Half-life Measurement of 7Be in Different Chemical and Physical Environments

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VI. 1. Half-life Measurement of ^{7}Be in Different Chemical and Physical Environments

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As first suggested by Segr'e et al.[1)], the electron-capture (EC) decay rate depends on the density of atomic electrons within the nucleus. Environmental factors such as chemical forms and pressure etc. may alter the electron contact densities in the nucleus and thus affect the electron-capture decay rates. The nucleus of ^{7}Be is a good candidate in which to look for such variations in environmental factors because of its simple electronic structure, $1s^2 2s^2$, in the EC decay nucleus. The ^{7}Be decays directly to a $3/2^-$ ground state of ^{7}Li with a branching of 89.6%, it goes with a branching of 10.4% to a first excited state of $^{7}Li(1/2^-$ at 478 keV), which decays by γ emission to the ground state. In experiments to determine the decay rate of ^{7}Be in various environments, different chemical forms and/or host materials have been investigated by several groups. Differences found in the decay rate of ^{7}Be as a function of different chemical forms, host materials and under high pressure had been limited almost to within 0.2%. In recent studies, however, large variations have been observed as a function of different chemical forms and pressure etc[2,3)]. Therefore, a precise measurement is still needed to obtain the absolute decay rate. So far, the success of the ^{7}Be endohedral C_{70} ($^{7}Be@C_{70}$) has allowed us to measure the half-life of ^{7}Be inside C_{60} and C_{70}[4,5)]. Then, we have measured the half-life of ^{7}Be in the sample of $^{7}Be@C_{70}$ by using a reference method.

To produce the source of ^{7}Be, Li_2CO_3 was used in powder form. The grain size of the materials was smaller than 100 meshes (20 μm). Purified fullerene (C_{70}) was carefully mixed with each material (weight ratio=1:1) in an agate mortar, adding a few ml of carbon disulfide (CS_2). After drying up, about 100 mg of the mixture sample was wrapped in a pure aluminum foil of 10 μm in thickness for irradiation. Irradiation with 16 MeV protons was performed at the Cyclotron and Radioisotope Center, Tohoku University.

The beam current was typically 2.5 μA and the irradiation time was about 24 hours. The ^{7}Be can be produced in the ^{7}Li(p,n) reaction. The irradiated sample was dissolved in o-dichlorobenzene and filtered through a Millipore filter (pore size=0.2 μm) to remove insoluble materials. The soluble portion was injected into a HPLC device equipped with a 5PBB (Cosmosil) at a flow rate of 3 ml/min. For confirmation of fullerenes and their derivatives, a UV detector was installed with a wavelength of 290 nm. In order to measure the γ-rays emanating from ^{7}Be, eluent fractions were collected for 30 sec intervals. The $^{7}Be@C_{70}$ portion was checked with 478 keV γ-ray by a HPGe-detector. After confirmation of the existence of $^{7}Be@C_{70}$, the sample was dried and pressed to use a measurement sample.

In order to measure the half-life at T=293K and 5K, the $^{7}Be@C_{70}$ sample was placed in the top of a sample holder and a He closed-cycle cryostat, respectively. Here, the two samples, $^{7}Be@C_{70}$ (fastened in sample holder (293K) or the cryostat (5K)) and Be metal (^{7}Be) (293K), were placed in a computer-controlled sample changer, which precisely moved the samples in front of a γ-ray detector. The measurement was started after the $^{7}Be@C_{70}$ sample underwent sufficient cooling at T=5K under vacuum. This arrangement allowed the decay rates of the two samples to be measured in a consistent fashion while reducing systematic errors. In the system, the internal clock time of the computer for data acquisition was constantly calibrated by a time-standard signal distributed via a long-wave radio center in Japan. The 478 keV γ-rays emanating from the EC-decay daughterof ^{7}Be (the first excited state of ^{7}Li) were measured using a HPGe detector coupled to a 4096-channel pulse-height analyzer. Here, we set the specific measurement duration to 21600 seconds (21480 seconds for the live measurement time and 120 seconds for the dead-time of the measurement system plus the sample exchange) for one data point. The amount of radioactivity associated with the decay of ^{7}Be (E_{γ}=478 keV) could be uniquely analyzed through the identification of the characteristic γ-rays. The decay curves obtained in the present measurements were fitted, by use of the MINUIT program distributed by the CERN Program Library. The reduced chi-square values of the exponential fits are between 0.9 and 1.1. The uncertainty due to the dead time was estimated to be less than 0.04%, and the systematic error in the measurements was estimated to be less than half of the statistical errors.

In this term, we have measured the decay rates and deduced the corresponding half-lives of ^{7}Be in samples of $^{7}Be@C_{70}$ at T=293K and 5K, and in Be metal (^{7}Be) at

T=293K with durations of almost three half-lives of ^{7}Be. All data obtained so far was plotted in Fig. 1. The closed squares indicate the half-lives obtained for the $^{7}Be@C_{60}$ sample at T=293K, the open circles for those obtained for the $^{7}Be@C_{60}$ sample at T=5K and, the closed circle for the half-life of the $^{7}Be@C_{70}$ at T=293K, further, the cross symbols for that of the Be metal (^{7}Be) at T=293K. It is surprising to note that the half-life of ^{7}Be in the $^{7}Be@C_{60}$ at T=5K and that in the the $^{7}Be@C_{70}$ at T=293K as well as T=5K stays in 52.44~52.47 days. These values are dramatically different from that in the Be metal (^{7}Be) at T=293K by almost 1.5%. This fact implies that the ^{7}Be atoms are located in a unique environment inside fullerenes[6-8].

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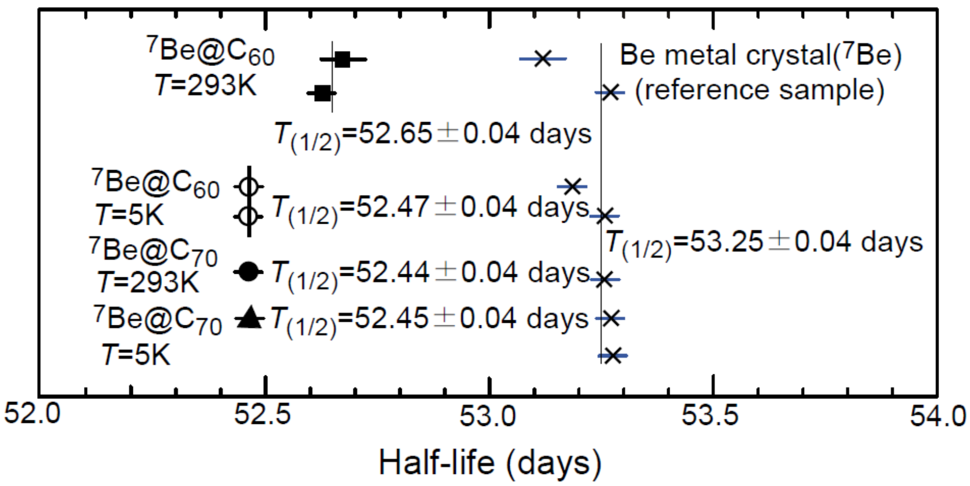

Figure 1. Half-lives are plotted: the closed squares for the $^{7}Be@C_{60}$ at T=293K, the open circles indicate the half-lives obtained for the $^{7}Be@C_{60}$ sample at T=5K, the closed circle for the $^{7}Be@C_{70}$ at T=293K, the cross symbols for the Be metal(^{7}Be) at T=293K. the closed triangle for the $^{7}Be@C_{70}$ at T=5K, the crossed symbols for Be metal(^{7}Be) at T=293K.