Properties of light nuclides produced in the fragmentation of ^{238}U

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In the last years, motivated by the plans for the construction of ADS and RIB facilities, fragmentation and fission reactions at intermediate energies have acquired a greater interest. The physics of such reactions is still a subject of research, and precise experimental data are needed to test the reliability of the theoretical estimations.

Experiments on the formation of residual nuclei from ^{238}U, ^{208}Pb, ^{197}Au, and ^{56}Fe beams on several targets at relativistic energies have already been performed in inverse kinematics with the fragment separator (FRS) at GSI [1]. Some attractive peculiarities of the in-flight separation are that radioactive fragments can be measured before they decay, the whole isotopic distribution can be obtained for every element, and, once the isotopes are identified, their velocities can precisely be evaluated from their magnetic rigidities. This method yields absolute and extremely accurate velocity values. Here, we will present the result of our investigations on the light residues produced in the fragmentation of 1·A GeV ^{238}U + Ti, and we will compare our preliminary results to previous knowledge.

An important result concerns the velocities of these residues. Morissey [2] showed that the average longitudinal momentum transfer for residual nuclei with masses close to the mass of the mother nucleus ($\Delta A<50$) increases linearly with the mass loss ΔA. Although the validity of this systematic dependence on ΔA could not be proved for large mass loss due to the uncertainties of the measurements, it seemed reasonable to expect that a more violent collision will produce a larger momentum transfer. On the contrary, Lindenstruth [3], analysing the residual nuclei produced in the interaction of gold with several targets, showed that for $\Delta A>70$ the momentum transfer stops definitely to increase and eventually starts slowly to decrease. In the present experiments, the velocities of the reaction products could be determined with high precision, and this allows us to check the finding of Lindenstruth. In figure 1 (left) the mean values of the velocity-spectra of fragmentation residues are collected for several elements. Our preliminary data (●) are compared with those obtained in the reaction 1·A GeV ^{238}U + Pb [7] (●), where the acceleration of light elements is even more enhanced. Our results confirm the finding of Lindenstruth in the sense that the momentum transfer does not increase further when the mass loss becomes very important. In addition, we find a clear inversion of the trend for the very light products which are found to be even slightly faster than the projectiles. The reason for this acceleration is not obvious. A possible explanation could be the interaction between the surviving part of the projectile and the expanding fire streak behind it in the later stage of the collision.

Another interesting peculiarity of the fragmentation of ^{238}U is the mean N/Z of the produced elements. In figure 1 (right) the EPAX systematics [4] for a ^{197}Au projectile (---) and the stability line are reported (—). These two reference lines are compared with several experimental data. Results from the reactions 800·A MeV ^{197}Au + p [5] (□) and 414·A MeV ^{56}Fe + p [6] (△) follow the EPAX systematics. In these cases, the produced fragments are not far from the mother nucleus. However the reactions 1·A GeV ^{238}U + Pb [7] (●), 750·A MeV ^{238}U + Pb [8] (●) and 1·A GeV ^{238}U + Ti (our data) (●) leave the EPAX evaporation corridor, and the more the produced light-nuclides are far from the mother nucleus, the more neutron-rich they are, up to the point that they even cross the stability line. A possible explanation could be found in the predictions of statistical multi-fragmentation models (see [9]). In these models, the light products emerge from the freeze-out of a low-density configuration. Since most of the excitation energy was spent for the disintegration of the system, their secondary deexcitation starts from rather low temperature. Thus these products have larger N/Z-ratios than the fragments produced as a result of evaporation from the mother nucleus.

Properties of light projectile fragments from collisions of massive nuclei have been measured with a high-precision spectrometer. Unexpectedly high velocities and deviations of the N/Z ratio from the evaporation corridor have been found. While the N/Z ratio seems to scale with the mass loss, the velocities also strongly depend on the target nucleus. These features, which seem to be related to multifragmentation, give important information on the dynamics of relativistic nuclear collision.

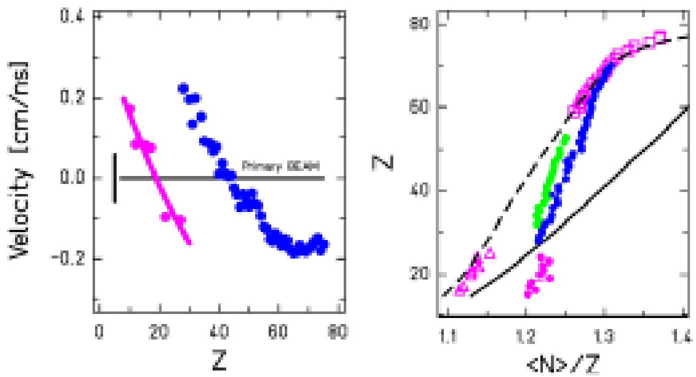

Figure 1: Left: Mean velocities of the fragmentation residues (see text for symbols). Right: Mean N/Z-ratio of the isotopic distributions of the produced elements (see text for symbols).

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