MLF Experimental Report	提出日 Date of Report 2017/6/26
課題番号 Project No. 2015A0305 実験課題名 Title of experiment Measurement of ^{6}Li(n,γ) cross section up to 10 keV 実験責任者名 Name of principal investigator Hiroyuki Makii 所属 Affiliation Japan Atomic Energy Agency	装置責任者 Name of responsible person Atsushi Kimura 装置名 Name of Instrument/(BL No.) ANNRI / BL-04 実施日 Date of Experiment 2017/2/23-2017/3/3

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。(適宜、図表添付のこと)
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

In this experiment, we used a following sample.

Name of sample	chemical formula	from shape	Quantity
Li-6 Carbonate	Li_2CO_3	solid	0.5 g
Li-7 Carbonate	Li_2CO_3	solid	0.5 g

We also used B, Au, Si, and melamine samples to estimate the neutron flux at the sample position and to make energy calibration of the NaI(Tl) detectors.

2. 実験方法及び結果 （実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

The measurement has been carried out with use of the ANNRI installed at beam line BL-04. The NaI(Tl) detectors placed at the flight length position of 27.9 m are used to detect the γ-rays from the samples. Two NaI(Tl) detectors with different size are placed at 90° (330 mm in diameter and 203 mm in length) and 125° (203 mm in diameter and 203 mm in length) with respect to the neutron beam direction. An enriched $^{6}Li_2CO_3$ sample with a diameter of 10 mm and a weight of about 0.5 g are located in a beam duct made of carbon fiber. The purpose of this study was to deduce the excitation function of the ^{6}Li(n,γ)^{7}Li reaction and the γ-ray branching ratio of transitions from a neutron capture state to low-lying states in ^{7}Li in incident neutron energy range up to 10 keV using time-of-flight (TOF) technique. Because of small cross section was expected for the ^{6}Li(n,γ)^{7}Li reaction, particular attention should be given to identify the background events due to the neutrons scattered by the sample. For this purpose, an enriched $^{7}Li_2CO_3$ sample was irradiated in the same arrangement. In addition, we also measure the γ-ray spectrum without placing any sample at the sample position to identify background events due to the neutrons scattered from the various instruments of chopper, filter, and collimator placed upstream the sample position. Neutron flux at the sample position was obtained by

measurements of $^{10}B(n,\alpha)^{7}Li$ and $^{197}Au(n,\gamma)^{198}Au$ reactions using B and Au samples since the cross sections of the reactions are well known. Energy calibration of the NaI(Tl) detectors was made using the γ–rays from the $^{28}Si(n,\gamma)^{29}Si$ and $^{14}N(n,\gamma)^{15}N$ reactions with Si and melamine samples. Measuring time and total dose of protons for each sample are summarized in Table 1. Proton beam power in this study was about 150 kW.

Table 1: Measurement time and total dose of proton beam.

sample	Measuring time [hours]	Proton dose (10^{19} protons)
^{6}Li	67.1	6.75
^{7}Li	48.3	4.82
Empty	52.2	5.30
B	5.8	0.60
Au	4.7	0.48
Si	1.2	0.13
melamine	3.7	0.60

Due to the simple structure of the nuclear levels of ^{7}Li, the $^{6}Li(n,\gamma)^{7}Li$ reaction cross section can be obtained by summing the partial cross sections. Here the $^{6}Li(n,\gamma)^{7}Li$ reaction proceeds through direct radiative transitions to the ground ($J^{\pi} = 3/2^{-}$) and to first excited ($J^{\pi} = 1/2^{-}$) states in ^{7}Li as shown in Fig. 1. The partial cross sections and the γ–ray branching ratio can be deduced from the intensities of the 6.77 MeV and 7.25 MeV γ–rays in ^{7}Li. Figure 2 shows γ–ray spectrum for the ^{6}Li sample putting the gate on TOF of neutrons corresponding to the incident neutron energy (E_n) range at $2 \leq E_n \leq 34$ keV. We see clearly the peak considered to be the γ–ray from the $^{6}Li(n,\gamma)^{7}Li$ reaction around 6.8 MeV. Here the background events contained in the spectra of the ^{7}Li and empty samples are already subtracted. The analysis to determine the absolute partial cross sections and the γ–ray branching ratio is now in progress.

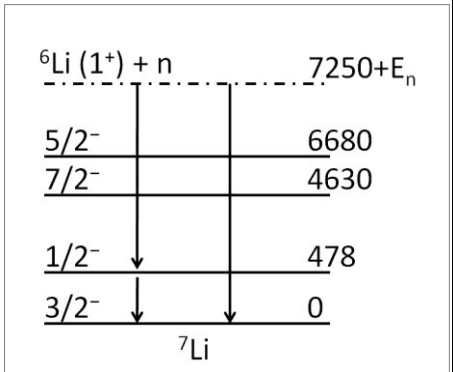

Figure 1. Level scheme of ^{7}Li.

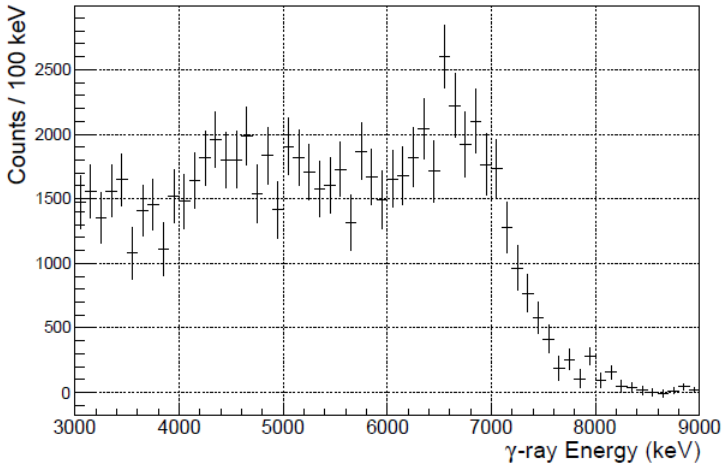

Figure 2. γ–ray spectrum obtained by NaI(Tl) detector for the ^{6}Li sample putting the gate on TOF corresponding to the neutron energy (E_n) at $2 \leq E_n \leq 34$ keV.