Research Group for Heavy Element Nuclear Science

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Studies of chemical properties of the heaviest elements and determination of the limits of nuclear stability are among the most interesting, but also most challenging topics in modern chemistry and nuclear physics. The research of the group strongly addresses these fundamental questions.

In nuclear physics, our core program is on fission, which is a unique physical process observed only in nuclear matter, and which provides the basis for numerous atomic energy applications. Our experimental and theoretical programs includes structure and reaction study of exotic neutron- and proton-rich nuclei as well as super-heavy nuclei. For nuclear chemistry, our work is concentrated on the heaviest elements, whose chemical properties are crucially determined by the relativistic effects. Atomic and chemical properties of the exotic atoms and molecules will be studied on an atom-at-a-time chemistry approach.

Investigation of prompt fission measurement using multi-nucleon transfer reactions

Nuclear fission is a unique decay process which may be described by the interplay of macroscopic (collective) and microscopic (single particle) degrees of freedom in a nucleus. In particular, fission-fragment mass distribution (FFMDs) and their sensitivity to the excitation energy and isospin provide a deep insight into the mechanism of the process of fission.

The scope of the present work is to explore the potential of the multi-nucleon transfer (MNT) reactions to measure FFMDs and their excitation energy dependence for the neutron-rich actinide nuclei, which cannot be accessed by particle-capture and/or heavy-ion fusion reactions. Advantage of this method is that fission of many compound nuclei can be studied in one experiment. A key development for this method is a silicon ΔE-E detector to separate ejectile isotopes to identify transfer channels and determine the excitation energy of compound nuclei. Fission fragments were detected in coincidence using multi-wire proportional counters. We studied the reaction ^{18}O + ^{232}Th using an ^{18}O beam from the JAEA tandem accelerator.

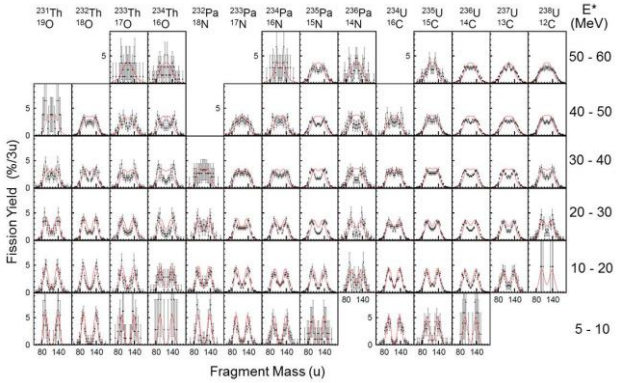

Fig.1 FFMD obtained in the MNT channels in ^{18}O+^{232}Th. The curves are the Langein model calculation [2].

Figure 1 shows the FFMDs of $^{231\text{-}234}$Th*, $^{232\text{-}236}$Pa*, and $^{234\text{-}238}$U*, for excitation bins of 10 MeV [1]. Data of ^{231,234}Th*, ^{234,235,236}Pa* nuclei were obtained for the first time. It is found that the measured spectra reveals larger peak-to-valley ratio in the FFMDs for nuclei with large isospin values, as seen for the most neutron rich isotopes of the same element, considered at the same excitation energy, for instance at the E^{*}=20-40MeV. This might be explained by the growing influence of the magic ^{132}Sn nucleus on the mass division toward neutron-rich nuclei.

First on-line vacuum chromatography experiments with single atoms of Tl as the lighter homolog of E113

Our international collaboration with the Paul Scherrer Institute (PSI) demonstrated the feasibility of on-line vacuum chromatography experiments with the heaviest elements. The experiment at the JAEA Tandem accelerator facility acts as a proof of principle aiming at a first unambiguous chemical characterization of E113.

A first-ever on-line isothermal vacuum chromatography experiment (IVAC) has been developed and successfully used for determining the adsorption of thallium on quartz at one-atom-at-a-time level [3]. The radioactive nucleus as a tracer ^{184}Tl ($T_{1/2}$=10.1 s) was produced in the ^{152}Gd(^{35}Cl, 3n) reaction and transported to the JAEA-ISOL setup with a CdI_2/He aerosol gas-jet system. ^{184}Tl was ionized and the separated ^{184}Tl^{+}-ion beam was guided to a newly developed IVAC experiment setup (P_{exp} <10^{-2} Pa). By changing isothermal temperature of the innermost quartz column, retention time of the Tl atom on the quartz surface was measured. The retention time is correlated with a probability of the atom passing through the column. The escaped atom from the column is attached on a gold surface of a diamond-based detector, where α-decay of ^{184}Tl was detected to determine the fraction. The experimental data were compared with a microscopic kinetic model (Monte Carlo approach) [4] which can describe the adsorption process. The measured adsorption enthalpy of 158±3 kJ/mol is in excellent agreement with the calculation. The set up was found to have a fairly high throughput efficiency of 37% at the highest temperature [3]. The result demonstrates the applicability of the newly developed IVAC system for the E113 chemistry and for even higher elements.

References

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