Nuclear Data for Science and Technology (1988 MITO), 295- 297, Copyright © 1988 JAERI.

MEASUREMENT OF THE CROSS SECTION FOR $^{27}Al(n,2n)^{26}Al(T_{1/2}=7.16x10^5Y)$ REACTION WITH ACTIVATION TECHNIQUE AROUND 14 MeV

S. Iwasaki, J. R. Dumais and K. Sugiyama

Department of Nuclear Engineering, Tohoku University
Aramaki-Aza-Aoba, Sendai 980, Japan

ABSTRACT: Measurement of the cross section for $^{27}Al(n,2n)^{26}Al$ ($T_{1/2}=7.16x10^5Y$) reaction have been made at RTNS-II around 14 MeV using activation technique. The irradiation was performed as an add-on experiment of a main long term, high temperature irradiation on the various fusion materials with maximum fluence in the RTNS-II operation. Reliable cross sections have been obtained from 14.1 MeV to 14.7 MeV and the results are not fully consistent with the previous data.

(aluminum, (n,2n) cross section, 14 MeV, long life activity)

Introduction

As well known, the structural material activation is one of the most important issues in the material development of the magnetic fusion energy program[1]. Aluminum has been considered one of the low activation materials among the structural material candidates, because of the short lives of their main activities. However, the (n,2n) reaction on aluminum leaves the very long activity of about 10^6years. The cross section for this reaction had not been measured because of its very long life and small cross section. Therefore its evaluated cross section has large uncertainty. Very recently, however, Smither and Greenwood[2] of Argonne National Laboratory, measured the cross section using the RTNS-II (Rotating Target Neutron Source II) of Lawrence Livermore National Laboratory and accelerator mass spectrometry technique. Sasao et al.[3] of Nagoya University, also measured the cross section using activation technique at Oktavian, the intense 14 MeV neutron source of Osaka University. Their cross section data were smaller than those of an evaluated cross section file of ENDF/B-IV by about factor of two or three, and also disagree with each other.

Aim of the present study is to obtain the high reliable cross section data of the reaction than above two by using the maximum fluence irradiation condition among the experiments performed at RTNS-II.

Samples and Irradiation

According to the results of the previous experiments, we have chosen rather large size of the sample. Aluminum disc samples of 2 cm-diameter and 0.5 cm-thickness were machined from high purity aluminum metal ingot. Total 21 samples were devided into 7 groups by three discs, and lapped by Kapton tape, and fixed on an aluminum arch frame. The samples with the frame was positioned beside the HEDL's material irradiation container with two temperature furnace of the main experiment at a distance of about 12 cm from the source position around the rotating target to span their angles from 25 to 85 degrees with respect to the incident deuteron beam. The main experiment was conducted to irradiate the material samples up to the maximum fluence of $10^{19}(n/cm^2)$. The experimental set up of the present experiment is shown in Fig. 1.

Twenty-one iron dosimetry foils were put on the surface of each aluminum disc to evaluate the neutron fluence on the sample through the irradiation term. In addition, seven sets of zirconium-niobium foils were attached in front of the each aluminum set to measure the average energies of the incident 14-MeV neutrons, using so called Zr-Nb ratio method, and were taken out after first 4-days of the irradiation.

The irradiation was continued from March 26 to November 3 of 1985. Through the term, the irradiation was stopped totally 41 times with the exception of short term machine stops by sparkouts, for ion source filament changings, and so forth. The irradiation history was recorded by acquiring the signal output of the two calibrated proton recoil counters and two propotional counters in the target room into a computer system.

Activity Measurement

The irradiated samples were cooled for three months and then shipped to Tohoku University. The activity measurement was initiated after additional cooling for eight months using a 70cc Ge(Li) detector at Cyclotron Radio Isotope Center

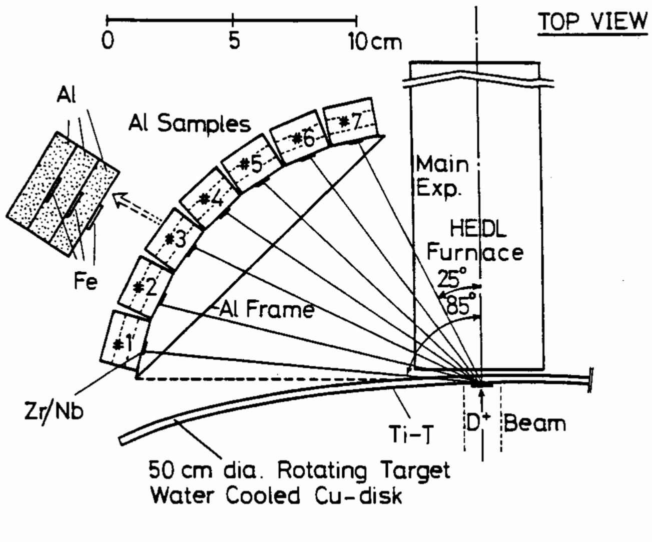

Fig. 1 Experimental set up of the present irradiation.

of the University. The distance of the samples from the surface of the detector was 20 mm. The measurement times were about 75 to 120 hours per sample, and total peak counts of the 1809keV gamma-rays associated to the decay of the aluminum-26(g.s.) were between 1500 and 6000. A typical measured gamma ray spectrum is shown in Fig. 2. Many gamma ray lines due to the activities of impurities in the sample are observed besides the natural background, but these gamma rays did not disturbed the 1809keV line. The measurement has finished for fourteen samples of the first and second column of neutron target side of each group, hitherto.

The activities of the iron dosimetry foils were also measured with the same detector system. The activities for the zirconium and niobium foils had been measured at RTNS-II by using a 80cc HPGe detector in the two or three days after the taking-out the foils.

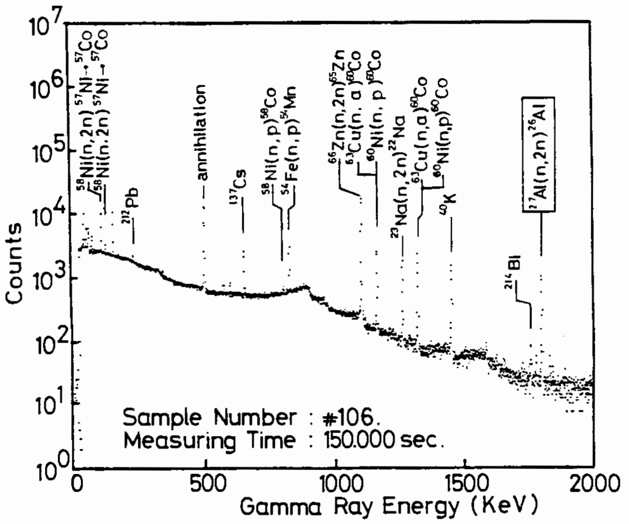

Fig. 2 Typical gamma-ray spectrum for an aluminum sample obtained in the present experiment.

Fluence Determination

Determination of the fluence of the 14 MeV neutron was done as follows. The dosimetry reaction was the $^{54}Fe(n,p)^{54}Mn$ ($T_{1/2}$=312.2days),which cross section was taken from the ENDF/B-V dosimetry files.

The half life of the residual nuclide was not so long enough to neglect the effect of the flux fluctuation during the irradiation. This effect was exactly corrected using the data of the irradiation record above mentioned.

In the present case, the most important correction on the fluence calculation is that on the effect of the scattered neutrons from the surrounding materials. The scattered neutron spectra have been estimated by simulating the scattering process taking account the neighbouring materials, such as, the rotating target copper disc and the specimen container of the main experiment. The calculation was performed using a Monte-Carlo code, MCNP[4] with a NJOY[5] processed cross section set. In order to get the correction factors, the calculated flux at each sample position was multiplied by the cross section curve from the dosimetry file. The amount of the factors was ranging from 6 to 11%.

The neutron fluence of a given sample was simply calculated by averaging the two data for the front and back side dosimetry data of each sample. The average fluence was about 5×10^{16} (n/cm^2).

Mean Energy of the Irradiated Neutrons

Because the (n,2n) cross section varies steeply with the incident neutron energy, it is important to determine the mean energy of the source neutrons at each sample position, unambiguously. We have adopted the so called the method of zirconium-niobium reaction rate ratio[6].

The mean energies were calculated using a formula by Iguchi[7], whose coefficients were derived by a least squares fitting method with a lot of reliable cross sections from 13.5 to 15 MeV. The validity of the formula was confirmed[8] by them at various intense 14 MeV neutron fields, such as, Fusion Neutronics Source at JAERI, Oktavian, at Osaka University and RTNS-II.

The present results are summarized in Table 1. In the calculation, the effect due to the scattered neutron, similarly as mentioned in above were also corrected by 0.5 to 0.8%.

Results and Discussion

The results for the cross sections are also summarized in the Table 1. The cross section for each energy is given as an average of the two front side samples' data. Major corrections applied in deriving the cross sections, not mentioned before, were those on the sum-coincidence loss effect, on the gamma-ray self-absorption effect, and on the finite solid angle in the measurement of the gamma rays, and on the effect of the large variation of the energy width of the source neutrons with the emission angles to the reaction rate of the steep cross section.

The half life and gamma-ray branching ratio data of aluminum-26 with their errors were taken from Table of Isotopes[9].

Neutron Energies (MeV)	Cross Sections (mb)
14.08 ± 0.04	11.6 ± 1.3
14.16 ± 0.05	14.3 ± 1.6
14.32 ± 0.07	21.4 ± 2.4
14.37 ± 0.07	27.8 ± 3.0
14.47 ± 0.08	32.0 ± 3.5
14.56 ± 0.10	36.1 ± 3.9
14.68 ± 0.11	40.6 ± 4.4

Table 1 Present results of the cross sections for the $^{27}Al(n,2n)^{26}$ reaction around 14MeV.

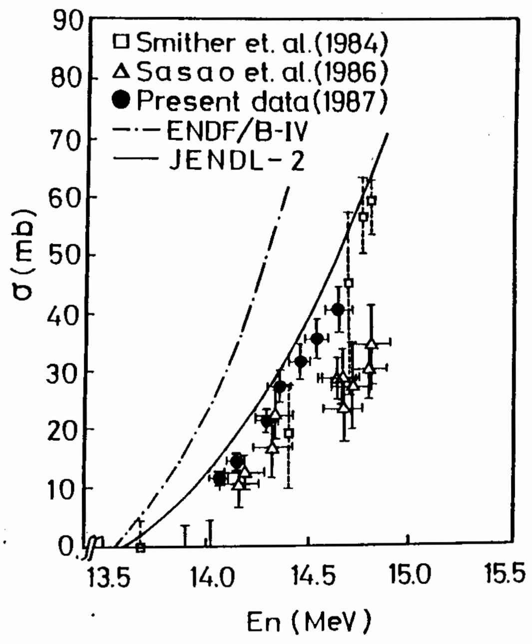

Fig. 3 Comparison of the experimental and evaluated data for the $^{27}Al(n,2n)^{26}Al$ reaction cross section around 14 MeV.

Main error sources of the cross section given in Table 1 are due to a statistical errors of peak areas (1.3 - 3.2%), the uncertainty of the gamma ray sources (2.5%) for efficiency calibration, the uncertainty of the cross section of the dosimetry reaction (5%), and uncertainties due to the various corrections(5%). Estimated total errors are from 10.8 to 11.2%.

The present results are compared with previous experiments along with the evaluated cross section files in Fig. 3. The present ones give the smallest error band among the experiments. Roughly speaking, three experiments show similar trend. In detail, however, three experimental data differ nearly by a factor of 1.5 above 14.4 MeV. Present experimental data are consistent with those of Smither et. al. above 14.5 MeV, while below 14.5 MeV are similar with those by Sasao et. al. ENDF/B-IV evaluation does not reproduce any experimental data.

Acknowledgment

This experiment was performed in the collaborative utilization program of RTNS-II between Japan-Ministry of Culture, Science and Education and US-DOE.

One of the author, S. Iwasaki expresses his sincere thanks to Professors K. Sumita, K. Kawamura and S. Ishino for their organization of the research program and continuous encouragement. He is grateful to Drs. D. Short and D. Heikkinen, Mr. E. Ambrose of RTNS-II and all the staff of the RTNS-II facility. He acknowledges to Drs. H. Kawanishi, University of Tokyo and H. Moriyama, Kyoto University for their great helps.

The authors would like to thank Dr. A. Yamadera and Mr. T. Miyata, The Cyclotron Radio Isotope Center, Tohoku University, for their helping our activity measurement. Prof. K. Kotajima, Tohoku University is also acknowledged for his helpful discussion.

References

1. G. Hopkins et al.: GA-A17389 UC-20d,e (1984).
2. R.K. Smither and L.R. Greenwood: J. Nucl. Mat., 122&123 1071 (1984)
3. M. Sasao et al.: IPPJ-805, Inst. Plasma Phys., Nagoya Univ. (1987) , and Phys. Rev. C, 35 (6) 2327 (1987).
4. Los Alamos Monte Carlo Group: LA-7396-M, Revised 2B (1981).
5. D.R. Mathews et al.: EIR-Bericht Nr.539 (1984)/ GA-A17857 (1984).
6. V.E.Levis and K.J. Zieba Nucl. Instr. Meth., 174 141 (1980).
7. T.Iguchi, University of Tokyo, private communication (1986)
8. M. Nakazawa et al., JAERI-M86-080, P117 (1986).
9. C.M. Lederer and V.S. Shirley, Ed. Table of Isotopes, 7th Ed. John Wiley & Sons, Inc., NY (1978).