CO2-1 Production Rate of *p* Nuclei Sm-146 via Pm-146 Using Bremsstrahlung

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INTRODUCTION: The *p* process, which synthesizes the neutron-deficient nuclei, proceeds via photo-disintegration, γ process, and rapid proton capture process, *rp* process, on existing heavy seed nuclei in the temperature of $T_9 = 2–3 \times 10^9$ K. The high temperature can be achieved in explosive environments, such as the O/Ne layers of Type II supernovae and deflagration flame fronts in Type I supernovae. Production rate by the photo-disintegration is expressed by the product of cross section and photon flux based on Plank's black body spectrum. Thus, cross section at the vicinity of threshold is of great importance for quantitative understanding of the *p* process. We have performed cross section measurement of ^{147}Sm(γ,n)^{146}Sm and ^{147}Sm(γ,p)^{146}Pm using low energy bremsstrahlung, focusing on ^{146}Sm which abundance at the time solar system has been known [1].

EXPERIMENTS: Oxide of isotopically enriched samarium-147 and gold foil as a flux monitor were irradiated using bremsstrahlung which generated from bombardment of electron to a platinum plate. Activity of ^{146}Pm in the samples were measured using a HPGe detector after the irradiation. The sample, which ^{146}Pm gamma-ray peak was scarcely detected, was measured at Ogoya Underground Laboratory. Spectrum of bremsstrahlung was calculated with GEANT4 code [2].

RESULTS: Photoactivation yield of ^{147}Sm(γ,p)^{146}Pm reaction in the bremsstrahlung is shown in Fig. 1 together with a theoretical calculation. Product of bremsstrahlung spectrum by GEANT4 and cross section by TALYS, which incorporates Hauser-Freshbach model [3], were considered for the theoretical calculation. Photoactivation experiments with the bremsstrahlung have the limitation that the data need to be unfolded to obtain a cross section. The cross section was extracted using the product of Breit-Wigner distribution and collection factor which depends on energy. Parameters of 15 MeV for median and 4.3 MeV for natural width of were used for the Breit-Wigner distribution, based on a giant dipole resonance of *A*=147. The extracted cross section by the unfolding and TALYS calculation are shown in Fig. 2. As a future plan, ^{146}Sm/^{147}Sm atom ratio will be determined with an accelerator mass spectrometry at Argonne National Laboratory [4].

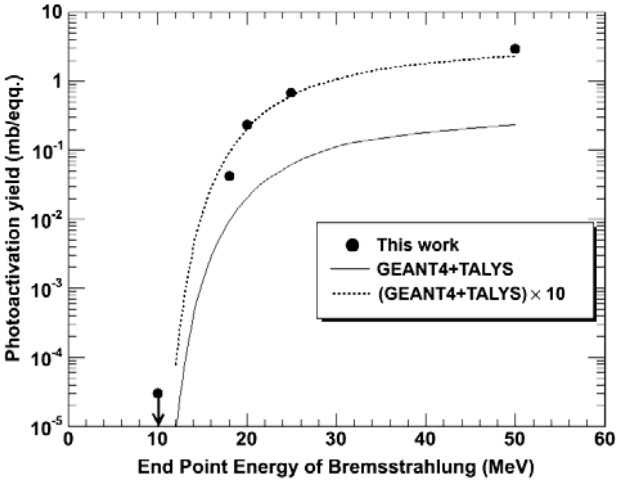

Fig. 1. Photoactivation yield of ^{147}Sm(γ,p)^{146}Pm reaction in bremsstrahlung.

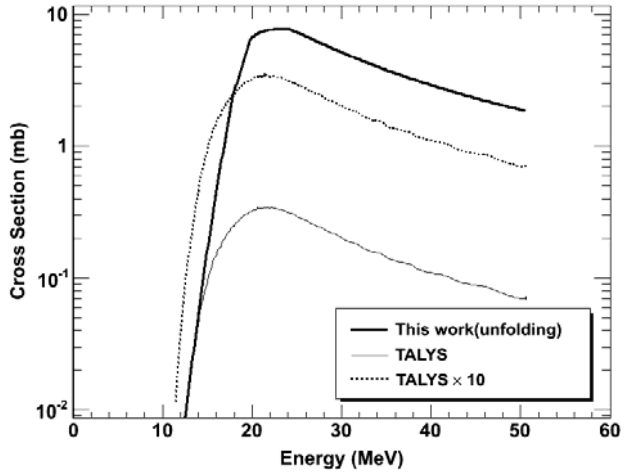

Fig. 2. Cross section of ^{147}Sm(γ,p)^{146}Pm reaction.

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採択課題番号 21009 光核反応を用いた p-プロセス核種 Sm-146 の元素合成に関する研究　共同通常
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（東北大・核理研）廣瀬健太郎、大槻勤（金沢大・LLRL）浜島靖典　（京大炉）八島浩、関本俊

CO2-2 Development of a Calibration Method for Neutron Detectors Using White Neutrons with Energy Range from Thermal to 10 keV

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INTRODUCTION: Precise determination of epithermal neutron fluence is important in various studies such as characterization of a thermal neutron reference field and irradiation dose evaluation in a boron neutron capture therapy [1]. Epithermal neutrons mixed in the thermal neutron reference field have an effect on calibration of neutron detectors. In the present study, we have developed a new calibration method for neutron detectors using a white neutron source with the epithermal energy range. In this calibration method, precise efficiency curves are experimentally determined by two-dimensional simultaneous measurements of the pulse height of detector outputs with the flight time. We also developed an epithermal neutron spectrometer for neutrons up to 10 keV.

EXPERIMENTS: Epithermal neutrons were produced by a photo-neutron reaction using a water-cooled tantalum target at the KURRI Linac [2]. At first, a lead shadow bar was set near the target to reduce effects of "gamma flash" from the neutron source. The position of the shadow bar was adjusted and optimized by remote control. Figure 1 shows output pulses observed with a total-absorption-type BGO scintillation detector before and after setting a shadow bar. The BGO detector counts neutrons by the ^{10}B(n,αγ) reaction and the reference neutron spectrum from the neutron source was obtained in a energy range up to 10 keV by the time-of-flight (TOF) method. Fast neutrons with energy above 10 keV from the neutron source can disturb calibration focusing on the epithermal region for detectors with a neutron moderator, because the fast neutrons appear in epithermal neutron region on the TOF spectrum due to a slowing-down time of a few microseconds in the moderator. A 2"×2" NE213 liquid scintillation detector was used to measure the fast neutrons with the TOF method.

The epithermal neutron spectrometer is composed of a ^{3}He proportional counter, a polyethylene moderator and filters made of Ag, Co, W, Mo and Mn having several absorption resonances. Response functions of the spectrometer were measured by the TOF method. The epithermal neutron spectrum was determined by an unfolding method using the response functions.

RESULTS: Figure 2 shows the TOF spectrum measured with the liquid scintillation detector, indicating that the gamma flash component is rejected by the pulse shape discrimination with the liquid scintillation detector. Linac-produced noise signals were found on the TOF spectrum which should be suppressed by improving the signal processing method.

The epithermal neutron spectrometer gave the response functions in Figure 3(a) and the epithermal neutron spectrum in Figure 3(b) obtained by being unfolded with SAND-II code. Figure 3(b) also shows the neutron spectrum obtained from the TOF measurement with the BGO detector. The two spectra are in good agreement except in the thermal energy region.

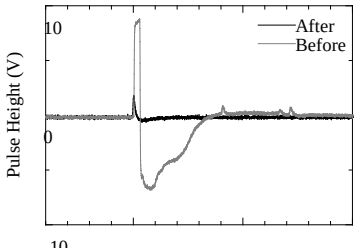

Fig. 1. Output pulses observed with the BGO detector before and after setting the shadow bar.

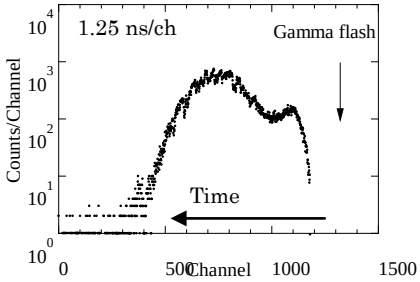

Fig. 2. TOF spectrum measured with the liquid scintillation detector.

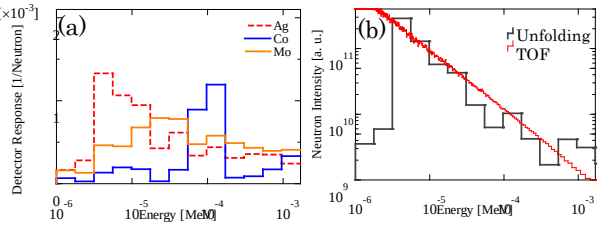

Fig. 3. (a) Response functions of the epithermal spectrometer for the Ag, Co and Mo filters, (b) epithermal neutron spectra obtained with the unfoilding method and the TOF method.

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採択課題番号 21019　　熱中性子フルエンス率の測定の高度化と　　共同通常
その国際標準化に関する研究
（産総研）原野英樹、松本哲郎、増田明彦、西山 潤（名大）井口哲夫、瓜谷章、河原林順、渡辺賢一、富田英生、辻 大樹、佐藤陽介、野村祐介（京大・原子炉）堀 順一、櫻井良憲