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Neutron capture cross section and capture gamma-ray spectra of ^{89}Y

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Abstract. The neutron capture cross section of ^{89}Y was measured by the time-of-flight method in an energy range from 15 to 100 keV. A pulse-height weighting technique was applied to derive the capture yield. The absolute cross section was determined based on the standard reaciotn ^{197}Au$(n,\gamma)^{198}$Au reaction. The neutron capture γ-ray spectrum was derived by unfolding the pulse-height spectrum with detector response functions.

1 Introduction

In the slow neutron capture process (*s*-process) model, heavier nuclides than ^{56}Fe are synthesized through the neutron capture process and successive β-decay in stellar environments. The *s*-process occurs along the stability line of the nuclear chart. The *s*-process model calculations are performed based on nuclear data of neutron capture cross sections and β-decay half-lives. Among the nuclear data inputs, the neutron capture cross sections of neutron magic nuclides (N = 50 and 82) are particularly important because the neutron magic nuclides form bottlenecks of the *s*-process reaction network due to their small neutron capture cross sections.

Yttrium-89 is an $N = 50$ neutron magic nuclide. The reliable neutron capture cross sections of ^{89}Y and other $N = 50$ isotones (^{88}Sr and ^{90}Zr) are necessary in the *s*-process model calculation. In our previous works, we have already measured the neutron capture cross sections of ^{88}Sr and ^{90}Zr in the Tokyo Institute of Technology [1, 2]. The present work was carried out to measure the cross section of the ^{89}Y$(n,\gamma)^{90}$Y reaction. The neutron capture γ-ray spectrum that provides more information on the reaction mechanism was also measured.

2 Experiments and Data Analysis

Experimental details of the Tokyo Tech experiments were described elsewhere [3]. Only a brief description is given here. Neutrons were generated through the ^{7}Li$(p,n)^{7}$Be reaction, bombarding a lithium target with a proton beam from a Pelletron accelerator at an incident proton energy of 1.902 MeV, 22 keV above the reaction threshold. The neutron energy distributes from a few keV

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to 100 keV. The time-of-flight (TOF) method was employed to measure the incident neutron energy. Neutrons were detected with a small ^{6}Li glass scintillator located at a flight distance of 30 cm from the neutron source. The yttrium sample was Y_2O_3 powder cased in a graphite container. An isotopically enriched sample was not needed since Yttrium is a monoisotopic element. The net yttrium mass was 18.5 g. The size was 55 mm in diameter and 7.5 mm in thickness. A gold sample with the same diameter was also used as a standard sample. The sample was placed at a flight distance of 12 cm. Gamma-rays emitted from the sample were detected with an NaI(Tl) detector with an anti-Compton shield [4]. Runs for ^{89}Y, Au and blank were repeated to average out change of experimental conditions. Both the pulse height (PH) and the TOF of signals from the NaI(Tl) detector were recorded event-by-event in a list-data format.

For data analysis, we set eight TOF gates: 15-20, 20-23, 23-26, 26-29, 29-39, 39-46, 46-54 and 54-100 keV. Two-dimensional PH-TOF data were sorted with the eight TOF gates, thereby giving gated foreground PH spectra. Another sorting with a background gate that is a fast-neutron absent TOF region provided background PH spectra. After subtracting the background PH spectra from the foreground PH spectra, net PH spectra were obtained.

A pulse-height wighting technique was employed to derive the neutron capture yields [5]. The weighting function was made from detector response functions calculated by the Monte Carlo simulation method. The absolute $^{89}\mathrm{Y}(n,\gamma)^{90}\mathrm{Y}$ cross sections were determined in reference to the standard $^{197}\mathrm{Au}(n,\gamma)^{198}\mathrm{Au}$ cross section from JENDL-4.0. In addition, corrections for neutron self-shielding and multiple scattering, chemical impurities, and discriminated γ-rays below 620 keV were made.

Capture γ-ray spectrum was derived by unfolding the net PH spectrum with the detector response functions. The detector response functions were calculated from Monte Carlo simulations. Spectrum unfolding was done with a unfolding code FERDOR [6].

3 Results and Discussion

Figure 1 shows the obtained cross section. Previous measurements and evaluated cross sections from JENDL-4.0 and ENDF/B-VII.1 are also plotted for comparison. The errors of the present data include the statistical and systematic uncertainties. Except for Gate 1 (15-20 keV), the total errors are 5 - 6%. The error in Gate 1 is 9%. As shown in Fig. 1, errors are smaller than previous experiments. The evaluated cross sections agree with the present results in the high energy region but deviate below 30 keV.

The unfolding capture γ-ray spectrum is shown in Fig. 2. The bars above the spectrum indicate the energy positions of primary γ-rays calculated from known excited levels of ^{90}Y. Transitions to the ground and the first excited states were observed clearly.

4 Summary

We measured the neutron capture cross section and capture γ-ray spectrum of ^{89}Y in the energy region from 15 to 100 keV. The capture cross section was determined with a smaller uncertainties than previous measurements. Evaluated cross sections from JENDL-4.0 and ENDF/B-VII.1 agree with the present work in high energy region but disagreement was found in low energy region. The neutron capture γ-ray spectrum was derived by unfolding the PH spectrum with detector response functions. We plan to measure the capture cross section of ^{89}Y at a higher energy point (550 keV). Combining with the upcoming high energy data, the present results must be included in future evaluation of nuclear data libraries.

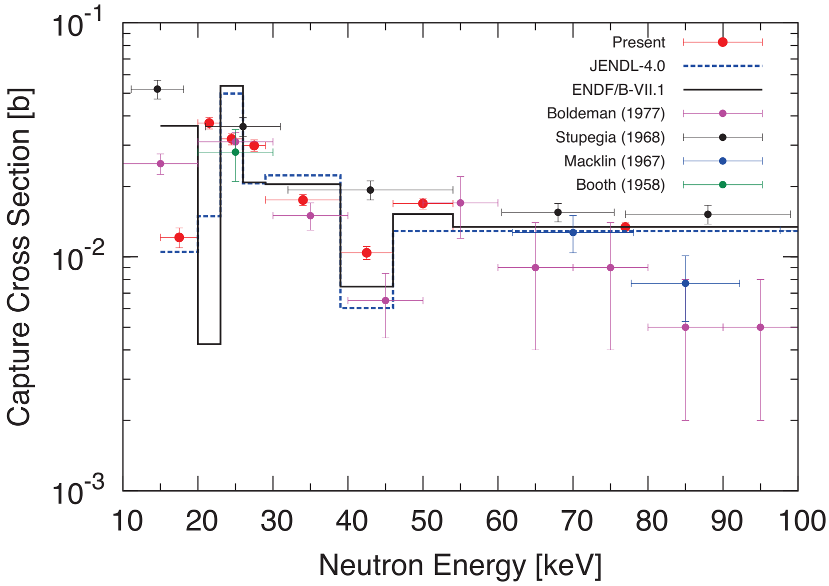

Figure 1. Neutron capture cross section of ^{89}Y compared with previous measurements and evaluated cross sections.

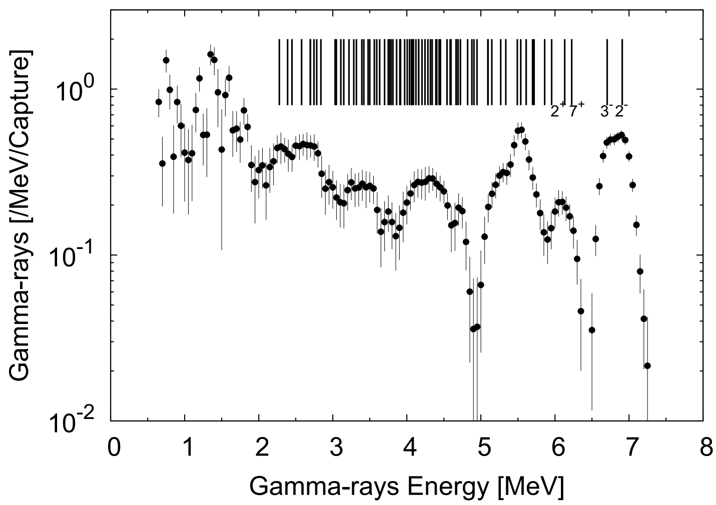

Figure 2. Neutron capture γ-ray spectrum of ^{89}Y. The bars indicate primary γ-ray positions calculated from known excited levels of ^{90}Y.

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