Excitation functions for the ^{51}V + ^{159}Tb fusion evaporation reaction

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Syntheses of elements from flerovium ($Z = 114$) till oganesson ($Z = 118$) were made using the hot-fusion reactions with ^{48}Ca beams on actinide targets. To synthesize the elements beyond $Z = 118$, reactions with either ^{50}Ti, ^{51}V, or ^{54}Cr beam on actinide targets are necessary. However, these beams have, so far, only been used on spherical targets around ^{208}Pb. Thus, any information regarding the reaction mechanisms using these beams on actinide targets will provide valuable information for the success of current and future searches for new elements. Unfortunately, the direct systematic study of reaction mechanisms on actinides target is unrealistic due to the too-small fusion-evaporation cross-sections (pb–fb range). Thus, the use of a lighter surrogate system based on deformed targets with similar deformation characteristics around lanthanide nuclei may give insight and valuable information regarding reaction mechanisms with ^{50}Ti, ^{51}V, or ^{54}Cr beams, especially regarding the side collision effect.[1,2] The reaction of ^{51}V beam on ^{159}Tb target presents much higher production rates (μb range) while being an excellent surrogate reaction. Indeed, the ^{159}Tb deformation parameters ($\beta_2 = 0.271$, $\beta_4 = 0.066$) are similar to the one of the ^{248}Cm ($\beta_2 = 0.286$, $\beta_4 = 0.039$) that is currently used in the search for the new element $Z = 119$ at RIKEN.

This similarity in deformation parameters allows for the study of the side collision effect using ^{51}V beam on deformed target. Has it been pointed out in Refs. 1) and 2). this side collision effect is involved in the relation between the barrier distribution and the maximum production cross-section of production for the super heavy elements. This relation also shows surprising differences between spherical and deformed targets as indicated in Refs. 1) and 2). Furthermore, these relations were derived using beams lighter than ^{48}Ca and never had been directly extracted for ^{50}Ti, ^{51}V, or ^{54}Cr beams.

The ^{51}V + ^{159}Tb → ^{210}Ra* reaction was selected as the first test surrogate reaction, measuring a wide range of excitation energies from 32 to 66 MeV. The barrier distribution was also measured separately and reported elsewhere.[3)]

The GARIS-III separator was set to transport the Evaporation Residue (ER) nuclei to the focal plane detector array.[4)] The ^{51}V^{13+} beam was provided by the newly upgraded SRILAC accelerator.[4)] The experiment used a rotating target of metallic ^{159}Tb with an average density of 365 ± 16 μg/cm^2 and beam intensities ranging from 152 particle nA to 345 particle nA. The ER nuclei were implanted into a Double-sided Strip Silicon Detector[4)] that was also used for the detection of the subsequent α-decays.

The identification of reaction channels was only based on the known α-decay energies and branching ratios, without any timing selection. The overall fit of the α-spectrum accumulated over 24 hours at each energy was used to extract the individual yield of ERs produced. Considering the transmission and detection efficiency, the cross section of various exit channels was extracted from those yields. Figure 1 shows the measured cross section of the xn, pxn, and αxn exit channels for the ^{51}V + ^{159}Tb → ^{210}Ra* reaction.

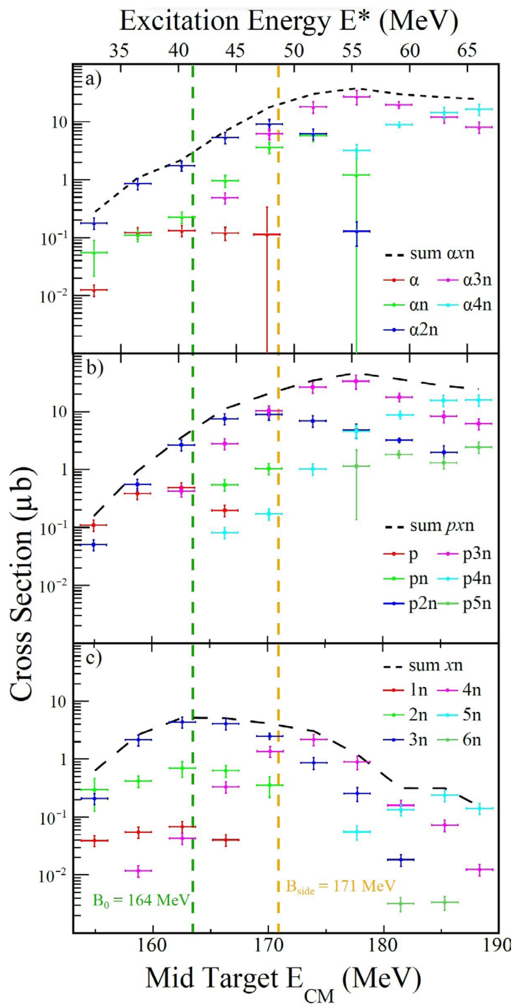

Fig. 1. Excitation function of the reaction ^{51}V + ^{159}Tb: (a) αxn exit channel, (b) pxn exit channel, (c) xn exit channel.

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The maximum cross-sections are the $p3n$ with 33.1 ± 8.9 μb, followed by the $\alpha 3n$ at 27.2 ± 7.3 μb and then the $3n$ at 4.4 ± 0.9 μb. The increase of the charged particle exit channel has been observed in this lower mass region but are not yet well reproduced by models. Discussions with the team of M. Kowal in Poland are ongoing to reproduce this behavior and our data based on their model.[5] It also seems that the side collision effect is not as present as expected for the xn exit channel and is under discussion with K. Hagino.[6]

References

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