^{8}Li, i.e., there was no background assumed. The residual counts after fitting are shown in the lower part of Fig. 2. The time spectrum contained virtually no counts after about six seconds, demonstrating that no long-lived nuclides were being made in the ^{8}Li implantation. The possibility of a short-lived contributor was tested for by fitting different portions of the decay spectrum separately to see if different half-life values would result from the different portions. Since the first portion would be much more sensitive to a background decay having a shorter half-life than that of ^{8}Li than would later portions, this gives a measure of short-lifed contributions. The results from the separate fits for the resulting half-life, together with their respective time regions, are 840.3±0.9 ms (0.64–8.32 s), 842.0±1.0 ms (1.92–8.32 s), and 843.3±1.6 ms (3.20–8.32 s). The closeness of these three results suggests that the only decay contributing to our time spectrum was that of ^{8}Li. The fit to the dead-time-corrected data set produced the lifetime of 840.3±0.9 ms, with the uncertainty including the dead-time correction.

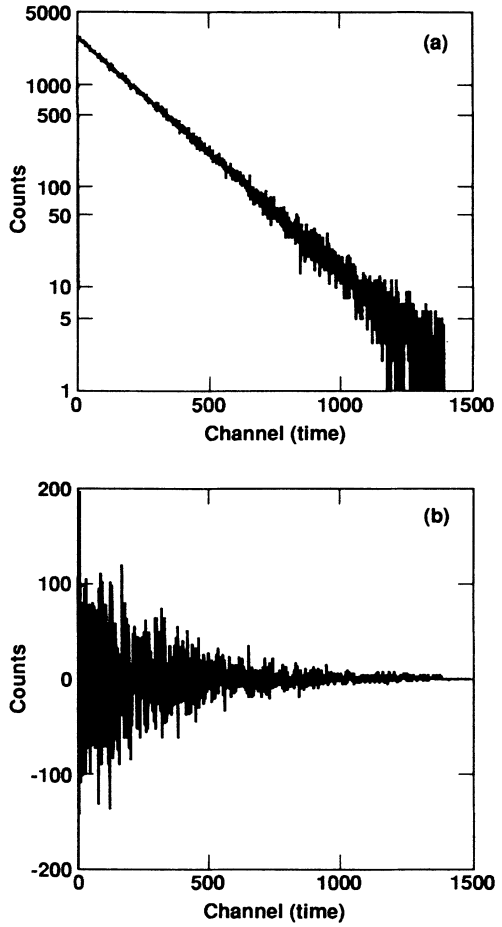

FIG. 2. (a) Number of dead-time-corrected ^{8}Li decay events versus time after data acquisition began. (b) Residual counts after fitting the dead-time-corrected curve with a decaying exponential.

Previous results obtained for the ^{8}Li half-life are summarized in Ajzenberg-Selove.[4] Recent measurements include those by Wilkinson and Alburger[1] of 838±6 ms, and by Mingay[5] of 836±3 ms. Our result is in agreement with those. Another recent experiment[6] obtained a value of 844±0.7 ms, a result with which our result, though close, is not in agreement. However it should be noted that their analysis apparently did not include a dead-time correction. As noted above, even though our count rate was kept low, had we not corrected our data for dead-time effects we would have obtained a half-life 6 ms higher than the value we did obtain.

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[1]D. H. Wilkinson and D. E. Alburger, Phys. Rev. Lett. **26**, 1127 (1971).

[2]K. E. Sale, R. W. Bauer, R. N. Boyd, G. J. Mathews, R. C. Haight, and P. B. Corn, Nucl. Instrum. Methods Phys. Res. B **24/25**, 490 (1987).

[3]E. K. Warburton, Phys. Rev. C **33**, 303 (1986).

[4]F. Ajzenberg-Selove, Nucl. Phys. **A413**, 76 (1984).

[5]D. Mingay, S. Afr. J. Phys. **2**, 107 (1979).

[6]D. H. Classen and H. Dinter, Nucl. Phys. **81**, 155 (1966).