MEASUREMENT OF NUCLEAR REACTION CROSS-SECTION FOR THERMONUCLEAR APPLICATIONS

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1. INTRODUCTION

The interaction of a deuteron beam with lithium is characterized by high neutron yield, high neutron energy, and a wide variety of reactions. Neutron beam generation with such characteristics is necessary for such topical issues as testing of promising materials, including material for the first tokamak wall, and equipment, production of radioactive isotopes, and other applications. Experimental cross-section data in databases [1] are very discrepant, and for some reactions are missing. Measurements of the reactions cross-sections were carried out at the accelerator-based neutron source VITA at Budker Institute of Nuclear Physics (Novosibirsk, Russian Federation) using an α-spectrometer and a diamond detector. The ^{6}Li(d,α)^{4}He, ^{6}Li(d,p)^{7}Li, ^{6}Li(d,p)^{7}Li*, ^{7}Li(d,α)^{5}He, ^{7}Li(d,nα)^{4}He, ^{7}Li(d,n)^{8}Be, and ^{7}Li(d,n)^{8}Be* reactions cross-sections at deuteron energies from 0.3 MeV to 2.2 MeV were measured [3, 4].

Studying the ^{11}B(p,α)αα reaction is important for the developing aneutronic fusion and proton-neutron capture therapy. Despite a considerable number of theoretical works describing the reaction mechanisms, experimental data on the cross-section in different works strongly disagrees, and there is no agreement in the determination of the decay mechanism as well. The reaction cross-sections were also measured at the accelerator-based neutron source VITA using an α-spectrometer. It was found that the proton-boron interaction reaction proceeds predominantly in the form of decay into an α-particle and a beryllium nucleus in the excited state with its subsequent decay into two α-particles. The ^{11}B(p,α_0)^{8}Be, ^{11}B(p,α_1)^{8}Be*, and ^{11}B(p,α)αα reactions cross-sections have been measured [5].

2. EXPERIMENTAL FACILITY

The studies were carried out at the accelerator-based neutron source VITA at Budker Institute of Nuclear Physics (Novosibirsk, Russian Federation) [2]. The layout of the experimental facility is shown in Fig. 1. The facility includes the tandem electrostatic charged particle accelerator of the original construction *1* which produces a beam of protons or deuterons and directs it to the target *6*. The beam energy ranges from 100 keV to 2.3 MeV (0.1% stability), and the current ranges up to 10 mA (0.4% stability). The beam current is measured with a non-destructive DC current transformer (Bergoz Instrumentation, France) *2*. A cooled collimator *3* with a hole of 1 mm diameter is used to reduce the beam current during experiments.

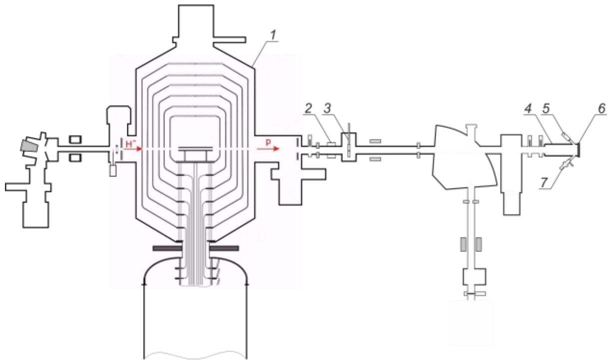

FIG. 1. The layout of the experimental facility: 1 – vacuum insulated tandem accelerator, 2 – non-destructive DC current transformer, 3 – collimator, 4 – target assembly, 5 – α-spectrometer at 135°, 6 – target, 7 – α-spectrometer at 168°

The reaction cross-section is measured by irradiating of the target with a proton/deuteron beam and registering the charged particles using an α-spectrometer with a silicon semiconductor detector PDPA-1K (IPTP, Dubna, Russian Federation). The spectrometer is placed at angles 135° *5* and 168° *7* to the beam axis on the branch pipes of the target assembly *4*. Thin lithium and boron targets were used in this experiment. The lithium target is a copper disk on which a thin layer (~ 0.5 μm) of lithium is thermally evaporated. The boron target is a thin layer of boron (~ 0.7 μm) deposited on a copper disk by magnetron sputtering with thermal isolation of the target. The thicknesses of the deposited layers were measured by several independent methods, including the method proposed and developed by us for comparing the radiation intensity from the thin layer under study and from the thick one, which provided a high accuracy of the result in the calculation of the nuclear reaction cross-section [3, 4].

3. RESULTS

The ^{6}Li(d,α)^{4}He, ^{6}Li(d,p)^{7}Li, ^{6}Li(d,p)^{7}Li*, ^{7}Li(d,α)^{5}He, ^{7}Li(d,nα)^{4}He, ^{7}Li(d,n)^{8}Be, and ^{7}Li(d,n)^{8}Be* reactions cross-sections at deuteron energies from 0.3 MeV to 2.2 MeV have been measured with high accuracy [3, 4]. The energy spectrum of neutrons generated in the most productive reaction ^{7}Li(d,n)^{8}Be has been determined for the first time.

The ^{11}B(p,α_0)^{8}Be, ^{11}B(p,α_1)^{8}Be*, and ^{11}B(p,α)αα reactions cross-sections at proton energies up to 2.2 MeV have been measured [5]. It was found that the proton-boron interaction reaction proceeds predominantly in the form of decay into an α-particle and a beryllium nucleus in the excited state with its subsequent decay into two α-particles. The measured reaction cross-section was at most 700 mb at an energy of 600 keV which is about a factor of 2 smaller than the reaction cross-section often used when considering the prospects of aneutronic fusion. The second decay via the ground state beryllium nucleus is less probable (10–100 times smaller) and has a maximum at proton energies around 2 MeV. By analyzing the spectrum of registered α-particles, we measured for the first time the probability of the direct decay into three α-particles – it is 2000–3000 times smaller than the probability of the sequential decay.

ACKNOWLEDGEMENTS

This work was supported by the Russian Science Foundation (grant number19–72-30005). The authors would like to thank colleagues A.G. Nikolaev, E.M. Oks from Institute of High Current Electronics and Tomsk State University of Control Systems and Radio-Electronics (Tomsk, Russian Federation), and also N.B. Rodionov, Yu.A. Kashchuk, S.Yu. Obudovsky, A.S. Dzhurik, T.M. Kormilitsyn, R.N. Rodionov, V.N. Amosov from Institution Project Center ITER, State Atomic Energy Corporation Rosatom (Moscow, Russian Federation).

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