(LNS Experiment : #2427, #2442, #2457, #2474, #2489, #2499, #2512, #2524)

Life-time measurement of ^{7}Be in beryllium metal

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The decay rate of ^{7}Be (nucleus of electron-capture decay) was measured in Be metal. The half life of ^{7}Be in Be metal (Be metal (^{7}Be)) is found to be 53.12 ± 0.05 days. We have found that the decay rate of ^{7}Be in Be metal is almost corresponding to that in graphite host, Lithium fluoride host etc. reported within the errors.

§1. Introduction

As first suggested by Segré *et al*. [1-4], electron-capture (EC) decay rates depend on the density of atomic electrons within the nucleus. Environment factors such as chemical form, pressure, etc. may alter the electron contact densities at nucleus, and thus, affect the electron-capture decay rates. Here, the nucleus ^{7}Be is a good candidate in which to look for such variations in environmental factors because of its simplest electronic structure, $1s^2 2s^2$, in the EC decay nucleus. The ^{7}Be decays directly to the $3/2^-$ ground state of ^{7}Li with a branching of 89.6 %, and goes to the first excited state in ^{7}Li ($1/2^-$ at 478 keV) with that of 10.4 %, which decays by γ emission to the ground state [5-7]. In recent research, there have been several reports of variations as a function of the host metals [8-12] and chemical forms [13-15] and pressure [16-17]. Although, a precise measurement may be still needed to obtain the absolute decay rate in the different circumstances [18-21].

Because of the uniform lattice structure (*hcp*) including ^{7}Be in Be metal, the electron contact density on ^{7}Be nucleus should be essentially surveyed. In the present study, we have measured the half-life of ^{7}Be in Be metal by using a standard clock time.

§2. Experimental procedure

Be metal (*hcp* lattice structure) of 10 mm (in diameter) × 0.3 mm (in thickness) was utilized to produce ^{7}Be uniformly in the metal. After being washed with HCl solution, the Be metal was sealed in a quartz tube (vacuum packing) of 12 mm in diameter as a target. The irradiation with a bremsstrahlung (50 MeV electrons) was carried out at the Electron Linear Accelerator, Laboratory of Nuclear Science, Tohoku University. The sample in a quartz tube was set in the middle of a sweep magnet placed on the axis of the electron beam. A platinum converter in 2 mm thickness was set in front of the sweep magnet to generate a bremsstrahlung. Then, the sample was irradiated only by the bremsstrahlung (all electrons were ruled out by the magnetic field). Therefore, the damage to a lattice of Be metal was confined to the minimum. The experimental setup for irradiation is shown in Fig.1. The ^{7}Be can be produced uniformly by the $^9Be(\gamma, 2n)$ ^7Be reaction in the Be metal. After irradiation, the sample was baked in an electric oven of vacuum packing at 1100 ℃ (a melting point of Be metal: 1278 ℃) for 1 hour to recover the lattice defect even if the lattice defect occurs by the (γ, 2n) reaction. Finally, the sample was washed again with HCl solution to clean up the surface.

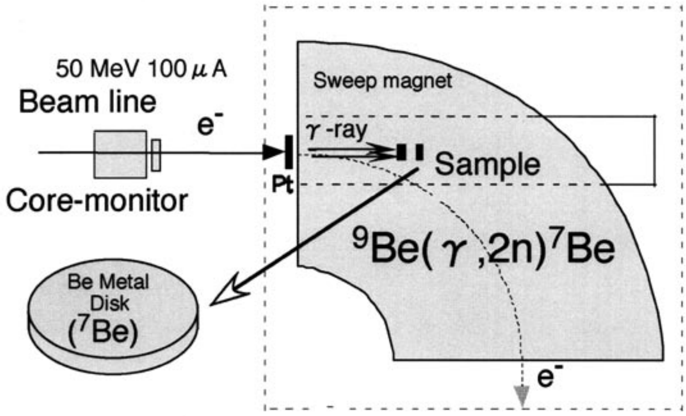

Fig.1. Setup for irradiation of Be metal.

The two samples of Be metal(^7Be) and $^7Be@C_{60}$ for reference of the sample were placed in an automated sample changer, which horizontally moved the samples in front of a γ-ray detector. This allowed the decay rates of the two samples to be measured in a comparable way. The system is shown in Fig.2. The activities of the ^7Be, the 478 keV γ-rays emanating from ^7Be, was measured with a high-purity germanium (HPGe) detector (ΔE_{FWHM} is 1.8 keV and 50 % relative efficiency) coupled to a 2048-channel pulse-height analyzer. Due to the excellent energy resolution of the HPGe detector, a good

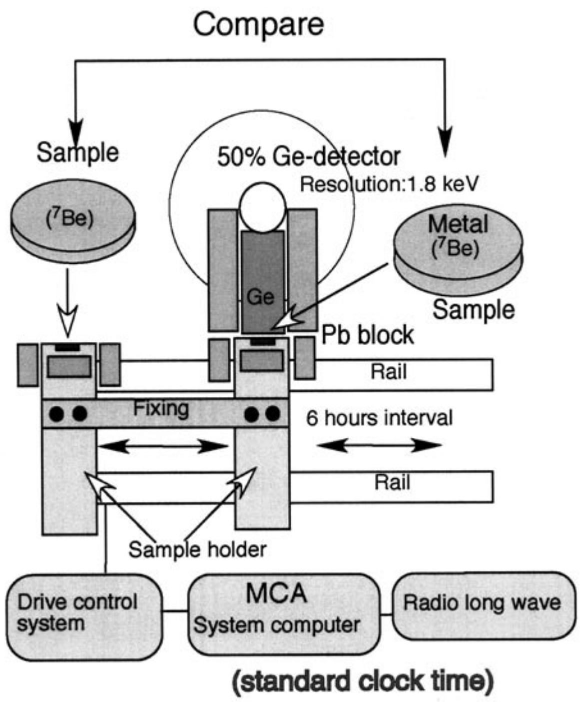

Fig.2. Experimental setup.

signal-to-noise ratio was obtained. The background was reduced by a lead shield. Therefore, the background peaks do not impair the determination of the half-life of ^{7}Be in the present experiment. The radioactivities of ^{7}Be could be uniquely detected by means of its characteristic γ-rays, and any other sources were ruled out. We measured 330 points with durations of $T_d \sim 6$ hours. Total measuring time was now 170 days that was over three half-lives of ^{7}Be. The start time for each run was taken from a time standard signal distributed via a long-wave radio center in Japan. Therefore, the uncertainty in time measurements can be neglected.

§3. Results and discussion

A typical γ-ray spectrum obtained in the sample of Be metal (^{7}Be) is shown in Fig.3. The expected γ line at E_γ = 478 keV and a natural background line at E_γ = 1461 keV can be seen as two giant peaks. No peaks were seen at around E_γ = 478 keV when the ^{7}Be sources was absent. In Fig.4, the exponential decay curve of the ^{7}Be activities for sample of Be metal (^{7}Be) is shown as a function of the time (days). The decay curve obtained in the present measurement was fitted including the statistical errors by a Minuit program distributed from the CERN Program Library. The statistical error is dominating the uncertainty in each data point in Fig.4. The uncertainty of our measurement is given by the uncertainty of the slope of the straight line fitted to the logarithm of the counts (*i.e.* counts per second) of the decay spectrum. The result for the sample Be metal (^{7}Be) is $T_{1/2} = 53.12 \pm 0.05$ days. The dead time in the data acquisition system is evaluated to be about 8 ~ 9 sec to the each running time. Therefore, the uncertainty due to the dead time is estimated to be almost 0.04 % and this value is smaller than the fitting errors of the half-life of ^{7}Be. The counting rates of the natural background, which is the 1461 keV γ-rays emanating from ^{40}K, is also shown in Fig.4. The data for ^{40}K obtained was also fitted with

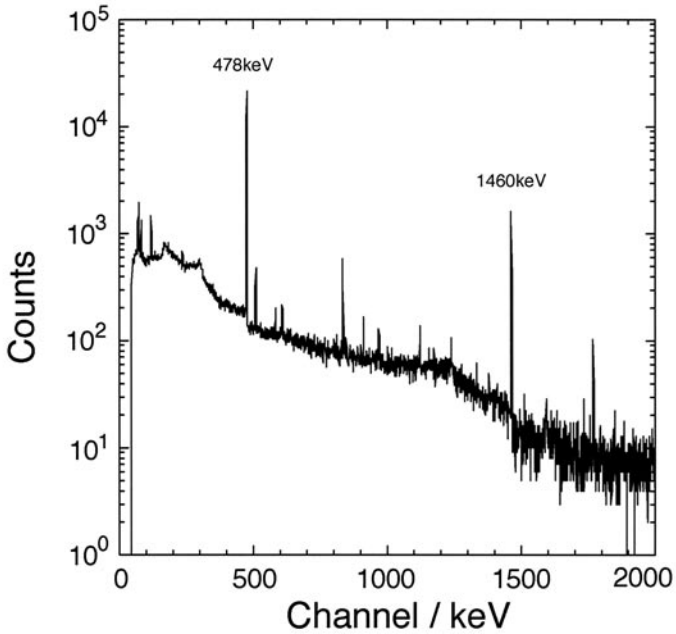

Fig.3. Typical γ-ray spectrum of the ^{7}Be in the sample of Be metal.

the same procedures. It was found that the fitted line is corresponding to a horizontal one. (It should be noted that we have also measured the half-life of ^{7}Be in the sample of ^{7}Be@C_{60}. The result have been presented in another paper [22])

The half-life obtained in the sample of Be metal (^{7}Be), $T_{1/2}$ = 53.17 ± 0.05 days, is almost corresponding to the data, LiF (^{7}Be) and graphite etc., which is reported by Jaeger *et al.* and Norman *et al.* [8, 11], in which, the start time for each run were taken from the time standard signal distributed publicly. Further, the half-life of ^{7}Be in several host materials (Graphite, Boron nitride etc.) has been summarized by Notrman *et al.* [11]. The value ($T_{1/2}$) is almost with in 53.1 ~ 53.3 days as shown in Table 1. Therefore, we found that the variation ($T_{1/2}$) of ^{7}Be for Be metal (^{7}Be) almost corresponds to the data presented so far.

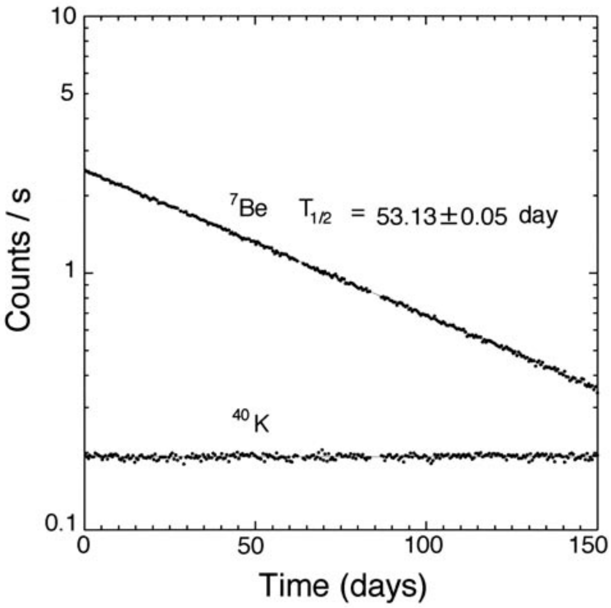

Fig.4. Exponential decay line of ^{7}Be in the sample of Be metal (^{7}Be). Background radioactivities of ^{40}K are also shown in the figure.

Table 1. Half-life of ^{7}Be in Be Metal as determined with a least-squared fit. Half-lives previously measured are also shown as a comparison.

Host material	$T_{1/2}$	Ref. No.
Beryllium	53.12 ± 0.05	This work
Lithium fluoride	53.12 ± 0.07	8)
Graphite	53.107 ± 0.022	11)
Boron niteride	53.174 ± 0.037	11)
Tantalum	53.195 ± 0.052	11)
Gold	53.311 ± 0.042	11)
Aluminum	53.17 ± 0.02	15)

§4. Conclusion

We have measured the half-life of ^{7}Be which is produced in Be metal using a HPGe detector taking into account a standard time. We found that the half-life of ^{7}Be in Be metal was $T_{1/2} = 53.12 \pm 0.05$ days.

Acknowledgments

The authors are grateful to the technical staff of the Laboratory of the Nuclear Science, Tohoku University for beam-handling.

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[18] The half-life of ^{7}Be in the different chemical forms has been measured in several experiments. It should be noted that: Huh [13] has reported the half-life of ^{7}Be in the different chemical forms, $Be^{2+}(OH_2)_4$, Be $(OH)_2$, and BeO, and they claimed that the observed difference is as much as 1.5% (in Ref. 13). In early study, Johlige [14] *et al.* have reported the half-life of ^{7}Be in similar chemical forms (Be^{2+} $(OH_2)_4$, BeO, etc.) and the variations were only within around 0.1%.

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