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α-particle emission in the reaction ^{48}Ca+Ta at Coulomb energy

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Inclusive energy spectra have been measured for light charged particles emitted in the bombardment of Ta target by ^{48}Ca ions at 261 MeV and 471 MeV. The reaction products were analyzed and detected by means of a ($\Delta E \times E$) telescope placed in the focal plane of a magnetic spectrometer located at forward angles with respect to the beam direction. In all the reactions studied light charged particles with an energy close to the respective calculated kinematic limit for a two-body exit channel are produced with relatively great probability. The results obtained make it possible to draw some conclusions about the reaction mechanism involving the emission of light charged particles.

Keywords: Inclusive energy spectra, jinr cyclotrons,reaction mechanism.

Introduction

In heavy ion reactions light charged particles are emitted with cross sections, which constitute a significant part of the geometrical cross section of the reaction [1,2,3], particularly in the case of α-particles. The measured energy spectra, angular distributions and cross sections of these particles are not describable in the framework of the evaporation model of compound nucleus decay. The noticeable increase in the yields of energetic light particles, as well as their strongly forward-peaked angular distributions, suggest a fast mechanism of their formation [2,3]. The experimental investigation of α-particle spectra as a function of momentum transfer, reported in [2,3], convincingly shows that the emission of fast particles takes place during the early stages of the reaction, when the final fate of the interacting nuclei is yet not determined.

The experiments described in the present report are an extension of our earlier studies [2,3] and were carried out in order to measure the probability of emission of α-particles with energies close to the kinematic limit at the forward angles with respect to the beam direction in the reaction induced by ^{48}Ca-projectiles .

Experimental Method

The experiments have been performed using ^{48}Ca ion beams from the U400 heavy ion cyclotron of the Flerov Laboratory of Nuclear Reactions (JINR). The energy of ^{48}Ca ions was equal 261 and 471 MeV. The tantalum targets were placed in the entrance focus of a high resolution magnetic separator MSP-144 [4].

The average beam current during the experiment was maintained at value about 200 nA. The self-supporting Ta target with thickness 5 μm was prepared from a thin foil of 99 % purity. To measure reaction products a set of two telescopes each consisting of ΔE and E_r detectors with thicknesses of 100 μm and 3 mm, respectively, were used. Particle identification was performed based on the energy-loss measurements ΔE and residual energy E_r, i.e. by the so-called ($\Delta E \times E$) method. The example of two-dimensional plots (yield versus energy loss ΔE and residual energy E_r) is shown in Figure 1a. This method gives absolute identification of detected reaction products in atomic number Z neutron exceeds N-Z (see Figure 1b). We found that accuracy $\Delta Z/Z = 0.4$ for oxygen isotope and mass uncertainty is less than 0.5%.

To obtain cross section value we used values of experimental yield and beam flux, measured by Faraday cup. Overall efficiency of the detection system, including solid angle of the spectrometer and Si-telescope, was determined by a very intensive α-particle source of ^{238}Pu isotope with calibrated intensity. By this we found that the value of total detection efficiency is about 2×10^{-6}.

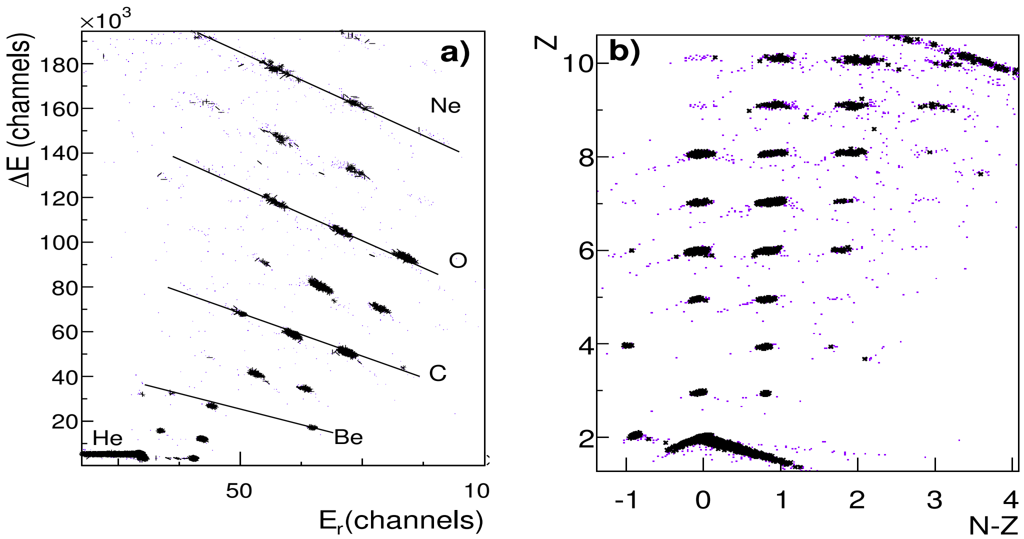

Figure 1. a) Particle identification plot for the products of the (^{48}Ca+Ta) reaction from ^{4}He upto Ne-isotopes. ΔE is the energy loss and E_r is the residual energy. b) Identification matrix (product yield versus atomic number Z and neutron excess $N - Z$ values) obtained by so-called ($\Delta E \times E$) method.

This experimental technique allows us to identify the particles from ^{4}He till Ne isotopes. Mainly we concentrate on study of the production cross sections for ^{4}He and ^{7}Li isotopes in the reaction (^{48}Ca+Ta).

Results and Data Analysis

Energy spectra for α and ^{7}Li are presented in Figure 2a and Figure 2b respectively. Energy spectra of α particle measured in the (^{48}Ca+Ta) at 261 MeV are shown by (■) at 0 degrees and (●) at 10 degrees in Figure 2a.

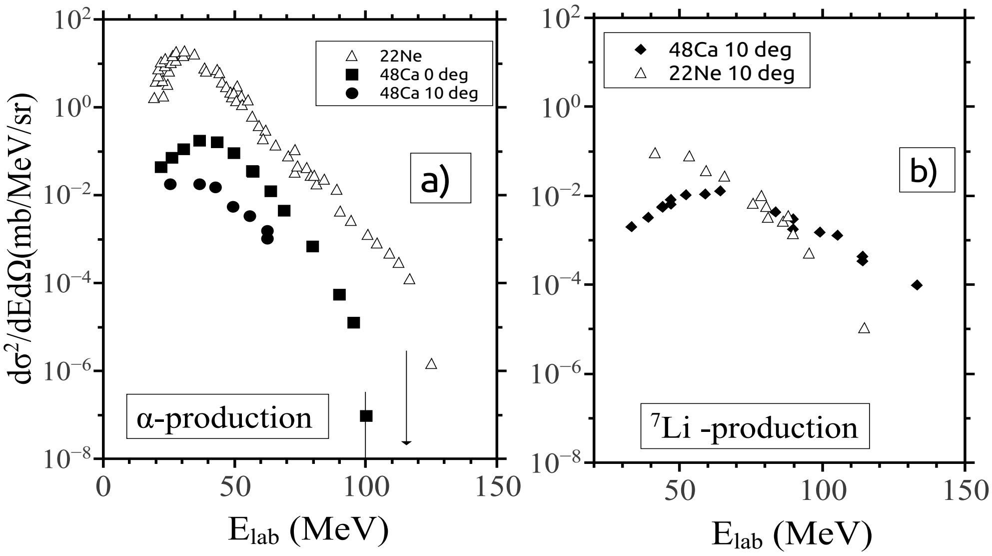

Figure 2. a) Energy spectra of α particle measured in the ^{48}Ca+Ta at 261 MeV (■) at 0 degrees and (•) at 10 degrees. For comparison, experimental data for the α particle, obtained in the reaction ^{22}Ne+Ta [3] at 178 MeV, are shown by △ . The arrows indicate the calculated end-point energies for the corresponding isotope in the case of a two-body exit channel. b) shows energy spectra of ^{7}Li particle measured in the ^{48}Ca+Ta (♦) and for reaction ^{22}Ne (△) measured at 10 degrees.

In Figure 2a the arrow on the E_{lab} axis indicates the limiting values of the particle energies (specified for different particles by their mass numbers), calculated on the basis of the energy and momentum conservation laws under the assumption of two-body kinematics. These energy limits were estimated with an accuracy corresponding to the accuracy of determining both the heavy ion beam energy and the reaction Q-value, and amounting to about 2 MeV. As seen from the figures, in the case of α-particle, an experimental energy limit was obtained. These result together with conclusion given in [3] indicates that in heavy ion reactions α-particles with an energy close to the kinematic limit for a two-body exit channel are formed with great probability. It has been shown that in this case a "cold" nucleus is formed whose mass is by 4 units and atomic number by 2 units smaller than those of the compound nucleus.

For comparison, experimental data for the α-particle, obtained in the reaction ^{22}Ne+Ta [3] at 178 MeV, are shown by (△). In the case of ^{48}Ca projectile at energy 261 MeV, the production cross section is smaller that in the case of ^{22}Ne [3]. During the similar measurement on energy of α-particle with higher value of the ^{48}Ca projectile at 471 MeV, we found larger value of the production cross section than at the projectile energy 261 MeV by factor of two orders. It seems, that the higher energy of the bombarding ions leads to deexcitation intensively.

Figure 2b shows energy spectra of ^{7}Li particle measured in the ^{48}Ca+Ta (♦) reaction and for reaction ^{22}Ne (△) [3] measured at 10 degrees. Contrary to of strong dependence of production cross section of α-particle against sort and value of energy of projectile (which it is demonstrated in Figure 2), ^{7}Li production does not show this dependence, and values of the cross section are very similar both for ^{22}Ne and ^{48}Ca projectiles (see Figure 2b).

Comparison of angular distributions of α-particles from the ^{48}Ca at 261 MeV (♦) and 471 MeV (■) and ^{22}Ne [3] (△) are shown in Figure 3. The curves are drawn through the experimental points to guide the eye. These angular distri-

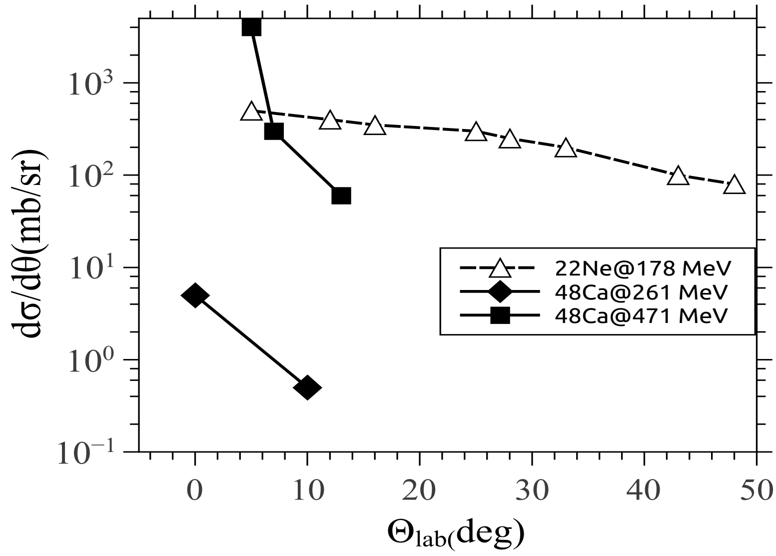

Figure 3. Comparison of angular distributions of alpha particles from the ^{48}Ca at 261 MeV (♦) and 471 MeV (■) and ^{22}Ne (△) [3]. The curves are drawn through the experimental points to guide the eye.

butions were obtained by integration of the obtained energy distribution of α-particles, particularly presented in Figure 2a. The angular distribution in the case of ^{48}Ca projectile is more foward peaked than in the case of ^{22}Ne projectile due to higher momentum.

Conclusion

To summarize, in our preliminary experiments involving the bombardment of ^{181}Ta with ^{48}Ca (261 MeV and 471 MeV) ions a number of light charged particles were observed. We have measured reaction products cross-section for ^{4}He and ^{7}Li isotopes detected at different emission angles.

We observed that the alpha particles with an energy close to the respective calculated kinematic limit for a two-body exit channel were produced with relatively great probability in the studied reaction. The production cross-section for emitted alpha is strongly forward peaked.

The larger value of the production cross section for alpha was observed for the higher value of the projectile energy.

Acknowledgments

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References

[1] V.V. Volkov et al., Izv. AN SSSR: Phys. **42** (1978) 2234.
[2] Yu.E. Penionzhkevich et al., PEPAN. **17** (1986) 165.
[3] C. Borcea et al., Nucl. Phys. **391** (1982) 520.
[4] V.Z. Maidikov et al., Pribori i Tech. Expt. **5** (1979) 68.