Measurement of Neutron Spallation Cross Sections of 12C, 27Al and 209Bi

I. 4. Measurement of Neutron Spallation Cross Sections of ^{12}C, ^{27}Al and ^{209}Bi

Kim E., Nakamura T., Konno A., Imamura M., Nakao N.*, Shibata T.*, Uwamino Y.**, Nakanishi N.**, Tanaka Su***.*

Cyclotron and Radioisotope Center, Tohoku Uninersity
*Institute for Nuclear Study, University of Tokyo**
*Institute of Physical and Chemical Research***
*Japan Atomic Energy Research Institute****

At present, a demand for neutron reaction data is world-wide increasing from the view points of intense neutron source of material study, induced radioactivity and shielding design of high energy accelerators. Neverthless, neutron reaction data in the energy range above 20MeV are very poor and no evaluated data file exists at present. In this study, we measured the neutron spallation cross sections using quasi-monoenergetic p-^{7}Li neutrons in the energy range of 20MeV to 210MeV. The irradiation experiments were performed at four cyclotron facilities of 1) INS of Univ of Tokyo, 2) CYRIC of Tohoku Univ, 3)TIARA of JAERI, and 4)RIKEN.

The ^{7}Li targets of 2 to 10 mm thicknesses were bombared by proton beams of 20 to 210MeV energies which were extracted from these cyclotrons. The neutrons produced in the forward direction from the target were transported through the collimator for sample irradiation and the proton beams passed through the target were swept out by the magnet to the beam dump. The neutron spectra were measured with the TOF method using an organic liquid scintillator. The absolute neutron fluence of the monoenergetic peak was determined with the PRT(Proton Recoil counter Telescope) at TIARA, and with the Li activation method to detect the ^{7}Be activity from the ^{7}Li(p,n)^{7}Be reaction at INS, CYRIC and RIKEN. The irradiation samples are ^{12}C, ^{27}Al and ^{209}Bi. The sizes of the samples are 20mm to 80 mm and thickness are 0.6 mm to 10.8 mm. Irradiation time consisted of short irradiation time (1 to 2 hours below E_p = 120MeV, 30 min above E_p = 120MeV) and long irradiation time (about 20 hours) by considering the half lives of produced nuclei. The gamma-ray activities of irradiated samples were counted by using a Ge detecter. The carbon samples were put into an aluminum case to absorb the positron energy from ^{11}C nuclei produced by the $^{12}C(n,2n)^{11}C$ reaction, since the annihilation gamma rays of 511keV were measured with the Ge detecter. The peak efficiency of the Ge detecter was obtained from the mixed standard source and the self absorption of samples was calculated with the PEAK code[1] and the EGS4 code[2].

The reaction rates of identified radioisotopes were obtained by analyzing gamma-ray spectra after corrected for the peak efficiency, sum-coincidence and self-absorption effects, also for the beam current fluctuation during sample irradiation. The spallation cross section data were obtainded from the neutron spectra and the reaction rates.

From the obtained cross sections, Fig.1 and 2 exemplify the cross section values of $^{209}Bi(n,4n)^{206}Bi$ to $^{209}Bi(n,10n)^{200}Bi$, $^{12}C(n,2n)\ ^{11}C$ reactions. The cross section data of $^{209}Bi(n,xn)^{210-x}Bi$ reactions were compared with the ENDF/B-VI high energy file data calculated with the ALICE code[3]. Our experimental results are the first experimental data and are generally in good agreement with them except for $^{209}Bi(n,9n)^{201}Bi$. A big discrepancy, about a factor of 4, between our experiment and ENDF/B-VI may come from the uncertainty of the decay scheme of ^{201}Bi, where we assumed the 100% branching ratio of 628keV gamma rays from the first excited state to the ground state. If this ratio is 25%, then our data well agree with the ENDF/B-VI. Our cross section data of $^{12}C(n,2n)^{11}C$ shown in Fig. 2 are lower in the peak region around 40MeV than the ENDF/B-VI high energy file data, but much higher than the ENDF/B-VI data above 60MeV. Our results below 40MeV show good agreement with the Brill's data[4]. Our first experimental data above 40MeV show almost a constant value of 20mbarn, which revealed that the ENDF/B-VI data of $^{12}C(n,2n)^{11}C$ reaction may be inaccurate.

References

1) Nakamura T., and Suzuki T., Monte Carlo Calculation of Peak Efficiencies of Ge(Li) and Pure Ge Detecter to Voluminal Sources and Comparison with Environmental Radioactivity Measurement. Nucl. Instr. and Meth. **205, 211** (1983).
2) Nelson W. R., Hirayama H., and Rogers D. W. O, SLAC-265.
3) Blann M., CODE ALICE/89, private communication (1989).
4) Brill O. D., N. A. Vlasov, S. P. Kalinin and L. S. Sokolov, Cross Section of the (n,2n) Reaction in
C^{12}, N^{14},O^{16} and F^{19} in the Energy Interval 10-37MeV, DOK 136, Inst. Atom Energy I.V., Kurchatova, Moscow, **55** (1961).

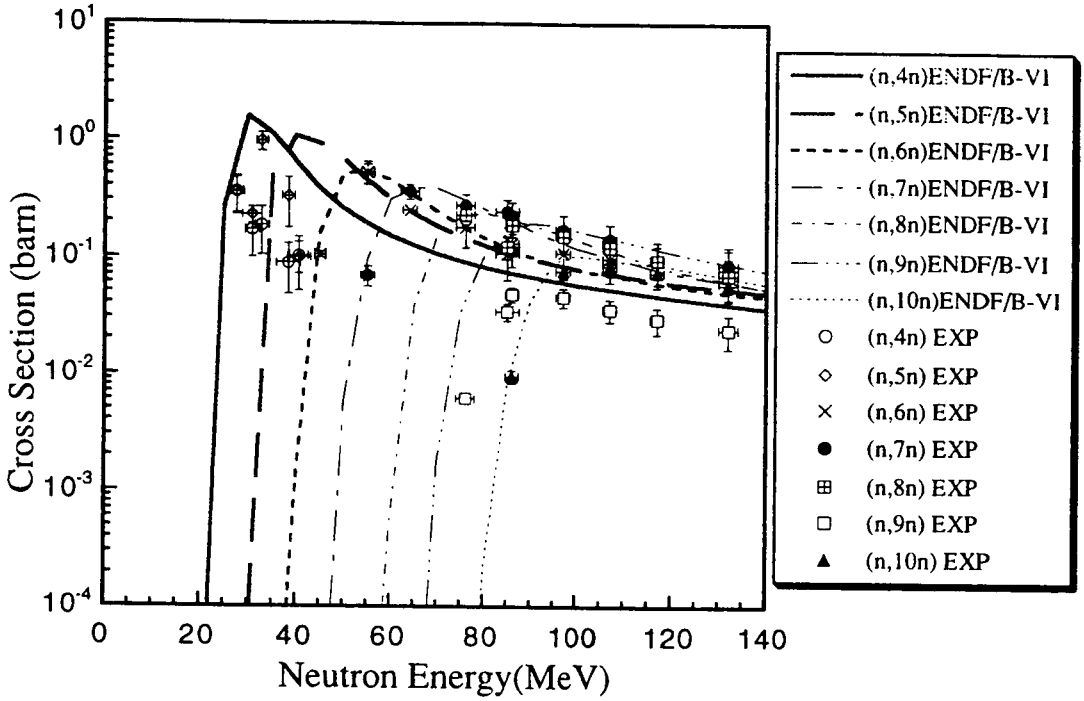

Fig. 1 Cross sesction data of ^{209}Bi(n,xn) $^{210-x}$Bi reaction compared with ENDF/B-VI.

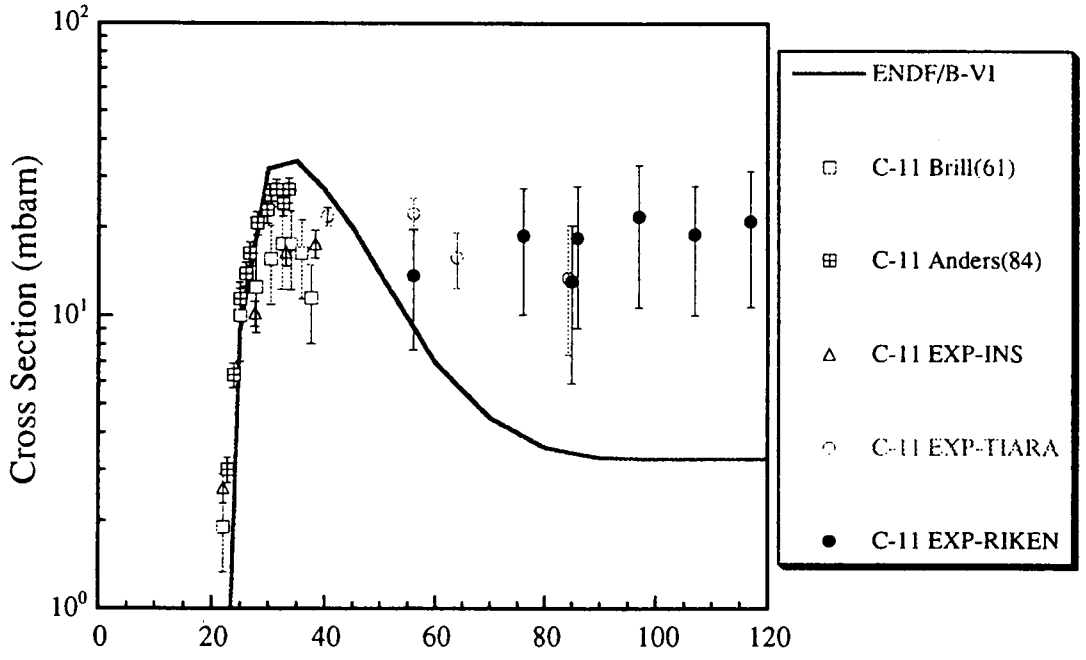

Fig. 2 Cross sesction data of ^{12}C(n,2n) ^{11}C reaction compared with ENDF/B-VI.