Neutron Capture Cross Section Measurements of Sn-120,122,124 in ANNRI

1. Introduction

In the study of transmutation of radioactive waste, accurate data of the neutron-capture cross section for long-lived fission products (LLFPs) are required [1]. ^{126}Sn, which is produced in spent-fuels of light water reactors with relatively large yields, is one of the most important LLFPs. However, for ^{126}Sn, there is only one experimental data at the thermal energy [2]. Accurate cross-section measurements for ^{126}Sn are required.

A ^{126}Sn sample for a nuclear data experiment contains a large amount of tin stable isotopes, because they also have fission yields and the sample is normally prepared only through a chemical process from spent fuel. These isotopes have large effects on neutron-capture cross-section measurements for ^{126}Sn. Therefore, to obtain accurate cross-section data for ^{126}Sn, a series of neutron-capture cross-section measurements for all the tin stable isotopes have been started with Accurate Neutron-Nucleus Reaction measurement Instrument (BL04:ANNRI) of Materials and Life science experimental Facility (MLF) in Japan Proton Accelerator Research Complex (J-PARC). Neutron capture cross sections for ^{112}Sn and ^{118}Sn have been measured.[3] In this proposal, neutron-capture cross-sections for ^{120}Sn, ^{122}Sn and ^{124}Sn are measured in the neutron energy range from 10 meV to 2 keV.

[1] H. Harada et al., J. Nucl. Sci. Tech. Suppl. 2, 366 (2006).

[2] S. Zhang et al., Radiochimica Acta 94, 385 (2006).

[3] A. Kimura, K. Hirose, et. al., Nuclear Data Sheets 119, 150 (2014)

2. Experimental procedure

Capture cross section measurements with neutron Time-of-Flight (TOF) method were performed with the array of Ge spectrometer in ANNRI. In the measurements, two cluster-type Ge detectors were used, but the coaxial-type Ge detectors were not used because they suffered from severe electrical noise. The pulsed neutron beam was collimated to a 7 mm at the sample position.

Samples were isotopically enriched metallic tin with a diameter of 5 mm. The weight of the Sn-120, 122 and 124 samples was 68.7, 99.7 and 88.2mg, respectively. The samples were put in fluorinated ethylene propylene (FEP) film bag and attached to a polytetrafluoroethylene (PTFE) sample holder. The total measuring times for Sn-120, 122 and 124 samples were about 63, 30 and 32 hours, respectively.

To deduce the background, measurements for a Pb-208 sample with a diameter of 5 mm, a weight of 159.7 mg, and an isotopic enrichment of 99.60 mole % and a sample holder with an empty FEP film bag (Blank) were also carried out during 16 and 22 hours.

3. Data Analysis

The analysis procedure was almost the same manner as that described in Ref.[4].

The energy dependences of the relative cross section for Sn- 120, 122 and 124 samples were deduced by using the TOF spectra with the dead time correction, the deduced backgrounds, the self-shielding and multiple scattering correction factors and the neutron flux.

Correction factors for neutron self-shielding and multiple scattering were calculated with the Monte Carlo simulation code MCNP. In the calculation, the sample size, shape, mass, isotope abundances, and intensity distribution of neutrons were taken into consideration. The neutron spectrum was measured by detecting the 478-keV gamma rays emitted from the Boron sample.

Results of the neutron capture cross sections for the Sn- 120, 122 and 124 samples were obtained by normalizing the relative cross sections to the data in JENDL-4.0 at the largest 426.7-eV, 107.0-eV and 62.05-eV resonances, respectively.

4. Results

The preliminary neutron capture cross section of Sn- 120, 122 and 124 were obtained in the energy range from 20 meV to 4 keV with the array of germanium detectors in ANNRI at MLF/J-PARC.

The results were obtained by normalizing the relative cross sections to the data in JENDL-4.0 at the largest resonances, respectively.

The 67.32- and 150-eV resonances for Sn-120 and the 579- and 950-eV resonances for Sn-124 which are listed in JENDL-4.0 and/or ENDF/B VII.1 were not observed.

Three new prompt gamma-ray emissions were observed in the Sn-122 capture reactions.