Production of New Neutron-Rich Isotopes of Heavy Elements in Fragmentation Reactions of ^{238}U Projectiles at 1*A* GeV

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The possibility to extend the present limits of the chart of the nuclides provides unique opportunities for investigating the nuclear many-body system with extreme values of isospin and most of the stellar nucleosynthesis processes leading to the production of the heaviest elements in our universe. This is the reason why presently, several new-generation in-flight radioactive-beam facilities are being commissioned, built, or designed.

The access to heavy neutron-rich nuclei—in the "north-east" region of the chart of nuclides—is a real challenge. Indeed, the heaviest known isotopes in this region are still located relatively close to the β stability line. A few years ago, it was proposed to use fragmentation reactions of heavy stable projectiles such as ^{238}U or ^{208}Pb at relativistic energies to populate that region of the chart of nuclides [1,2]. The extreme case for these reactions involves the proton-removal channels where the projectiles lose only protons, and the excitation energy gained is below the particle-evaporation threshold.

To test this idea, we performed an experiment at GSI Darmstadt using ^{238}U beam at 1*A* GeV. The fragmentation residues were analyzed with FRS. For details, see [3].

In Fig. 1 we represent the isotopic distributions of the cross sections measured in this work. The error bars are shown when larger than the data points. Those points in the figure surrounded by a square correspond to the *40 new* isotopes discovered in this experiment. In a few days' measurements we were able to reach cross sections as low as 100 pb. As expected, the production cross sections decrease drastically with the neutron number. On average, an additional neutron decreases the production cross section by about a factor 4. In the same figure we also compare the measured cross sections with predictions obtained with the codes EPAX [4] and COFRA [1,5]. The EPAX code describes rather well the production of residual nuclei relatively close in mass number to the projectile; however, it over-predicts the production cross sections of neutron-rich residual nuclei produced in mid-peripheral collisions where the projectile loses a larger number of nucleons. COFRA provides an overall good description of the cross sections of neutron-rich nuclei produced in fragmentation reactions induced by ^{238}U projectiles. A more detailed analysis indicates a slight overestimation of the cross sections of nuclei close to the projectile (e.g., Fr isotopes) and far from the projectile (e.g., Au and Pt isotopes).

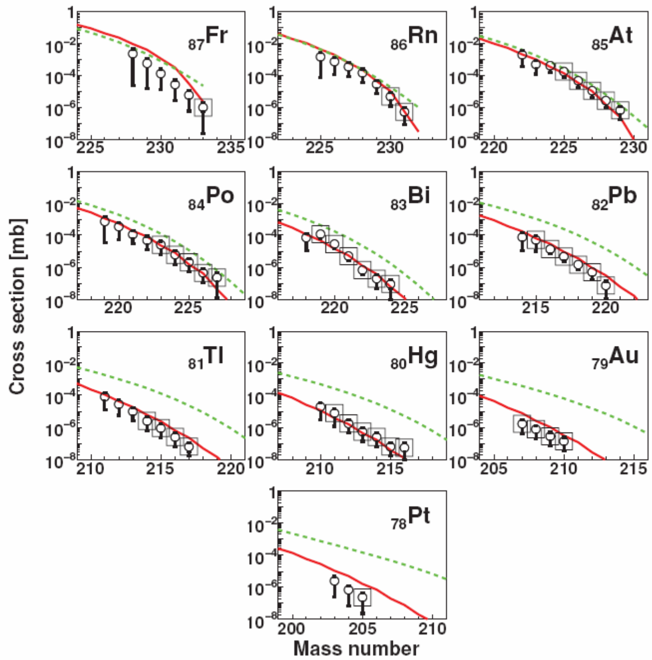

Figure 1: Isotopic distributions of the production cross sections of heavy neutron-rich nuclei determined in this work. Nuclei observed for the first time are surrounded by a square symbol. The experimental measurements are compared with the predictions obtained with the code COFRA (solid line) and EPAX (dashed line).

The large fluctuations in the number of abraded protons and neutrons in this type of reaction make it possible to populate cold-fragmentation reaction channels leading to the production of the most neutron-rich nuclei. These results pave the way for a considerable extension of the northeast limit of the chart of nuclides expected with the new generation of radioactive-beam facilities.

References

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