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The neutron total cross-section measurement of ^{56}Fe and ^{57}Fe by using Japan Proton Accelerator Research Complex facility

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1. Introduction

The measurement of neutron cross section using Time-Of-Flight (TOF) method gives significant information for the nuclear data research. In the present work, the neutron total cross section of ^{56}Fe and ^{57}Fe has been measured in the energy range between 10 eV and 100 keV by using the neutron beam produced from 3-GeV proton synchrotron accelerator. The 3-GeV proton synchrotron accelerator is located at Japan Proton Accelerator Research Complex (J-PARC) facility in Tokai village. In this study, the neutron total cross section data measured by ^{6}Li glass scintillator detector was compared with the evaluated values of ENDF/B-VII.0.

2. Experimental Procedure

The neutron total cross section and capture cross section of ^{56}Fe and ^{57}Fe were measured by the neutron beam produced from the 3-GeV proton synchrotron accelerator in J-PARC facility. The high intensity pulsed neutron beams are produced by using 3-GeV protons with 1 MW power and a repetition rate of 25 Hz incident to neutron target.[1] The neutron beam pulses are double bunch with 50 nsec width during 600 nsec and neutron target is mercury with hydrogen moderator. There are 23 neutron beam lines, and the experiment was done at 4th beam line (BL04) which has 30 m Time-Of-Flight path length. The NaI gamma spectrometer and ^{6}Li glass scintillator was installed to measure capture and total cross section at 4th beam line. The NaI gamma spectrometer and ^{6}Li glass scintillator are placed at 28 m and 30 m respectively from the neutron target to measure total cross section and capture cross section simultaneously. Furthermore, the sample is placed at 28 m from the neutron target that is in front of the NaI gamma spectrometer.

The neutron total cross section based on the transmission measurement is determined by the ratio of neutron transmitted from the sample-in position to sample-out position. In order to measure the transmission data, the incident neutron spectrum was measured by means of a time-of-flight method with a ^{6}Li glass scintillation detector. The set of notch filters such as ^{nat}B, Au, C, Mn, Co, Ag, and In were used for the energy calibration of ^{6}Li glass scintillator detector. Moreover, the incident numbers of neutrons were recorded at the same time to get the normalization factor of each measurement. The measured samples are ^{56}Fe and ^{57}Fe, the physical parameters of the samples are given in Table 1. The total data taking time for ^{56}Fe and ^{57}Fe samples each was 15 hours, and for sample-out and notch filter was each for 2.5 hours.

Table I: Physical parameters of the samples

Sample	Purity (%)	Thickness (mm)	Size (cm^2)
^{56}Fe	99.94%	0.5	5×5
^{57}Fe	95.90%	0.4	5×5

3. Data Analysis and Results

The neutron spectrum measurement by ^{6}Li glass scintillator shows the neutron time-of-flight to neutron counts with a 16 nsec width per channel. In order to calibrate the energy of spectrum data by time-of-flight method, we used notch filter with accurate and well known energy resonance peaks.

The neutron total cross section is related to the neutron transmission rate. The transmission rate is the ratio of the attenuated and incident neutron fluxes. However, to normalize the neutron intensity between the sample-in and sample-out, the neutron counts obtained integrating TOF counts in each channel were used. Accordingly, the neutron total cross section is obtained as follows,

$$\sigma(E_i) = -\frac{1}{N}\ln\left(\frac{\Phi_{sample}(E_i)/M_{sample}}{\Phi_{open}(E_i)/M_{open}}\right) \quad (1)$$

Where $\Phi_{sample}(E_i)$ and $\Phi_{open}(E_i)$ are the neutron flux for the sample-in and sample-out, M is the numbers of incident neutrons, and N is the atomic density per cm^2 of the sample. This calculation was performed by the program written by ROOT code. Additionally, the statistical uncertainty contributed to cross section error is given by

$$\Delta\sigma = \frac{1}{N}\sqrt{\frac{1}{\Phi_{open}} + \frac{1}{\Phi_{sample}}} \qquad (2)$$

The results of the calculation of neutron total cross section for the samples of ^{56}Fe and ^{57}Fe were compared with ENDF/B-VII.0 are shown in Figure.1.

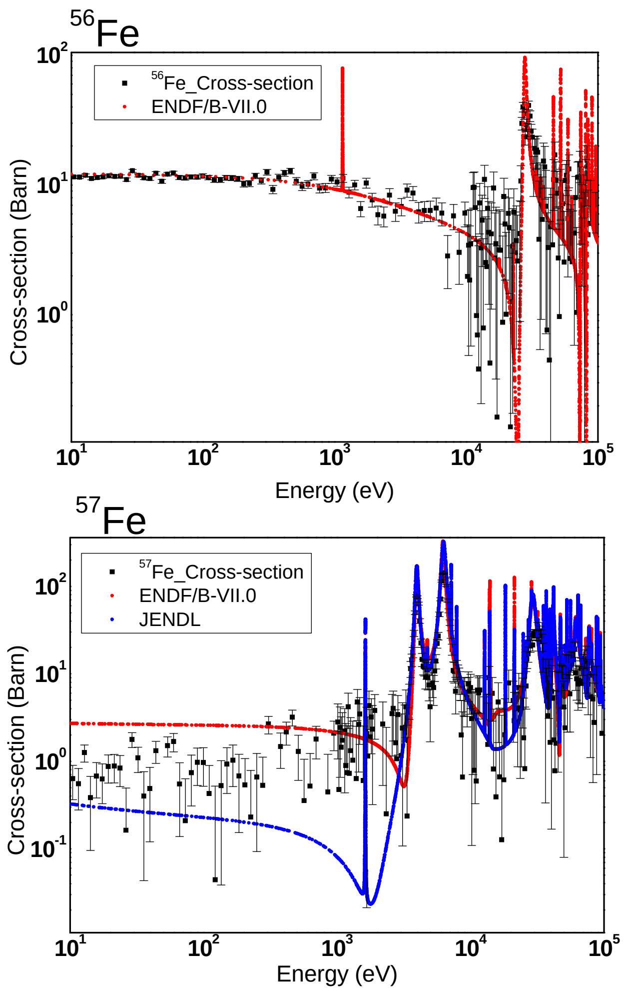

Fig.1. Comparison of the present result with the evaluated data of ENDF/B-VII.0.

4. Conclusions

The experiment results are nearly in good agreement with the evaluated data of ENDF/B-VII.0. The total cross section result for ^{56}Fe sample shows large error in high energy region and the peak shown in evaluated data is not notable at the present result. The result for ^{57}Fe sample shows approximately similar to evaluated data but the error is large on the whole region. We think we could not see the sharp resonance in the ^{56}Fe is too thin sample thickness. Due to the small cross sections of ^{57}Fe and too thin sample thickness, the results are much more fluctuated. We need at least 10 times more thick samples for ^{57}Fe in order to get reasonable result.

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