Research Group for Heavy Element Nuclear Science

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Determination of the limits of existence of heaviest nuclei is among the most interesting and challenging topics in nuclear physics. Nuclear fission is our core subject in nuclear physics program. Our experiments also include nuclear structure studies of a broad range of nuclides, in addition to super-heavy nuclei. The heavy elements also open unique opportunity for studies of relativistic effects in chemistry and atomic physics.

In the chemistry program in FY2020, the formation and the chemical characterization of single atoms of dubnium (Db, element 105), in the form of its volatile oxychloride, was investigated using the on-line gas phase chromatography technique. Comparative studies with the lighter homologs of group-5 in the Periodic Table clearly indicate the volatility sequence being $NbOCl_3 > TaOCl_3 \geq DbOCl_3$ [1]. The results are presented in Research Highlight.

In this report, we introduce the results of fission study and production of radioactive isotopes in an attempt to application study.

Measurement of fission-fragment mass distribution in the multinucleon transfer channels of the ^{18}O + ^{237}Np reaction

Recently we have developed a setup to study fission in multinucleon transfer (MNT) reaction. Depending on the number of exchanging neutrons and/or protons between projectile and target nuclei about 20 compound nuclei are produced, and their fission data can be taken in one reaction measurement. This was realized by identifying outgoing ejectile isotopes using a silicon dE-E telescope developed by us. Also, measurement over a broad range of excitation energy up to 60 MeV is possible. Up to now data from the reactions of ^{18}O+^{232}Th [2] and ^{18}O+^{238}U [3] were taken. We found that the mass-asymmetric shape of the fission-fragment mass distribution (FFMD) remaining at high-excitation energies is due to the multichance fission (MCF), i.e. neutron evaporation before fission [3]. As excitation energy is successively lowered by multiple neutron emission, fission from higher-order fission chances tends to have a pronounced double-humped shape in FFMD due to revival of the shells responsible for mass asymmetry.

In the present experiment, we studied the MNT reaction of ^{18}O + ^{237}Np [4]. Some of the nuclei produced in this reaction were also studied by us in the different channels of ^{18}O+^{232}Th [2] and ^{18}O+^{238}U [3]. The data from 3 reactions are compared in Fig.1. It is found that for all the nuclei and the measured excitation energies, the general shape of the FFMD remains apparently insensitive to the number of transferred nucleons, i.e., remains independent on the way the compound nucleus is produced. In Fig. 1, the calculations based on the Langevin equations are shown by solid curves, where MCF is introduced. The number of neutrons emitted before fission depends on the angular momentum of the fissioning nucleus. In the analysis, experimental data are explained when the fissioning nucleus has angular momentum less than 20 $\hbar$.

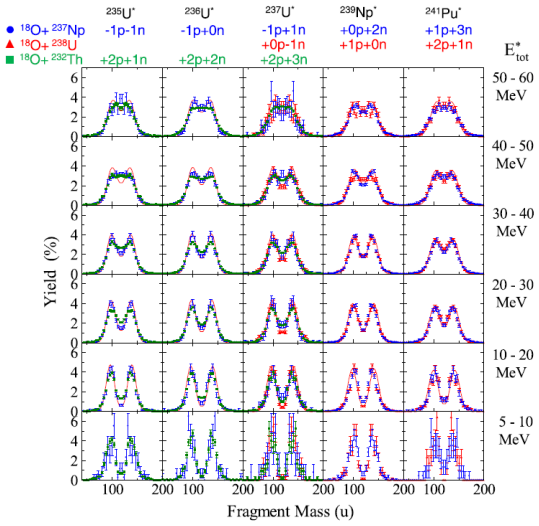

Fig.1 FFMDs for U, Np, and Pu isotopes obtained in the present ^{18}O+^{237}Np reaction (blue circles), in comparison to those from the reactions of ^{18}O+^{232}Th [2] (green squares) and ^{18}O+^{232}U [3] (red triangles). Langevin calculation assuming zero angular momentum in fissioning nucleus is shown by the curves.

Generation of Medical Radioisotopes with Accelerator Neutrons

We proposed the production technique of medical radioisotopes (RI) for cancer diagnosis and therapy such as ^{99}Mo/^{99m}Tc, ^{90}Y, ^{67}Cu, and ^{64}Cu using fast neutrons from an accelerator. The neutrons were obtained by irradiating 40-50 MeV deuterons to beryllium metal or graphite target. Such high energy neutrons gave us many reaction channels, such as (n,*2n*), (n,*p*), (n,*d*), (n,α), and so on [5], and gave us a variety of radioisotopes.

In Japan, approximately 0.7–0.9 million diagnostic procedures per year are carried out using ^{99m}Tc (half- life $T_{1/2}$= 6 h). This radioisotope is obtained from the decay of ^{99}Mo (66 h), all of which Japan imports. ^{99}Mo has been produced by a limited number of overseas research reactors. Thus, we developed the alternative production method by accelerator driven neutrons with ^{100}Mo(n,*2n*)^{99}Mo reaction. We precisely measured the yield of ^{99}Mo using a $^{nat}MoO_3$ target. The result leads to the conclusion that approximately 50% of the demand for ^{99}Mo in Japan could be met using a 100 g $^{100}MoO_3$ with 40 MeV deuteron beams of 2 mA [5,6].

References

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