Measurement of Deuteron-Induced Activation Cross-Sections for Tantalum, Iron, Nickel and Vanadium in 33-40 MeV Region

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Activation cross-sections for deuteron-induced reactions on tantalum, iron, nickel and vanadium were measured by using a stacked-foil technique in TIARA facility, JAERI. We irradiated stacked-foil with 41 MeV deuteron beam accelerated by AVF cyclotron and the activation cross sections for the ^{181}Ta(d,x)^{178,180}Ta, ^{nat}Fe(d,x)^{55,56}Co, ^{nat}Ni(d,x)^{55}Co, ^{60,61}Cu and ^{51}V(d,4n)^{49}Cr reactions were obtained in 33-40 MeV region. Thess data were compared with other experimental data and the calculation data in ACSELAM library.

1. Introduction

IFMIF (International Fusion Materials Irradiation Facility) is an accelerator-based D-Li neutron source designed to provide an intense neutron field for testing fusion reactor candidate materials. IFMIF has two 40 MeV deuteron linear accelerators with each 125 mA beam current [1]. In the design of IFMIF, the total facility availability is conceived to be at least 70 % for long-term operation. However, activation of the structural materials along the beam transport lines by deuteron beam loss limits the maintenance and makes the long-term operation difficult. Thus the accurate estimation of deuteron-induced activities and the selection of structural materials are important to determine the beam loss criteria.

We started to measure deuteron-induced activation cross-sections for IFMIF accelerator structural material in TIARA facility and had already measured the cross sections for aluminum, copper and tungsten in 22-40MeV region [2].

In this work, measurements of deuteron-induced activation cross sections for tantalum, iron, nickel and vanadium were performed by using a stacked-foil technique. Tantalum is candidate material for coating to protect the beam facing materials. Iron is used as the inner material of the drift tube. Nickel is the impurity of the steel and Vanadium is corrosion material.

2. Experimental Procedure and Data Processing

Activation cross sections were measured by using a stacked-foil technique. The stacked-foils consisted of natural composition tantalum, iron, nickel and vanadium foils with chemical purity more than 99.5 %. All of these foil size was 1cm x 1cm. Each thickness of foils was 10 μm for Ta, 50 μm for Fe, 20 μm for Ni and 25 μm for V. The stacked-foils were irradiated with 41MeV deuteron beam (current = 0.1 μA.) accelerated by the AVF cyclotron in the TIARA facility of JAERI. After suitable cooling time, the decayed gamma-rays emitted from the irradiated foils were measured by a calibrated high purity germanium detector. The induced activities were obtained for eight nuclide (^{181}Ta(d,x)^{178,180}Ta, ^{nat}Fe(d,x)^{55,56}Co, ^{nat}Ni(d,x)^{55}Co, ^{60,61}Cu and ^{51}V(d,4n)^{49}Cr) from the measurement data of gamma-rays .

The energy degradation along the stack and the effective deuteron energy at the middle position of each foil were estimated by the IRACM code system [3]. The number of incident deuterons on each stacked-foil was determined from ^{65}Zn activities produced by the ^{nat}Cu(d,x)^{65}Zn reaction cross section, where we used the data reported by Takács *et al.*[4]. The elemental cross sections were derived from the induced activities and the number of incident deuterons.

The error of the present results was 13-19%. This value results from the error in the determination of continuous background for net counts of the decayed gamma-ray, the error of the standard cross sections for the ^{nat}Cu(d,x)^{65}Zn reaction, the full energy efficiency of the Ge detector and the foil thickness.

3. Results

The production cross sections for the eight radioactive nuclei were measured and compared with previous ones by other groups and the data in ACSELAM library calculated by the ALICE-F code [5]. As the cross sections in ACSELAM library are calculated for each isotope target, the value of its cross sections were normalized by weighting with natural abundance to compare with the experimental results in figures.

3-1. Tantalum

The present cross sections, compared with other experimental ones and the data in ACSELAM for ^{178}Ta ($T_{1/2}$=2.4h) and ^{180}Ta ($T_{1/2}$=8.2h) are shown in FIGURES 1-2. For these Ta nuclide there is only one experimental data reported by Bisplinghoff *et al.*[6]. The present results were smaller than the data in ACSELAM by a factor of 2-3 for ^{178}Ta and 2 times as high as the data in ACSELAM for ^{180}Ta.

3-2. Iron

FIGURES 3-4 show the present cross sections for the ^{nat}Fe(d,x)^{55}Co($T_{1/2}$=17.5h) and ^{56}Co($T_{1/2}$=77.2d) reactions compared with other experimental ones and the data in ACSELAM. For ^{55}Co, there are two experimental data, which are reported by Clerk *et al.* [7] and Hermanne *et al.*[8]. The present results were in agreement with the data reported by Hermanne within 20% and 4 times as low as the data in ACSELAM. For ^{56}Co, the present results were in agreement with the data reported by Takacs *et al.* [4] within experimental error and 2 times as low as the data in ACSELAM.

3-3. Nickel

Figures 5-7 show the present results for the ^{nat}Ni(d,x)^{55}Co($T_{1/2}$=17.5h), ^{60}Cu($T_{1/2}$=23.7m) and ^{61}Cu($T_{1/2}$=3.33h) reactions. The present results were in agreement with the data in ACSELAM within 50% for ^{55}Co and 4 times as low as the data in ACSELAM for ^{60}Cu. For ^{61}Cu the present results were in good agreement with the data reported by Takacs *et al.* [4] and 2 times as low as the data in ACSELAM.

3-4. Vanadium

Figure 8 shows the present results for the ^{51}V(d,4n)^{49}Cr($T_{1/2}$=42.3m) reaction. The present results were 2 times as high as the data reported by Weinreich[9] and smaller than the data in ACSELAM by a factor of 4-5 .

4. Summary

The activation cross-sections for the deuteron-induced reactions had been obtained for Ta, Fe, Ni and V in 33-40 MeV region. The present results were compared with previous experimental ones and the data in ACSELAM library. For ^{nat}Fe(d,x)^{56}Co and ^{nat}Ni(d,x)^{61}Cu reaction, the present results were in good agreement with the data reported by Takacs. The data in ACSELAM were overestimation for the ^{181}Ta(d,x)^{178}Ta, ^{nat}Fe(d,x)^{55,56}Co, ^{nat}Ni(d,x)^{60,61}Cu and ^{51}V(d,4n)^{49}Cr reactions and underestimation for the ^{181}Ta(d,x)^{180}Ta, ^{nat}Ni(d,x) ^{55}Co reactions. In the future we will measure these activation cross-sections below 33MeV.

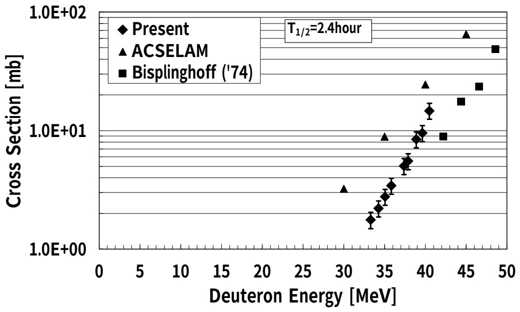

Fig. 1 Cross sections for the ^{181}Ta(d,x) ^{178}Ta

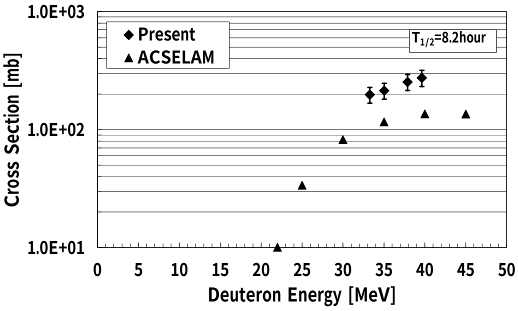

Fig. 2 Cross sections for the ^{181}Ta(d,x) ^{180}Ta

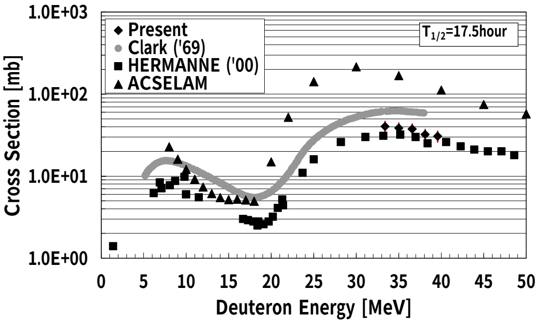

Fig. 3 Cross sections for the ^{nat}Fe(d,x) ^{55}Co

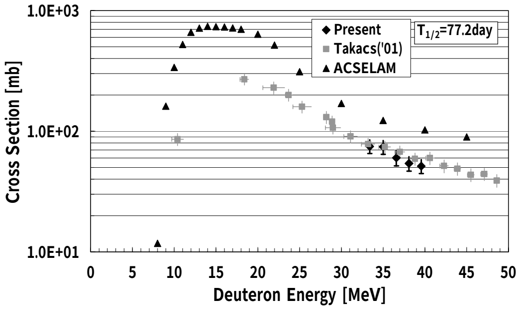

Fig. 4 Cross sections for the ^{nat}Fe(d,x) ^{56}Co

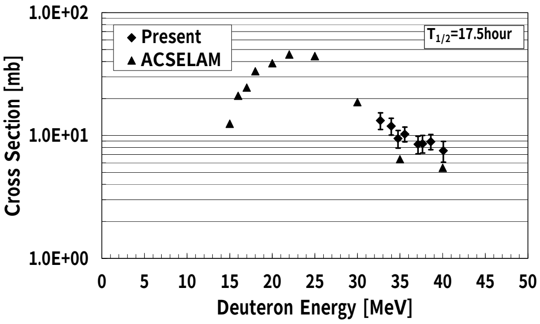

Fig. 5 Cross sections for the ^{nat}Ni(d,x) ^{55}Co

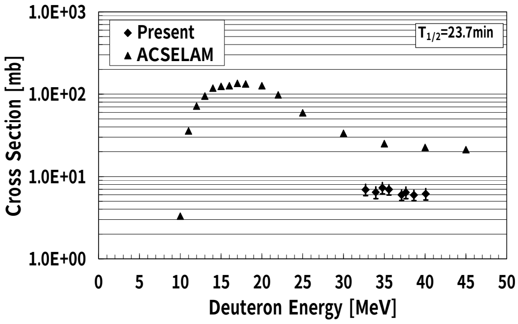

Fig. 6 Cross sections for the ^{nat}Ni(d,x) ^{60}Cu

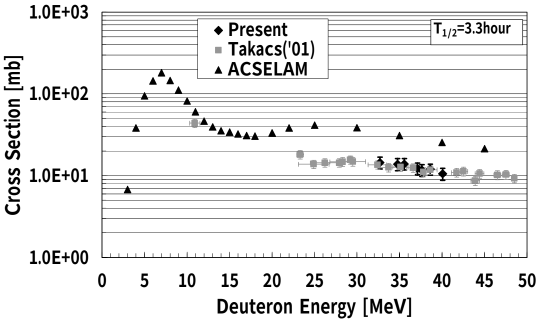

Fig. 7 Cross sections for the ^{nat}Ni(d,x) ^{61}Cu

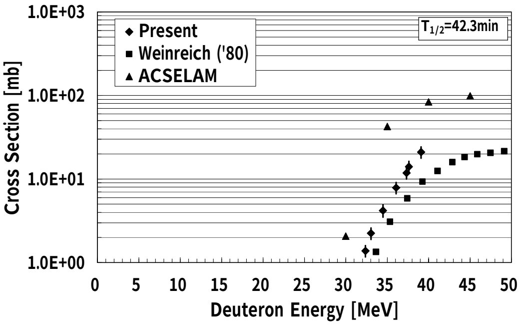

Fig. 8 Cross sections for the ^{51}V(d,4n) ^{49}Cr

Acknowledgments

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