Alpha-particle capture reactions in inverse kinematics relevant to p-process nucleosynthesis

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In the development of the theory of nucleosynthesis, it was realized very early that the synthesis of the so-called p-nuclei requires a special mechanism known as p-process [1]. This process occurs in stellar environments of very high temperatures where the preexisting more neutron-rich nuclei are involved in sequences of (γ,n), (γ,p) and (γ,α) reactions, whereby, in some scenaria, certain (p,γ) and (α,γ) reactions are also included. In order to perform abundance calculations, the reaction rates of more than 20000 nuclear reactions on about 2000 nuclei are needed. Consequently, all extended network calculations have to rely almost completely on cross sections predicted by the Hauser-Feshbach (HF) theory. However, some of the very few (α,γ) data show that the phenomenological alpha-particle optical potentials, used in these calculations, can be wrong by a factor of ten or more. Hence, systematic cross-section measurements of α-particle capture reactions at energies between 1 and 3.5 MeV/u are necessary. Such measurements are proposed to be carried out mainly in the A=80÷140 and A=170÷200 mass regions [2]. The measurement of these reactions in inverse kinematics is the only possible solution, when the radioactive nuclei are involved. Nevertheless, this was not ever performed for the medium-mass nuclei due to the small mass-difference between the beam particles and the recoils which sets tight experimental conditions for their separation.

For the first time we performed the inverse kinematics experiment with the medium-mass nuclei - ^{78}Kr(α,γ)^{82}Sr reaction. The aim was to prove feasibility of this type of experiment. The energy of the reaction was E(CM)=6.5 MeV and respective velocity of ^{78}Kr and ^{82}Sr were 1.8290 ± 0.0311 cm/ns and 1.7349 ± 0.0951 cm/ns, which is about of 5% difference. Beam intensity was around 10 nA (7.8×10^9 pps). The target consisted of 10^{17} atoms of helium (approximately 1 μg/cm^2) embedded in aluminum foil of 50 μg/cm^2. LISE3 spectrometer which includes 12m long Wien Filter was used for the separation of the ^{82}Sr from the primary beam – ^{78}Kr.

Considering very small difference of velocities – about 5%, between the primary beam and compound nucleus, very good rejection factor was achieved – more than 10^9. Unfortunately high intensity of the ions, at that time of unknown origin, completely masked the expected position of our ion of interest. It was hard to explain that these ions are scattered primary beam since they had too big difference in energy and too high intensity which could not be explained by the energy loss in the target with so high probability. The very probable explanation for the origin of this pollutant could be the microscopic dust deposited on the surface of the target.

The conclusion of the experiment is that the cross section measurement of the (α,γ) reactions is feasible regarding high rejection rate of the primary beam of factor >10^9, however the use of gas-jet target instead of solid one is compulsory.

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