DIFFERENTIAL CROSS SECTION MEASUREMENT OF REACTION $^7Li(p,\alpha)^4He$ IN THE ASTROPHYSICAL RANGE OF ENERGY

Baktibayev M.K., Burminskii V.P., Burtebayev N., Jazairov-Kakhramanov V., Sagindykov Sh.Sh., Zarifov R.A., Zazulin D.M.
Institute of Nuclear Physics, Almaty, Kazakhstan

The reaction $^7Li(p,\alpha)^4He$ is the key one in the cycle of hydrogen combustion into helium and is not passed over by an attention of experimenters. But, as the estimation [1] had shown, the contradictoriness of available experimental data requires additional measurements. At present there are several sets of data on measurements of total cross sections of the reaction $^7Li(p,\alpha)^4He$ in the region of $E_p = 0.01 \div 10$ MeV [2 ÷ 8]. Data of works [7,8] differ from those of others by 2 times. In the present work there were carried out measurements of yields of cross sections of the reaction $^7Li(p,\alpha)^4He$ and their angular distributions. The accelerated proton beam passed through the solid target with thin carbon base, and the Faraday cup, disposed behind the target detected the beam current. Theoretical investigation of reaction included the calculation of differential cross section within distorted wave Born approach.

Experiments on determination of $^7Li(p,\alpha)^4He$ reactions cross sections in low-energy region were carried out by means of the extracted beam of the complex recharged accelerator RAC-2-1 (INP NNC RK) at proton energies E_P = 350, 550 and 750 keV and beam currents of up to tens mkA. The spread of proton beam energy is not more than 1.5 keV.

A performance of experiments was realized with the use of special complex of equipments, allowing an irradiation of targets of different isotopes by accelerated particles beam and detection of nuclear reaction products. A peculiarity of measurements at super-low energies of the beam makes rather strict demands to the technique of an experiment: investigations are carried out with very fine targets (of up to several $\mu g/cm^2$); because of this circumstance there are sharply increased requirements to the purity of materials and to vacuum system, because the high vacuum is necessary to prevent a formation of carbon deposit on targets; small cross sections of second products emission dictate a necessity to use several gamma-radiation detectors of high efficiency; a duration of experiment on time requires the high stability of detecting spectroscopic apparatus.

At the end of proton accelerator's ion-tube there is the central reaction chamber, manufactured in the octahedron-shapes with the distance between parallel walls of 560 mm and with the height of 330 mm. Side walls have 8 hermetically-closed flanges. This allows a proton beam to pass through the chamber and hermetical windows at the flanges, to observe an internal state of the chamber and to detect reactions products by radiation detectors at different angles to the direction of the incident beam. In the centre of the chamber, on the axis of the beam the targets are placed. Inside the chamber the in devices for attaching of charged particles detectors are mounted. With help of external control, without a disturbance of vacuum inside of a detector may be moved around the target and installed at any angle to the direction of the accelerated particles beam. During beam current measurements the electrically isolated from the ion-tube central reaction chamber body is used as the Faraday cup. For formation of transverse dimensions and of beam shape, and for stabilization of its position on the target, in front of the chamber, there are installed two copper diaphragms in the distance of 2 m from each other with the set of collimators with diameters of 1, 2, 3 and 5 mm. An installation of necessary collimator is carried out from the outside through the gland vacuum seal.

^7Li targets of different thicknesses (several tens of micrograms) were prepared by means of spraying of lithium isotope onto thin carbon films. Measurements of spectra were carried out with the help of the charged particles detector at energies of protons E_P = 350, 550 and 750 keV.

At every energy there was measured the angular distribution of alpha particles (products of nuclear reaction) in the range of from 20^0 to 170^0 with the step of 15^0. During the measurements the lithium - targets was placed at the angles of 45^0 or 135^0 to the incident protons beam depending on the angle of the detector location. During the measurements there was an intensive background from elastic scattering of beam protons. In order to eliminate this background, between the detector and the target, close to the detector there was placed the 3.5 mg/cm^2 thick aluminum foil. By such thickness of the aluminum foil the threshold of the proton energy absorption was ~ 1MeV. As a result, the background from protons disappeared completely, but there was taken place the spreading of the spectral line of alpha-particles. However, this did not influence on the value of the count of detected alpha-particles.

The obtained results of angular distributions from the present measurements are well approximated by $A(1 + B*\cos^2(\theta))$ type functions. Data were obtained in relative units. The course of the excitation function curve of the reaction $^7Li(p,\alpha)^4He$ obtained from the present measurements corresponds to the data of work [4].

The calculations of theoretical cross sections were conducted within the framework of a method of the distorted waves with the using of the program DWUCK5. The scattering wave functions were calculated with the using of optical potentials. During the calculations of scattering states wave functions of the potentials calculated within the framework of the cluster folding-model were used. The potential of the input channel of the ^7Li-p - system was constructed by the convolution of αp- and tp-interactions on cluster αt-density. The potential of the output channel of the α-^4He-system was taken from the literature. As the vertex function of the p-^3He – subsystem, alpha-particle form-factors in the Sheffard's potential were used. As the wave function of the bound state of the αt-system the the two-particle wave αt-function of the ^7Li-nucleus was used. Calculated values of total cross-sections in the energy ranges of E=4.0÷5.0 MeV occurred to be 12% larger than experimental values of the work [4].

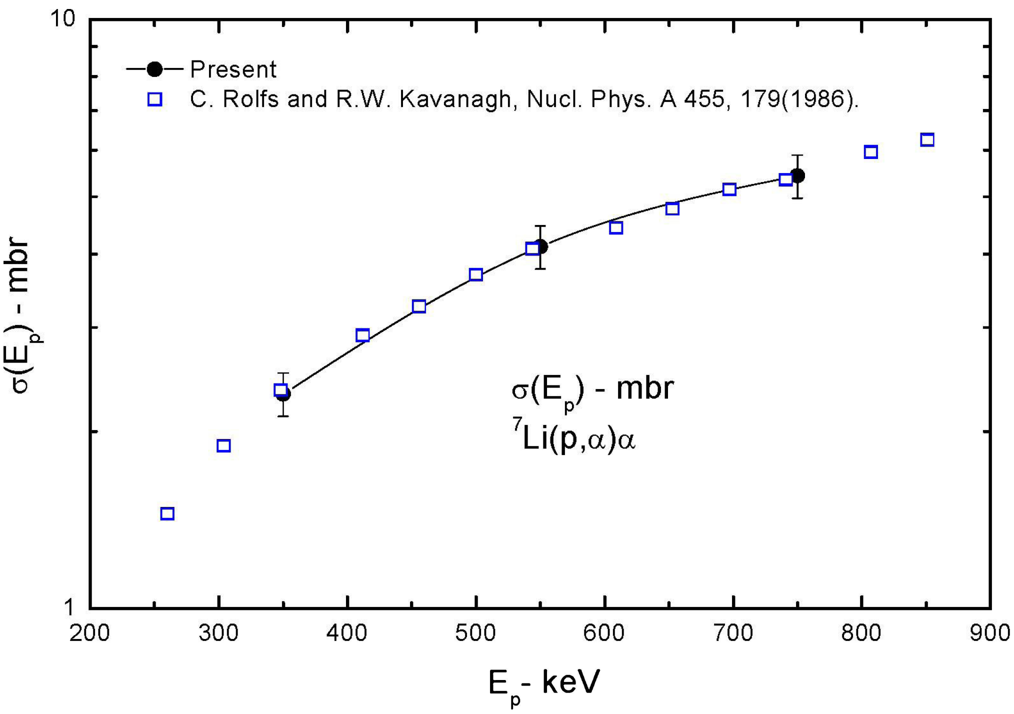

Fig. 1. The course of the excitation function curve of the reaction $^7Li(p,\alpha)^4He$ in comparison with data on absolute cross sections

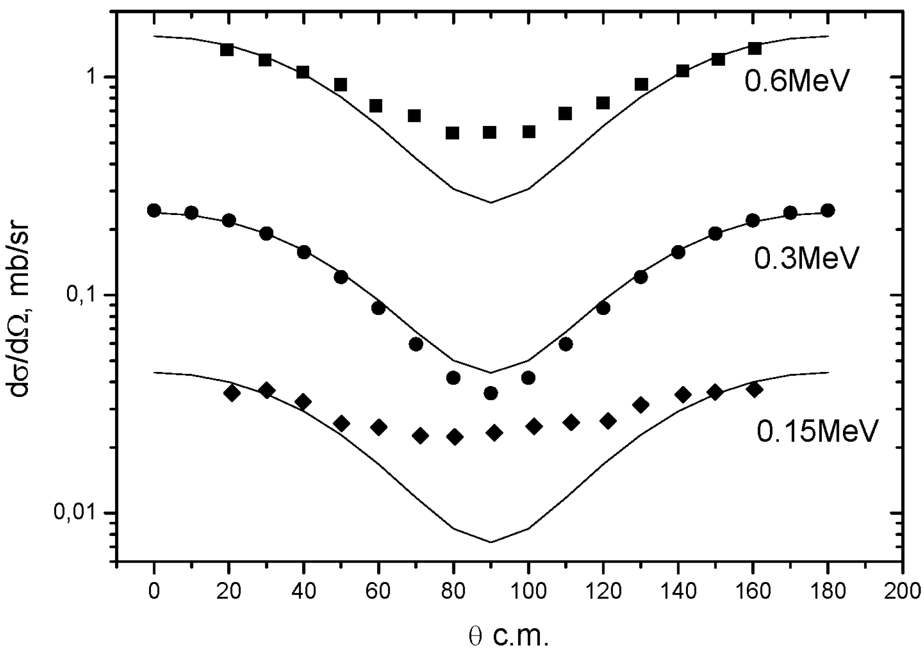

Fig. 2. Dependence of differential cross-section of the reaction $^7Li(p,\alpha)^4He$ at various energy.

REFERENCES

1. S. Abramovich, B.Guzhovskij, V.Zherebchov, A.Zvenigorodskij, A Reference Handbook. IAEA Report, INDC(CCP).
2. Y. Cassagnoy, J.M.F. Jeronymo, G.S. Mani, et al., Nucl. Phys. 33, 449(1962), 41, 176(1963).
3. O. Fiedler and P. Kunze, Nucl. Phys. A 96, 513(1967).
4. C. Rolfs and R.W. Kavanagh, Nucl. Phys. A 455, 179(1986).
5. S. Engstler, G. Raimann, C. Angulo, et al., Z. Phys. A 342, 471(1992), Phys. Lett. B 279, 20(1992).
6. G.S. Mani, R. Freeman, F. Picard, et al., Nucl. Phys. 60, 588(1964).
7. H. Spinka, T. Tombrello and H. Winkler, Nucl. Phys. A 164, 1(1971).
8. J.F. Harmon, Nucl. Inst. Meth. B 40/41, 507(1989).