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PRECISE MEASUREMENTS OF HALF-LIVES OF SHORT-LIVED NUCLEI

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Abstract: The half-lives of short-lived nuclei produced by 14 MeV or thermal neutron bombardments were measured with Ge detectors in the spectrum multi-scaling mode. The corrections for the pile-up loss and the dead time were performed by applying both source and pulser methods. A possible systematic uncertainty was checked by changing the fitting data points. Half-lives of ^{13}N, ^{18}F, ^{24}Na, ^{27}Mg, ^{28}Al, ^{37}S, ^{38}K, ^{42}K, ^{52}V, ^{62}Cu, ^{94m}Nb and ^{116m}In were determined with relative uncertainties of 0.05 to 0.8%.

(Half-life measurement, short-lived nuclei, neutron irradiation, Ge detector, spectrum multi-scaling)

Introduction

The half-life is one of the most fundamental constants on the radioactive isotopes. In the activation cross section measurements for short-lived nuclei the uncertainty brings a strong effect to the results. It is required that the half-life values are precise and reliable. Most of the values previously published have been obtained with GM counter, ionization chamber, proportional counter and scintillation counter. Recently the Ge detectors have been widely used for measuring the intensity and energy of γ-rays because of their excellent energy resolution. However during last 10 years works with Ge detectors are scarce. In order to improve the precision and the reliability of the half-life values, Ge detectors were used.

Experimental

Short-lived nuclei were produced by 14 MeV or thermal neutron bombardments. The 14 MeV neutrons were generated by a 3.75 MeV Van de Graaff accelerator of Nagoya University and by the intense 14 MeV neutron generator of Osaka University (OKTAVIAN). For thermal neutron irradiation the TRIGA-II reactor of Rikkyo University (100kW) was used. A pneumatic transport system was used for irradiations.

The γ-rays were measured with a Canberra 10 % Ge(Li) detector and an ORTEC 15 % Ge detector in the spectrum multi-scaling mode. Decay was followed for about 10 times the half-life at equal intervals of 1/3 to 1/6 of the half-life using a 4096 channel analyzer[1] controlled by a MZ-80B micro-computer. An accuracy of a quarz timer was better than 8×10^{-6}. The ^{133}Ba (or ^{137}Cs) source was simultaneously measured together with the short-lived activity for the correction of the pile-up loss and the dead time (source method). A constant-pulser with a rate of 60 cps was also connected to the preamplifier (constant-pulser method). Peak areas are evaluated by summing all recorded counts in the channel interval {C-30σ, C+3σ} and subtracting the background counts (N_B), where C is the position of the peak center and σ is FWHM. N_B is given by $(6\sigma)\times(N_L+N_H)/2$, where N_L and N_H are the average count of 3 channels in the vicinity of C-3σ and that in the vicinity of C+3σ, respectively. This summing method is similar to that by Debertin and Schötzig[2]. Half-life measurements were repeated 6 to 2 times for each short-lived nucleus.

Results and discussion

During the measuring time the counting rate greatly changes. For the correction of the pile-up loss and the dead time the source method seems most reliable. But statistical fluctuations of the reference source happen and the peak area evaluation might be effected by the decaying Compton backgrounds. On the other hand the constant-pulser method gives good statistics and no effect to the γ-ray spectrum. However the peak shape of the pulser is different from that of the γ-radiation and the constant-pulser produces no random pile-up pulse by itself. Hence there might be some difference between both the methods at high counting rates. The variation of the peak intensity ratios of the ^{133}Ba (or ^{137}Cs) and the pulser was examined. An example in the decay of 9.7 m ^{62}Cu is shown in Fig. 1. The ratios went down to a constant as

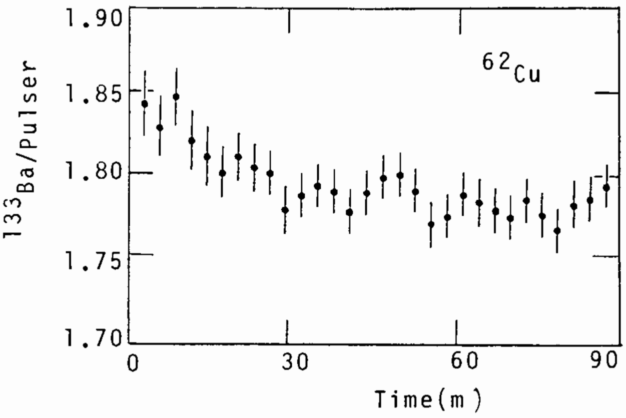

Fig. 1 Peak intensity ratios of ^{133}Ba and pulser in the decay of 9.7 m ^{62}Cu.

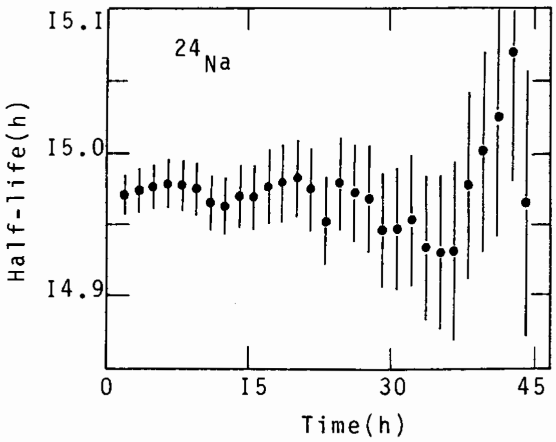

Fig. 2 Fluctuation in the half-life of ^{24}Na induced by changing fitting data points; starting from the first point, points were successively removed from the whole points.

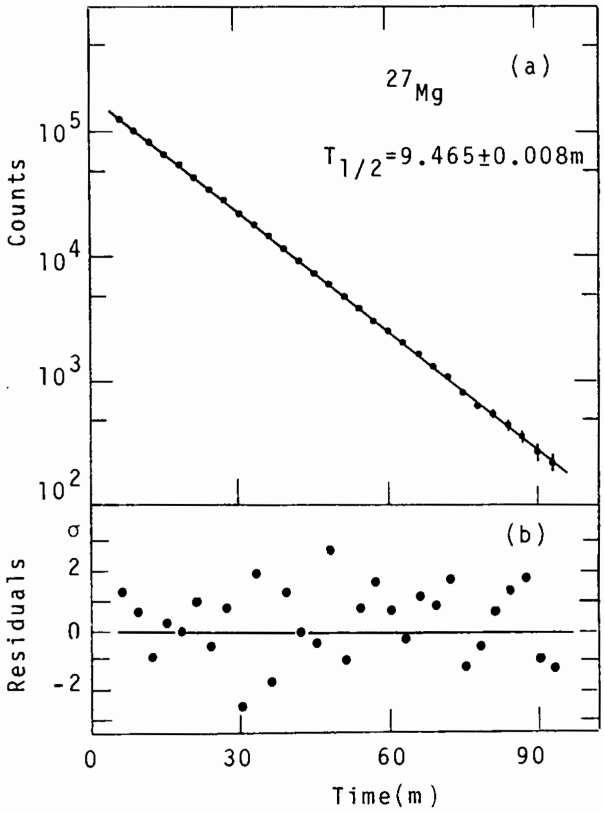

Fig. 3 Decay curve of 9.5m ^{27}Mg(a) and residuals obtained from a least-squares fitting analysis (b).

the time. If both the methods are reasonable, the ratios should be constant. Since the first 30 m data points showed a clear deviation, the higher counting rate data points were not used in a least-squares analysis. Each obtained data set was checked this way. When initial counting rates were less than 9×10^3cps, no deviation was always observed.

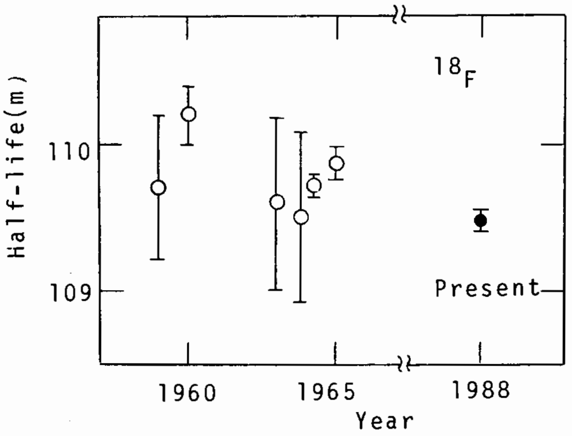

Fig. 4 Half-life of ^{18}F. Previous works taken from ref. 4.

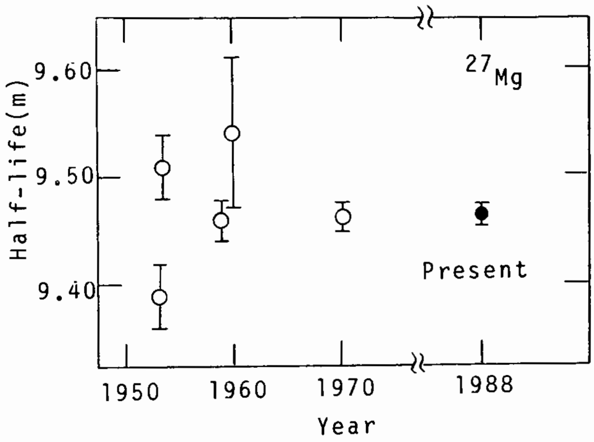

Fig. 5 Half-life of ^{27}Mg

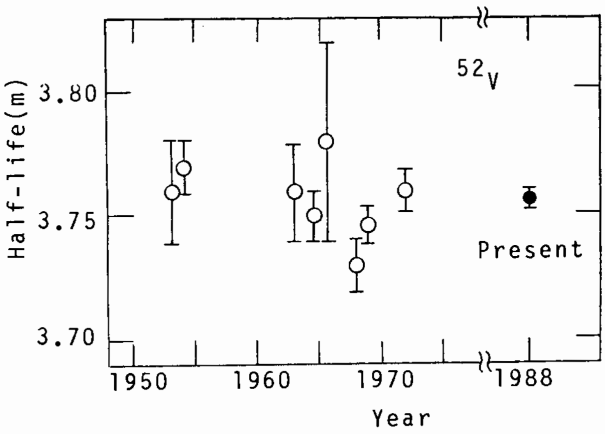

Fig. 6 Half-life of ^{52}V

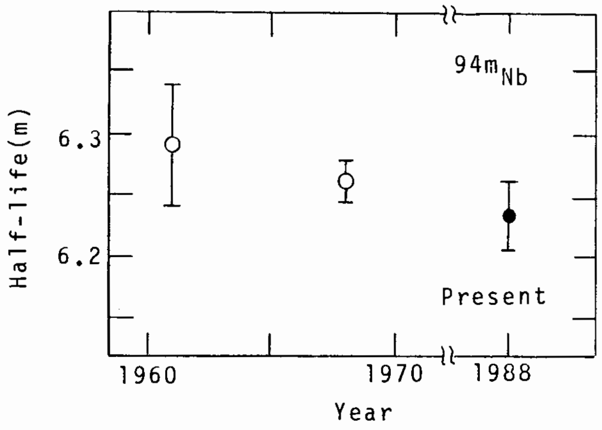

Fig. 7 Half-life of ^{94m}Nb

Table 1 Results of half-life measurements with Ge detectors

Nuclide	Production reaction	γ-ray E_γ(keV)	$T_{1/2}$ present	$T_{1/2}$ Ref.3
^{13}N	^{14}N(n,2n)	511	9.962(20)m	9.965(4)m
^{18}F	^{19}F(n,2n)	511	109.48(8)m	109.77(5)m
^{24}Na	^{27}Al(n,α)	1368	14.963(7)h	14.959(4)h
^{27}Mg	^{27}Al(n,p)	844	9.465(8)m	9.462(11)m
^{28}Al	^{27}Al(n,γ) ^{28}Si(n,p)	1779	2.239(9)m	2.2406(5)m
^{37}S	^{37}Cl(n,p)	3027	4.96(4)m	5.05(2)m
^{38}K	^{39}K(n,2n)	511	7.569(34)m	7.636(18)m
^{42}K	^{41}K(n,γ) from ^{42}Ar	1525	12.344(6)h	12.360(3)h
^{52}V	^{55}Mn(n,α) ^{51}V(n,γ)	1434	3.757(5)m	3.75(1)m
^{62}Cu	^{63}Cu(n,2n)	511	9.722(39)m	9.74(2)m
^{94m}Nb	^{93}Nb(n,γ)	871	6.232(28)m	6.26(1)m
^{116m}In	^{115}In(n,γ)	1294	54.12(6)m	54.15(6)m

Moreover, high counting rates at the beginning of the measurement might still bring systematic errors. In order to estimate possible systematic errors and the effect of counting rate on the deduced half-life, the fitting points of the measured data were chosen as follows. Starting from the first point, points were successively removed from the whole points and the remaining points were used in the analysis. The fluctuation thus induced was included in the experimental error as a systematic error. An example in the decay of 15 h ^{24}Na is shown in Fig. 2. In Fig. 3 the decay curve of 9.5m^{27}Mg is shown.

The results are summarized in Table 1. The values from Table of radioactive isotopes[3] are shown for comparison. For more detailed comparison the examples of ^{18}F, ^{27}Mg, ^{52}V and ^{94m}Nb are shown in Fig. 4-7. Most of the present results have shown good agreement with previous works except ^{18}F, ^{37}S, ^{38}K and ^{42}K. This work with Ge detectors have improved the precision and the reliability by applying both source and pulser methods and changing the fitting data points.

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