Measurement of Neutron Activation Cross Sections in the Energy Range between 2 and 7 MeV by Using a Ti-deuteron Target and a Deuteron Gas Target

T. Senga, H. Sakane*, M. Shibata*, H. Yamamoto*, K. Kawade*,
Y. Kasugai**, Y. Ikeda** and H. Takeuchi**
* Energy engineering and science, Nagoya University
** Japan Atomic Energy Research Institute
e-mail: h952521b@mbox.media.nagoya-u.ac.jp.

Using a Ti-deuteron target in the neutron energy range between 2 and 4.5 MeV and a deuteron gas target between 4.5 and 7 MeV, mono-energetic neutrons could be generated enough for activation cross section measurements. The KN-3750 Van de Grraff accelerator at Nagoya University and the Fusion Neutronics Source (FNS) at Japan Atomic Energy Research Institute (JAERI) were used. Preliminary results of activation cross sections were obtained for reactions of ^{27}Al(n,p)^{27}Mg, ^{47}Ti(n,p)^{47}Sc, ^{58}Ni(n,p)^{58}Co. The evaluation data of JENDL-3.2 showed reasonable agreement with our results.

1 Introduction

Database of activation cross sections for neutron energy up to 15 MeV was required for a design of fusion reactors. Available cross section data in the neutron energy range between 13 and 15 MeV were reported. However, in the energy range between 2 and 13 MeV, the experimental data were rather scarce owning to the lack of available intense neutron source. In the energy range of 5 to 10 MeV, Qaim et al.[1] reported cross section data by using a deuterium gas target at a compact cyclotron. In order to obtain adequate neutron flux, we also used a deuteron gas target until now. However, below 5 MeV, an influence of energy straggling of the incident deuteron in deuteron gas became a serious problem. In this work, two type target systems (a Ti-deuteron target and a deuteron gas target) were combined for measurements of neutron reaction cross section.

2 Neutron Source

The range of neutron energy, which was covered by using 2 type target systems and 2 type accelerators, were shown in Fig. 1. In the 4.5 to 7 MeV energy range, as shown in Fig. 2, a deuteron gas-target system[2] was used to obtained a high neutron flux. The characteristic of a deuteron gas target was described in Ref. 2. In the 2 to 3 MeV energy range, the d-D neutrons were generated by bombarding a Ti-d target occluded deuteron with a d^+ beam of 1.5 mA and 350 keV using FNS facility[3]. In the 3 to 4.5 MeV energy range, as shown in Fig. 3, a Ti-deuteron target system consists of a Ti board (0.5 mm-thick) and water-cooled system was used. The neutrons were generated by bombarding Ti-deuteron target with a d^+ beam of 10 μA and 0.35-1.4 MeV using the KN-3750 Van de Graff accelerator at Nagoya university. The neutron flux was measured with use of the standard reaction ^{115}In(n,n')^{115m}In reaction[4] ($T_{1/2}$=4.486h). In Fig. 4, as a implantation of deuteron in Ti was increased, neutron flux was increased. As a result, a typical neutron flux in the deuteron energy of 1.4 MeV was 1×10^6 n/cm^{2}s at 1 cm from the surface of Ti board. The effective neutron energies of incident neutrons at each kinematics energies of d^+ beam were determined by the reaction ratio of ^{64}Zn(n,p)^{64}Cu[4] to that of ^{115}In(n,n')^{115m}In[4]. Effective neutron energy was shifted about 500 keV lower than calculated value of neutron energy, due to deuteron beam size and irradiation position.

3 Cross Section Measurement

In this paper, the experiment by using Ti-D target at V. d. G. in Nagoya-University was described. Other experiments were described in Ref. 2, 5.

In Fig. 5, Samples were irradiated at 0 degree to incident deuteron beam and at 1.0cm from the surface of Ti-board. As shown in Fig. 6, irradiated samples were send back from neutron irradiation position (4) to measuring position (6) by using pneumatic transport system (5). The neutron flux at the sample position was measured with use of the ^{115}In(n,n')^{115m}In reaction[4]. The sample were sandwiched by two In foils of 10 mm × 10 mm and 0.5 mm in thickness, and were put in a sample cartridge as shown in Fig. 5. Each sample size was 10 mm × 10 mm and (0.2-0.5) mm in thickness. The fluctuation of neutron flux during the irradiation was monitored at interval of 10 s with a NE213 scintillator. Gamma-ray emitted from the irradiated samples were measured with coaxial-type 22% and well-type HPGe detectors. The efficiencies in the bottom of the well-type detector were 6-7 times larger than those at the surface position of coaxial-type 22% detector. Details of the corrections were described elsewhere.[5]

Measured reactions and decay parameters of the products were listed in Table 1.

4 Experimental results and Discussion

Preliminary cross section data of (n,p) reaction were obtained with a high efficiency well-type HPGe detector in an energy range between 2 and 7 MeV. Measured reactions were ^{27}Al(n,p)^{27}Mg, ^{46}Ti(n,p)^{46}Sc and ^{58}Ni(n,p)$^{57g+m}$Co.

Present cross section data were shown in Fig. 7 together with the evaluation data of JENDL 3.2 library. The evaluated values of JENDL 3.2 showed good agreement with our data.

5 Conclusion

Using a Ti-deuteron target in the neutron energy range between 2 and 4.5 MeV and a deuteron gas target between 4.5 and 7 MeV, mono-energetic neutrons could be generated enough for activation cross section measurements. In particular, neutron flux at 1.0 cm from the surface of target could be obtained 1×10^6 n/cm^{2}s by using Ti-deuteron implanted target.

Preliminary cross section data of ^{27}Al(n,p)^{27}Mg, ^{46}Ti(n,p)^{46}Sc and ^{58}Ni(n,p)$^{57g+m}$Co reaction were obtained. The evaluated values of JENDL 3.2 showed good agreement with our data.

Reference

1) Qaim, A. M., et al.: Nucl. Sci. Eng., 88, 143 (1984).
2) Furuta, T., et al.: JAERI-Conf 99-002, 186 (1995).
3) Nakamura, T., et al.: Proc. 4-th Symposium on Accelerator Science and Technology, RIKEN, Saitama, Japan, Nov. 24-26, 155 (1982).
4) Shibata, K., et al.: JAERI-Data/Code 98-006, (1998).
5) Kawade, K., et al.: JAERI-M 90-171 (1990).

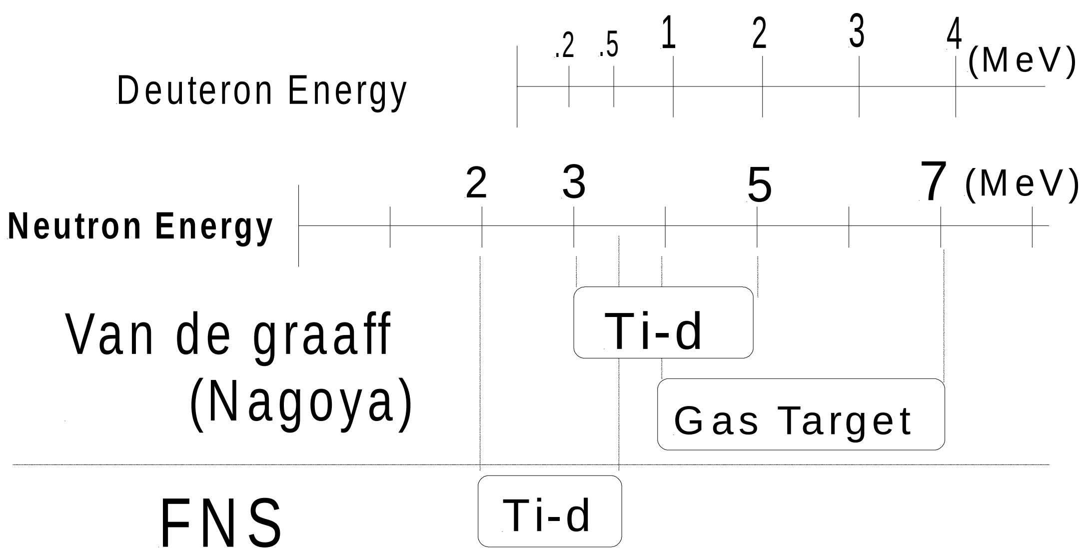

Fig. 1 A correlation between neutron energy range and neutron generator.

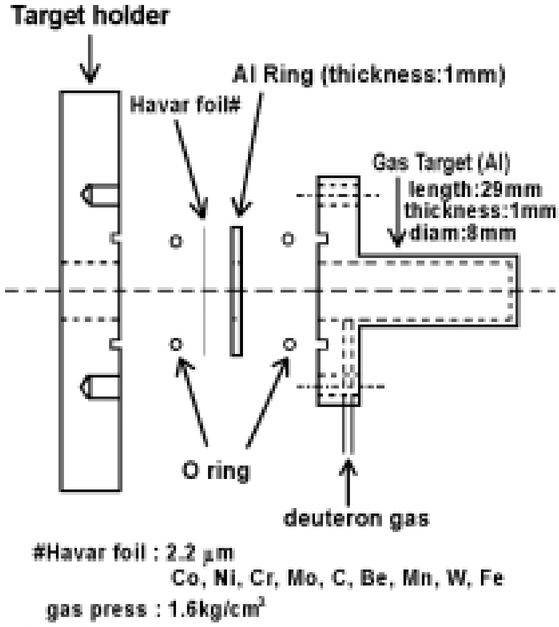

Fig.2 cross sectional view of deuteron gas target assembly.

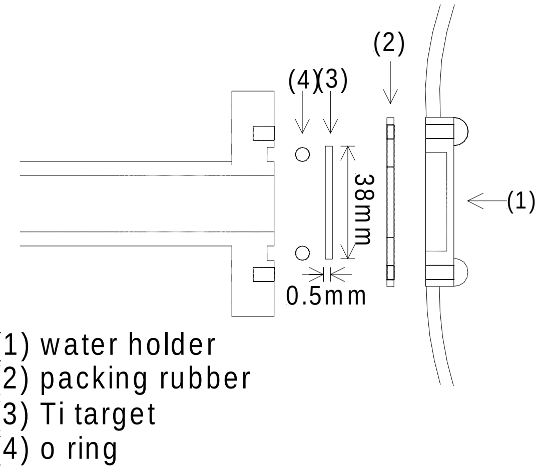

Fig.3 cross sectional view of Ti-d target assembly.

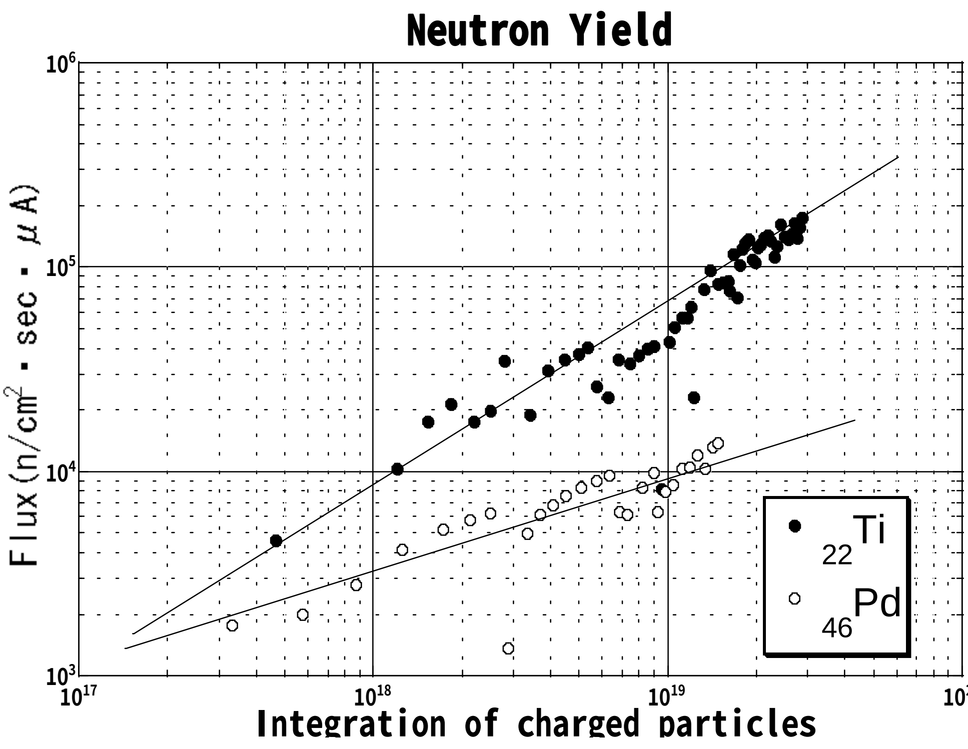

Fig.4 A correlation between integration of charged particles and neutron flux.

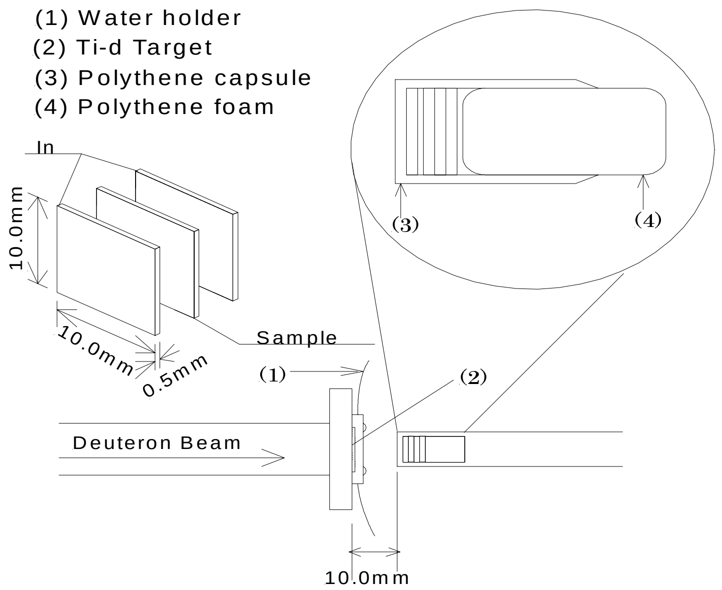

Fig.5 Pneumatic sample transport system.

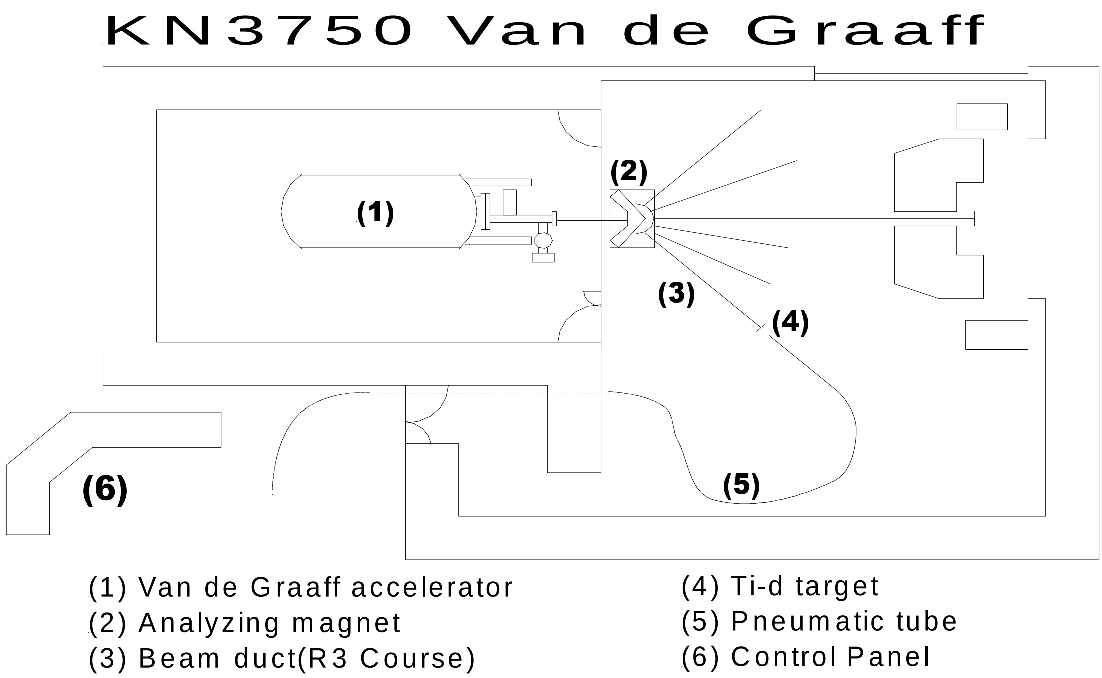

Fig.6 A sketch of KN3750 Van de Graaff accelerator in Nagoya University

Table1. Measured reactions and decay parameters.

Reaction	Half life	E_γ (keV)	I_γ (%)	Q-value(keV)
$^{27}Al(n,p)^{27}Mg$	9.462m	843.7	73(1)	-1827.9
$^{47}Ti(n,p)^{47}Sc$	3.422d	159.38	68.3(27)	182.2
$^{58}Ni(n,p)^{58}Co$	70.78d	810.7	99.44(2)	-400.0
$^{115}In(n,n')^{115m}In$	4.486h	336.4	45.9(1)	-340.0

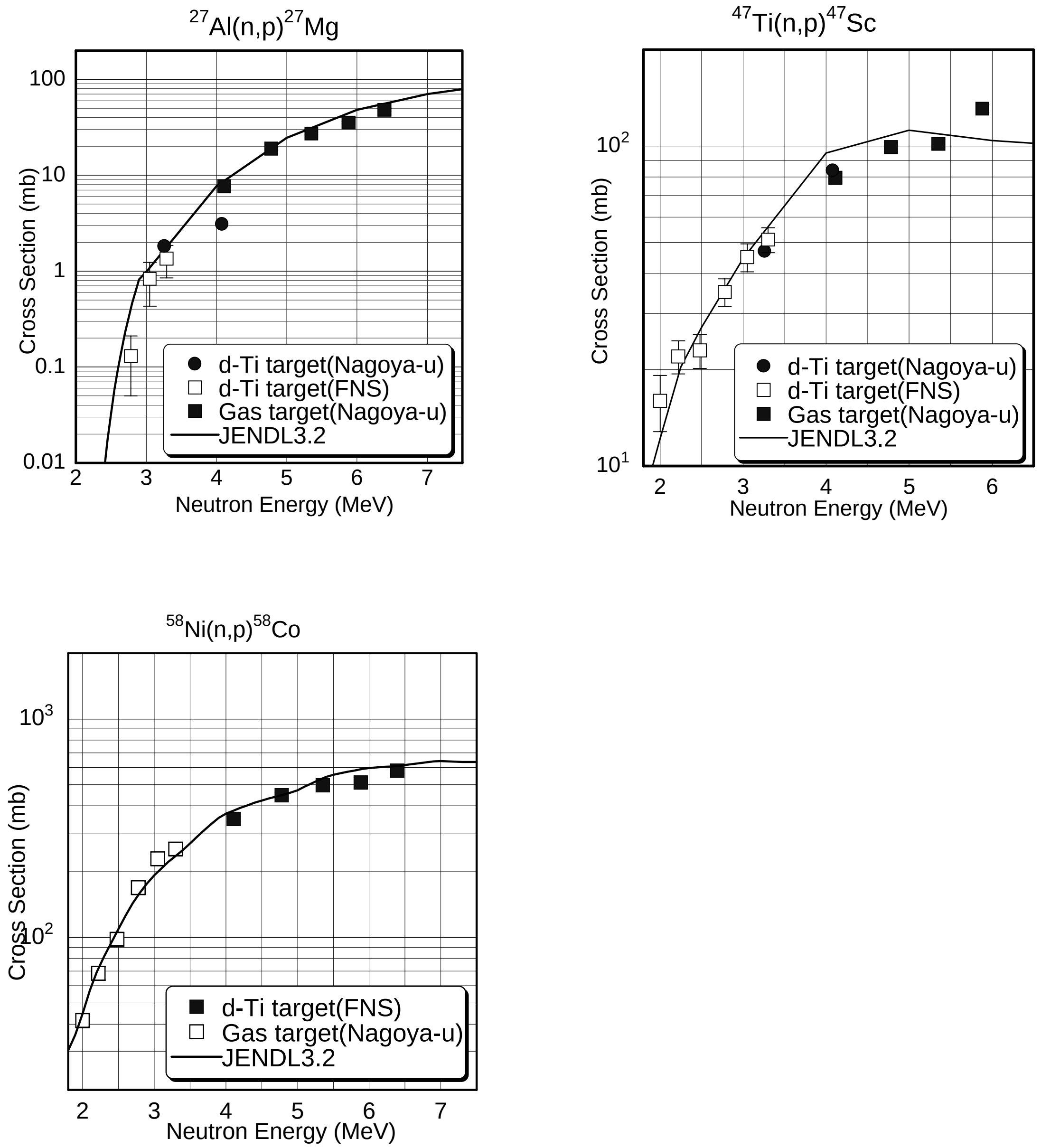

Fig.7 Experimental cross section data of (n,p) reaction.