Half-life of ^{71}Ge

W. Hampel
Max-Planck-Institut für Kernphysik, Heidelberg, West Germany

L. P. Remsberg
Brookhaven National Laboratory, Upton, New York 11973
(Received 4 October 1984)

The ^{71}Ge half-life has been redetermined in a series of measurements using different source preparation and counting techniques. The adopted value is 11.43 ± 0.03 days.

The half-life of ^{71}Ge is an important quantity for the gallium solar neutrino experiment to be performed by an international collaboration and designed to detect the low-energy neutrino flux from the sun.[1-3] This is because the *ft* value for the ^{71}Ge decay derived from the half-life is needed in order to calculate the cross section for neutrino capture in ^{71}Ga leading to the ^{71}Ge ground state. Table I summarizes the literature values of the ^{71}Ge half-life.[4-8] It is obvious that there are large discrepancies among the different results. In addition, all of these measurements, except one, are older than twenty-five years. We, therefore, have redetermined the ^{71}Ge half-life.

^{71}Ge decays by K(88.0%), L(10.3%), and M(1.7%) electron capture.[8] The K shell fluorescence yield is 52.8%.[9] The decay of the ^{71}Ge can thus be monitored by either counting the $K\alpha$ and $K\beta$ x rays with a solid source in front of a Ge x-ray detector or use of GeH_4 as part of the counting gas in a proportional counter which predominantly detects the Auger electrons. We have applied both of these techniques in six different experiments. ^{71}Ge was obtained either by the ^{70}Ge(n,γ) reaction in neutron irradiations of germanium (samples of natural isotopic composition and samples enriched in ^{70}Ge) or from the decay of 64-h ^{71}As produced by the ^{69}Ga(^{3}He,n) reaction (target enriched in ^{69}Ga). The absence of other radionuclides in the source, which in principle could interfere in the ^{71}Ge half-life determination, has been ensured by the time delay between ^{71}Ge production and start of counting (at least 11 days) to allow for the decay of short-lived species and/or by the chemical procedure of the source preparation. This has been checked by measuring the γ activity of the sources with a Ge(Li) detector. The only nuclide whose absence cannot be verified in this way is 288-day ^{68}Ge which also decays by electron capture; however, it was estimated that the activity ratio ^{68}Ge/^{71}Ge was always less than 10^{-5} at the beginning of counting. A ^{68}Ge contribution at this level has virtually no influence on the evaluated ^{71}Ge half-life.

The counting data have been analyzed by means of the CLSQ decay curve analysis program.[10] The results are summarized in Table II. In four of the six runs we have measured duplicate samples prepared under the same conditions. It turns out that, within the statistical errors, the duplicate measurements as well as the results from different

TABLE I. ^{71}Ge half-life values reported in the literature.

Measured half-life (days)	Remarks	Reference
11	^{71}Ga(d, $2n$), first observation	4
11.4 ± 0.1	^{71}Ga(d, $2n$), chemical separation, decay followed for 9 half-lives	5
12.5 ± 0.1	^{70}Ge(n, γ), solid source within proportional counter, decay followed for 3 half-lives	6
10.5 ± 0.4	^{75}As(p, $2p3n$), chemical separation, end window GM counter	7
11.15 ± 0.15	^{70}Ge(n, γ) solid source, Ge(Li)-x-ray detector	8

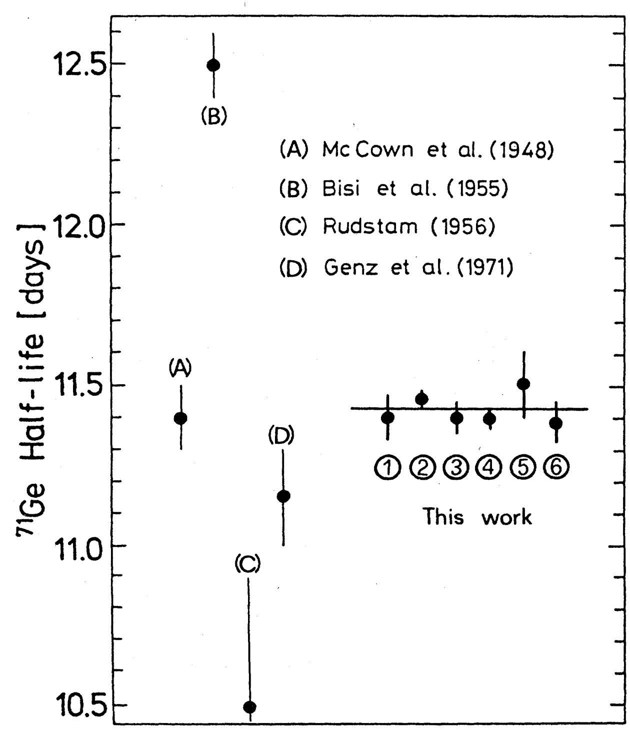

FIG. 1. ^{71}Ge half-life: Comparison of the new data with literature values. Numbers in circles refer to the run number in Table II.

TABLE II. Summary of the new ^{71}Ge half-life determinations.

Run No.	Detector	^{71}Ge source	Energy region analyzed (keV)	Duration of run (days)	Number of single measurements	Resulting ^{71}Ge half-life (days)
1	Ge x-ray detector	Semiconductor Ge (n,γ)	8.7–10.7 $(K_\alpha+K_\beta)$	56	2×35	11.43 ±0.08 11.40 ±0.08 11.41 ±0.06
2	Ge x-ray detector	GeS_2 (^{71}As decay)	8.7–9.8 (K_α)	61	49	11.46 ±0.02
3	Ge x-ray detector	Semiconductor Ge (n,γ)	8.5–10.9 $(K_\alpha+K_\beta)$	90	2×20	11.35 ±0.06 11.45 ±0.05 11.41 ±0.04
4	Ge x-ray detector	Ge enriched in ^{70}Ge(96.2%) (n,γ)	8.5–10.9 $(K_\alpha+K_\beta)$	90	2×20	11.41 ±0.03 11.41 ±0.03 11.41 ±0.02
5	Proportional counter (100 cm^3)	GeH_4+P10 gas (n,γ)	Integral (> 0.1)	138	2×12	11.52 ±0.13 11.50 ±0.14 11.51 ±0.10
6	Proportional counter (5 cm^3)	GeH_4+P10 gas (^{71}As decay)	8.8–12.0 (K peak)	59	26	11.39 ±0.06

runs are all in agreement with each other. Figure 1 shows the results of the present work along with the literature values.[5–8] The adopted value for the ^{71}Ge half-life is the weighted mean of all six runs, 11.43 ±0.03 days (indicated in Fig. 1 by the horizontal bar). The error assigned to this value is about twice the statistical error in order to account for possible systematic errors.

Our new half-life value is 2.5% larger than the only other recent determination, 11.15 days.[8] The reason for this difference is not known. On the other hand, the new value is considerably lower than that used so far for the evaluation of the ^{71}Ga solar neutrino capture cross section.[1] This value, 11.8 days,[11] is the weighted averaged of the literature values.[5–8] Our new half-life increases this cross section by 3.2%. Also, the uncertainty in the cross section contributed by the uncertainty in the half-life has been made negligible.

One of the authors (W.H.) wishes to thank the members of the Chemistry Department for their hospitality during his stay at the Brookhaven National Laboratory. This research was performed in part under contract with the U.S. Department of Energy and supported by its Office of Basic Energy Sciences.

[1]J. N. Bahcall, Rev. Mod. Phys. **50**, 881 (1978).
[2]W. Hampel, in *Science Underground—1982 (Los Alamos)*, Proceedings of the Workshop on Science Underground, AIP Conf. Proc. No. **96**, edited by Michael Martin Nieto *et al.* (AIP, New York, 1983), p. 88.
[3]J. N. Bahcall, W. F. Huebner, S. H. Lubow, P. D. Parker, and R. K. Ulrich, Rev. Mod. Phys. **4**, 767 (1982).
[4]G. T. Seaborg, J. J. Livingood, and G. Friedlander, Phys. Rev. **59**, 320 (1941).
[5]D. A. McCown, L. L. Woodward, and M. L. Pool, Phys. Rev. **74**, 1311 (1948).
[6]A. Bisi, E. Germagnoli, L. Zappa, and E. Zimmer, Nuovo Cimento **2**, 290 (1955).
[7]G. Rudstam, Ph.D. thesis, Uppsala University, 1956.
[8]H. Genz, J. P. Regnier, J. P. Pengra, and R. W. Fink, Phys. Rev. C **3**, 172 (1971).
[9]H. U. Freund, H. Genz, J. B. Silverts, and R. W. Fink, Nucl. Phys. **A138**, 200 (1969).
[10]J. B. Cumming, Brookhaven National Laboratory Report No. 6470 (unpublished).
[11]K. R. Alvar, Nucl. Data Sheets **10**, 205 (1973).