Angular momentum transfer in multinucleon transfer channels of $^{18}O+^{237}Np$

K. Hirose[1)], S. Tanaka[1,2)], K. Nishio[1)], K.R. Kean[1,3)], H. Makii[1)],
R. Orlandi[1)], K. Tsukada[1)], Y. Aritomo[2)]
1) : Research Group for Heavy Element Nuclear Science, JAEA
2): Kindai University 3) Tokyo Institute of Technology

The limit of existence of the heaviest elements/nuclei is substantially expanded due to the theoretically predicted "Island of Stability (IoS)", caused by the closed shell structure expected at neutron and proton numbers of N=184 and Z=114 (or 120,126), respectively. To reach the IoS is one of the ultimate goals in nuclear physics. Fusion reactions, occurred in the collision between two nuclei and used to explore the superheavy element (SHE) region so far, cannot allow us to reach the center of the IoS, because of the insufficient number of neutrons contained in the projectile and target nuclei.

Recently, multinucleon transfer (MNT) reactions have attracted considerable interest because the reactions, such as $^{238}U+^{248}Cm$, have the potential to produce neutron-rich SHE nuclei in the region toward the IoS. In the MNT reactions, there is a probability to transfer larger number of neutrons than protons from the projectile to the target, resulting in the production of neutron-rich nucleus. In contrast to fusion reaction, however, the reaction mechanism is scarcely studied due to a complexity of the MNT process. In the first step, the excited compound nucleus (CN) is produced, see Fig. 1. The CN needs to be deexcited by evaporating neutrons, in competition with fission, to survive as an evaporation residue, i.e. SHEs. One of the important quantities to determine the survival probability, thus largely changes the production rate of the SHEs, is the angular momentum distribution given in the CN. Typically, component less than 15 $\hbar$ can contribute to the production of SHEs.

We have investigated the average angular momentum given in the multinucleon transfer channels of the $^{18}O+^{237}Np$ [1]. For the first time, we clearly show the change of angular momentum with respect to the number of transferred neutrons and protons. In the experiment, we measured angular distribution of fission-fragments relative to the rotational axis of the CN. At a larger angular momentum, thus higher rotational energy, fission-fragments are more emitted at the directions perpendicular to the rotational axis. Thus, the angular anisotropy is directly correlated with the angular momentum.

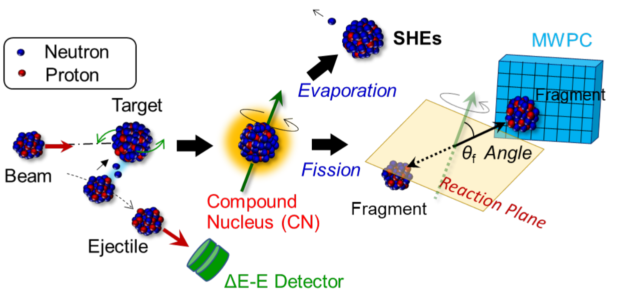

Fig. 1 Multinucleon transfer reaction and process to produce SHEs as an evaporation residue. In the present experiment, angular momentum of the compound nucleus is determined by detecting fission fragment.

The experimental approach is schematically shown in Fig. 1. In the collision of ^{18}O and ^{237}Np, many compound nuclides are produced ($^{236\text{-}239}Np$, $^{237\text{-}240}Pu$, $^{239\text{-}242}Am$). The produced nuclides were identified event by event by detecting the ejected nucleus using the silicon ΔE-E telescope. The beam direction and the ejectile flight-direction uniquely defines the reaction plane as shown in Fig. 1 (the rotational axis is aligned perpendicular to the reaction plane). The fission fragments were detected using the position sensitive multiwire proportional counters. To draw the angular distribution, fission fragments per solid angle was derived in the center-of-mass frame.

Examples of the fission-fragment angular distributions are shown in Fig. 2, obtained in the MNT channels of $^{18}O+ ^{237}Np\rightarrow ^{17}O+ ^{238}Np^*$ and $^{18}O+ ^{237}Np\rightarrow ^{16}O+ ^{239}Np^*$. Inelastic scattering $^{18}O+ ^{237}Np\rightarrow ^{18}O+ ^{237}Np^*$ is also shown. It is found that the angular anisotropy, W(90°)/W(0°or180°), increases with transferred neutron number. We have adopted the statistical saddle point model [2] to derive the average angular momentum I_0 from the experimental data. In this model, angular distribution is determined by the orientation of the symmetry axis (fission axis) of a nucleus at the saddle point. The angular distribution is thus described by the distribution of the spins I and the K quantum number, i.e. its projection of I on the symmetry axis. The best fit I_0 value obtained in the analysis is shown in Fig. 2. The value increases with the number of transferred neutrons. In the analysis of the fissions of $^{236\text{-}239}Np$, $^{237\text{-}240}Pu$, and $^{239\text{-}242}Am$, it is found that there is not difference between neutron and proton transfer. Also, the I_0 value levels off at ~15 $\hbar$ when the number of transferred nucleons is larger than three, which can be an important advantage in the SHE production. To see whether this behavior remains in larger transfer channels will be the next step of this research.

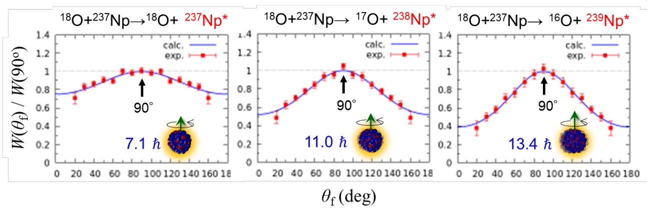

Fig. 2 Fission fragment angular distribution of compound nucleus $^{237,238,239}Np$. The data are normalized at θ_f =90°. The curve is the fit to the experimental data (solid points) in the framework of the saddle point mode. The obtained average angular momentum is indicated.

References

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[2] B. B. Back and S. Bjornholm, Nucl. Phys. A **302**, 343 (1978).