Study of neutron unbound states in ^{18}O by β-delayed neutron decay of ^{18}N

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Nucleus ^{18}O, which is one of the stable nuclei, consists of a core of doubly-magic ^{16}O and two neutrons. Although this nucleus has such simple structure, it is difficult to reproduce the level structure by the simple picture based on the shell model [1] or the cluster model [2]. To reveal the nuclear structure and to give an important information for nucleosynthesis (r-process, helium burning, and so on), we investigated neutron unbound states in ^{18}O by the β-delayed neutron decay of ^{18}N.

As nucleus ^{18}N has large Q_β value of 13.896 MeV, branching ratios of the β-delayed neutron ($P_{\beta n}$) and the β-delayed alpha decays are 12.0% and 12.2% [3], respectively, and half-life was reported to be 619(2) msec [4]. Although twelve β-delayed neutrons with neutron energy (E_n) of 0.58-3.22 MeV were observed in Ref. [4, 5], sum of branching ratio to each neutron unbound state (6.98%) could not reproduce the reported $P_{\beta n}$ of 12.0%. This indicates that low-energy neutron could not be observed, because the neutron detectors used in Ref. [4, 5] were not sensitive for low-energy neutrons with $E_n < 0.5$ MeV. In this work, neutron detectors with high sensitivity in low-energy region were developed to find new low-energy neutrons emitted after the β decay of ^{18}N.

Experiment was performed by using the RCNP RI beam line (EN beam line) [6, 7]. Nucleus ^{18}N was produced by the direct reaction of ^{18}O(^{9}Be,^{9}B)^{18}N. The primary ^{18}O beam at 9.4 MeV/u with the beam intensity of 0.6 pμA bombarded the Be target with thickness of 40 μm. The ^{18}N^{7+} RI beam was transported through an aluminum degrader (50 μm thick) at dispersive focal plane F1 to a gold catcher foil (50 μm thick) in a FRP (Fiber-Reinforced Plastic) vacuum chamber at achromatic focal plane F2. The beam intensity of the secondary ^{18}N beam was 2×10^3 pps. The beam purity of ^{18}N was 92.3% with the beam contaminants of ^{17}N (6.2%) and ^{16}C (1.5%).

Beta rays were detected by four thin plastic scintillators (1.5 mm thick $\times$ 173 mm $\times$ 66 mm) surrounding the gold catcher at 36 mm with a solid angle of $\sim$90%. Gamma rays emitted after the β decay of ^{18}N were measured by three coaxial high-purity germanium detectors with total photo-peak efficiency of $\sim$1% at 1 MeV. Neutrons emitted after the β decay were detected by six thick plastic scintillators (12.5 mm thick $\times$ 150 mm $\times$ 150 mm). These neutron detectors with time resolution (FWHM) of 1.0 nsec were installed at 70 cm from the gold catcher. These detectors were developed to measure neutrons with E_n in the wide energy region from a few hundreds keV to a few MeV. High-resolution measurement of neutron kinetic energy was carried out by means of time-of-flight (TOF) method. Flight time of neutron was deduced from time difference between β ray and neutron detected by thin and thick plastic scintillators, respectively. Total event number of β-neutron coincidence data was $\sim 5\times10^4$ for 18 hours.

Figure 1 shows the TOF neutron spectrum. We found a new intense low-energy neutron peak with E_n = 0.35 MeV emitted after the β decay of ^{18}N with intensity of 3.6% per 100% β decay. Twelve neutron peaks reported in Ref. [4, 5] were also observed in this work. In Fig. 1, neutron peaks originating from the beam contaminants of ^{17}N (E_n = 0.38, 1.17, and 1.70 MeV) and ^{16}C (E_n = 0.81 and 1.16 MeV) were additionally seen. Beam purities of ^{18}N, ^{17}N, and ^{16}C, mentioned above, were obtained from the analysis of this neutron data.

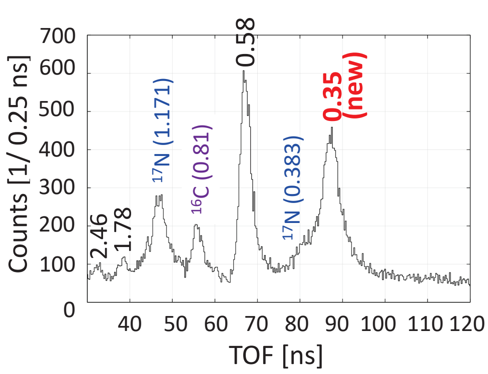

Figure 1: TOF neutron spectrum.

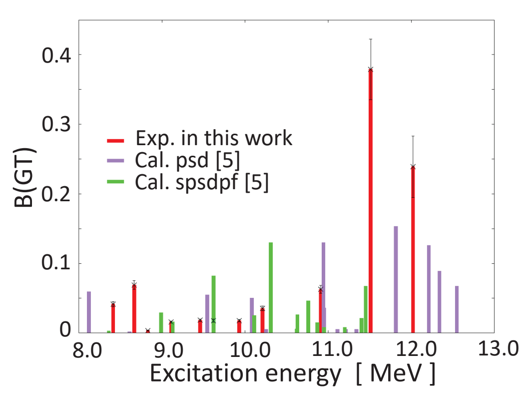

Figure 2: Experimental and theoretical B(GT) values vs. excitation energy of neutron unbound states.

Decay scheme of the β-delayed neutron of ^{18}N was constructed by the analysis of β-n and β-n-γ coincidence data. Sum of branching ratio of the β-delayed neutron decay to each neutron unbound state was deduced in this work to be 12.7(5)%, which is consistent with the reported value of $P_{\beta n}$ of 12.0(13)% [3].

Figure 2 shows the experimental B(GT) values (red bar) determined in this work for each neutron unbound state. These values are compared to the shell model calculations with WBT interaction in the model spaces of *pdf* (violet bar) and *spsdpf* (green bar) [5]. The experimental excitation energy of neutron unbound states and the experimental B(GT) values can not be reproduced well by the shell model calculations. Note that the experimental large B(GT) value can be seen in Fig. 2 at the excitation energy of ∼11.5 MeV, though there are no theoretical intense peaks. Theoretical calculations might be better by using simple shell model or collective model. To solve this problem, future model calculations would be required.

Results of this experiment were summarized in Ref. [8].

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