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PRODUCTION OF MULTIPLY CHARGED NUCLEI IN INTERACTIONS BETWEEN 75—350 MeV PROTONS AND NUCLEI

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THE production of multiply-charged particles or fragments was investigated by the nuclear emulsion method. The procedure, calculation of the characteristics of the process, and some experimental facts were reported earlier (see, for example, [1]).

Figure 1 shows the cross section for the production of multiply charged particles with charge $Z \geq 4$ and energy $> 1-2$ MeV/nucleon on light and heavy emulsion nuclei, at proton energies 75, 100, 200, and 350 MeV.

The remaining results, which are reported here, pertain essentially to fragments of Li and Be from the disintegration of heavy nuclei. The relative probability of emission of multiply-charged particles depends on the energy of the bombarding proton beam, and this dependence has a different form in stars with many and with few prongs.

A characteristic feature of the energy spectra is that the most probable fragment energy is independent of the incident proton energy. The energy spectra of the fragments are characterized by a large number (40—55%) of subbarrier particles. Another feature is that the maximum-energy part of the spectrum of the multiply-charged particles increases somewhat with increasing beam energy (at $E_p = 200$ MeV the fragments with energy more than 30 MeV amount to $19 \pm 4\%$, whereas for $E_p = 100$ MeV they amount to only $8 \pm 3\%$). It can also be noted that the greater part of the fragments has a momentum exceeding that of the incoming nucleon, and such multiply-charged particles amount to 80% at $E_p = 76$ MeV and 65% at $E_p = 100$ MeV.

The energies of the multiply-charged particles depend on the magnitude of the disintegration in which they are produced. High-energy fragments ($E > 24$ MeV) are produced in 50% of the cases in stars with few prongs (one or two), and at fragment energy < 16 MeV the contribution of the stars with few prongs is less than 30%. The energy spectra of the multiply-charged particles are sensitive to the emission angle, being harder at small angles relative to the proton beam. Because of this, the high-energy fragments are more strongly collimated along the bombarding proton beam.

We have previously discussed [1] the assumption that multiply-charged particles are knocked out from the nuclei by nucleons of 60—80 MeV energy. For a 100-MeV beam energy and higher, these nucleons will be those produced in a nuclear cascade, and therefore the characteristics of fragment production will be determined by the angular and energy distribution of the cascade particles. Analysis shows that the obtained experimental characteristics coincide with the results that can be obtained from a qualitative examination of such a cascade model. A quantitative comparison of

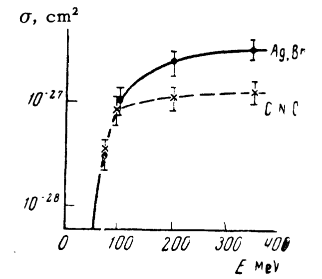

FIG. 1. Excitation function for the production of multiply-charged particles in the disintegration of heavy (solid curve) and light (dashed) emulsion nuclei.

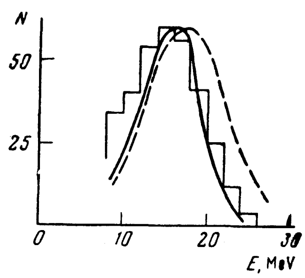

FIG. 2. Fragment energy spectra at 76 MeV proton energy. Curves—calculated at 70 MeV proton energy. Continuous line —Gaussian momentum distribution. Dashed line—Fermi momentum distribution. $\theta = 0 - 20°$.

the results of the experiment and calculation of quasielastic knockout was made at a proton energy 76 MeV. Figure 2 shows the experimentally obtained spectrum of multiply charged particles and the spectra calculated under the assumption that the intranuclear momenta have Fermi and Gaussian distributions. The experimental spectra coincide with those calculated under the assumption that the multiply-charged particles have a Gaussian momentum distribution in the nucleus, at other values of emission angle of the fragment, and also for a different energy of the incident protons (we have in mind a proton energy 100 MeV, at which the fragments in stars with few prongs can be knocked out directly by the incoming particle).

Special interest attaches to the presence of a large number of subbarrier multiply-charged particles. This can serve as an indication that the quantity r_0, used in the calculation of the Coulomb barrier, is actually larger than 1.5×10^{-13} cm. The latter indicates preferred production of multiply-charged particles on the periphery of the nucleus, where the density of the nuclear matter is low. In this sense subbarrier multiply-charged particles, like K^- mesons, can be used as indicators of the diffuse surface of the nucleus.

[1] M. M. Makarov, JETP **45**, 56 (1963), Soviet Phys. JETP **18**, 41 (1964).

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112