Fragmentation of Unstable Neutron-Rich Oxygen Beams

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Fragmentation of energetic heavy-ion beams is widely used to produce secondary beams of exotic nuclei far from stability. Recently, two-step fragmentation processes were discussed in the context of an efficient production of very neutron-rich isotopes at next-generation exotic nuclear beam facilities. This process involves an unstable neutron-rich fragment as an intermediate product which undergoes fragmentation again, yielding the final nucleus of interest. So far, the influence of the neutron-to-proton ratio of the projectile on the projectile fragment distributions (the "memory effect") was studied in a very narrow range of isospin only, since stable projectiles were used.

In this measurement [1], fragmentation of the unstable neutron-rich nuclei ^{19,20,21}O, together with that of the stable ^{17,18}O isotopes was studied. Secondary beams of $^{17-21}$O ions were produced in a fragmentation reaction of a primary ^{40}Ar beam (720 MeV/u) delivered by the synchrotron SIS at GSI. Secondary oxygen beams with kinetic energies around 600 MeV/u were subsequently separated in the Fragment Separator FRS and transported to the LAND experimental area. Both the incident projectiles and their fragments produced in interactions with carbon and lead targets were identified with regard to mass and charge number and the fragment angular distributions were measured; for experimental details see [1]. Fragment production cross sections could be determined for $^{17-21}$O projectiles and carbon, nitrogen, and oxygen fragments which include both stable and neutron-rich isotopes. The results obtained for the carbon target are shown in Fig. 1. The data are compared with fragment production cross sections obtained from the empirical EPAX parameterization [2] and with those obtained from two different abrasion-ablation models [3, 4], which are based on a microscopic description of the fragmentation process. As seen in Fig. 1, the EPAX parameterization seems to reproduce the general trend of the data rather well. Though the EPAX formula was obtained by adjusting to fragmentation data of stable beams only, the good, almost quantitative description indicates that the parameterization of the "memory effect" is valid also for unstable projectiles as neutron-rich as ^{21}O ($A/Z = 2.625$). An obvious deficiency of the EPAX parameterization, however, is the fact that the odd-even effects, observed in the experimental data particularily for the nitrogen fragments, cannot be reproduced. This is expected since the EPAX parameterization does not contain any physical description and no attempt has been made to parameterize the odd-even effects.

The experimental data show that isotopes with even neutron numbers, especially ^{15}N with a closed N=8 shell, are more abundantly produced than their neighbors with

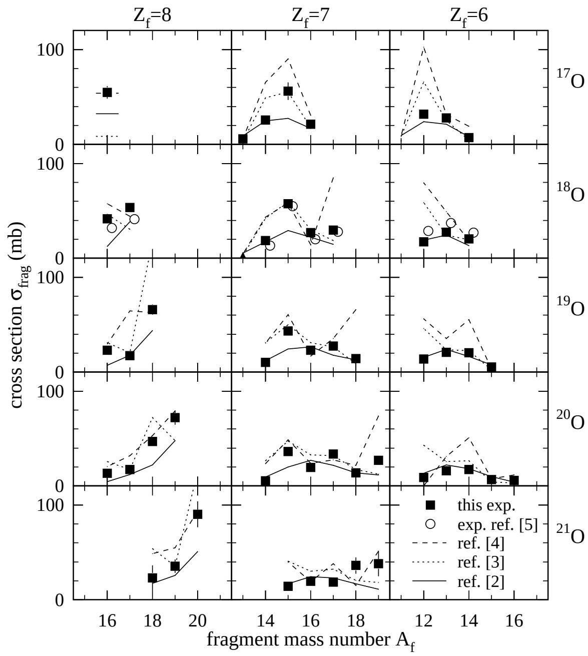

Figure 1: Production cross sections of fragments of $^{17-21}$O beams (carbon target).

odd neutron numbers. It is likely that the large difference in neutron separation energy between unpaired and paired neutrons is responsible for the odd-even staggering in the production cross sections. This is illustrated by quoting the one-neutron separation energies of the ^{15,16,17,18}N isotopes which amount to 10.8, 2.5, 5.9 and 2.8 MeV, respectively. The unpaired neutron in ^{16}N or in ^{18}N is thus easily removed at the end of the evaporation chain, explaining their lower production cross sections in comparison to ^{15}N or ^{17}N, respectively. Odd-even effects in the production cross sections are predicted by both formulations of the abrasion-ablation model as seen from Fig. 1. Apparently, both calculations, however, overestimate the effects. Nevertheless, the results, in general, agree with the experimental data within roughly a factor of two.

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