Measuring the survival of Rn compound nuclei in the fusion of Ti and Gd

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From 1981 to 2004, 11 new elements were synthesized: element 107 (bohrium) to element 116 (livermorium), and element 118 (oganesson). Since then, however, only one new SHE has been synthesized: element 117 (tennessine) in 2009, despite numerous attempts to do so. Attempts have been made to synthesize both elements 119 and 120 without success [1]. A lack of understanding of the factors that affect the survival of the compound nucleus is one of the reasons that previous attempts have been unsuccessful at producing elements heavier than 118 [1]. SHEs span a large range of quadrupole (β_2) deformations, with some SHEs, especially those away from the region of beta-stability, being predicted to have substantial deformations [2,3]. The consequence of a higher quadrupole deformation is an increase in the level density for the neutron decay mode, which increases the probability of the compound nucleus deexciting through neutron emission rather than fission. Deexcitation by fission, rather than neutron emission, results in a lower-than-expected cross section for fusion-fission reactions to form heavy spherical nuclei [4].

Previous work in the Heavy Elements Group focused on the effects of neutron binding energy on the survival probability of the compound nucleus, and the effects of deformation in the compound nucleus during fission (of otherwise near-spherical nuclei) [4-6]. The current work seeks to expand upon that previous analysis by examining how the highly deformed compound nucleus changes affects measured excitation functions. The long-term goal is to create an isotopic series by bombarding targets of Gd and Dy with ^{48}Ti, and to elucidate properties which can lead to successful synthesis of heavy compound nuclei. Recent research into production of elements 119 and 120 have focused heavily on the use of ^{50}Ti [7]. The current reactions being studied with ^{48}Ti projectiles provide an opportunity to learn more about the use of this projectile while being able to benefit from a much higher event rate. These reactions were chosen carefully, as they serve as both analogs for super-heavy element production, and the targets allow a variation in neutron number so that the effects of deformation can be observed. The more neutron deficient compound nuclei are more deformed. Further, these particular reactions are at the very limit of this type of experiment, as no systems exist beyond Ra whereby multiple compound nuclei of the same element can be viably produced with different neutron numbers by variation in the neutron number of the target in order to explore the effects of deformation on the compound nucleus.

In April 2022, an experiment was performed to measure the excitation function for the reactions of ^{48}Ti + Gd. These experiments were carried out using the K150 cyclotron at the Texas A&M University Cyclotron Institute. ^{48}Ti^{13+} with an energy of 6.6 MeV/u passed through a 15 μm Al window and a variable Al degrader, and a 2 μm Ti target backing. The targets were 446 μg/cm^2 ^{160}Gd and 334 μg/cm^2 ^{158}Gd, leading to compound nucleus excitation energies of 54.8-67.2 MeV for the ^{160}Gd target and 51.0-67.9 MeV for the ^{158}Gd target [8]. The products were separated using the AGGIE separator (Al Ghiorso's Gas-filled

Ion Equipment), which was set for magnetic rigidities of 1.62 T m and 1.61 T m (for ^{160}Gd and ^{158}Gd, respectively). The products were then focused to two double sided silicon detectors (DSSDs).

Preliminary results are shown in Figs. 1 and 2. The excitation functions appear to be surprisingly wide because the individual contributions have not been separated yet. We will also investigate the possibility of pxn exit channels, ^{48}Ti(^{158}Gd, pxn)$^{206-x}$At, which should be detectable as At isotopes with A< 204 have considerable alpha decay branches.

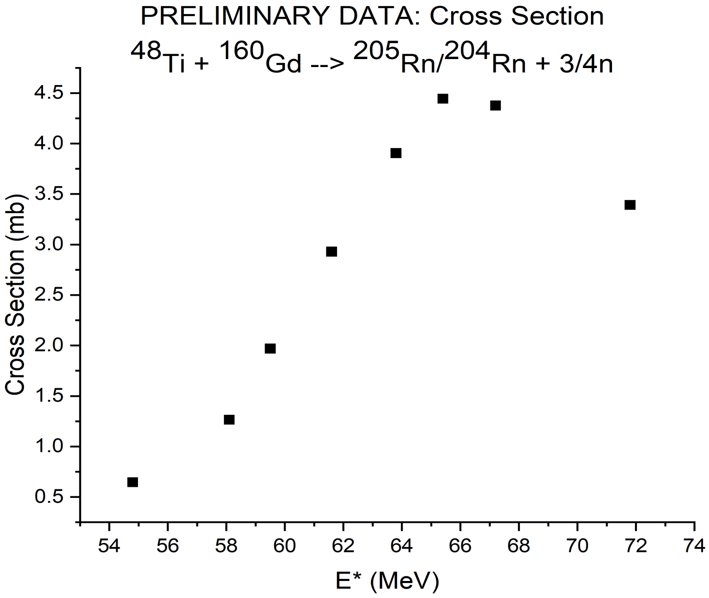

Fig. 1. Preliminary results on the ^{48}Ti + ^{160}Gd excitation function.

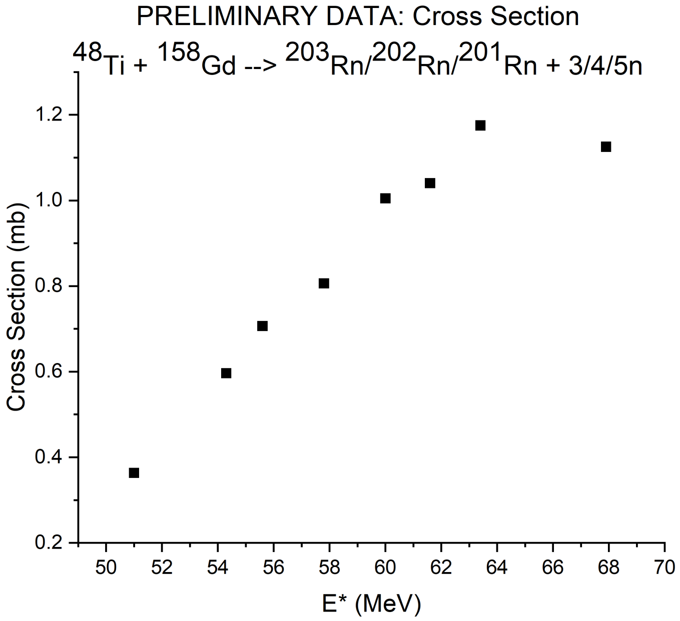

Fig. 2. Preliminary results on the ^{48}Ti + ^{158}Gd excitation function.

During an upcoming experiment, the excitation functions for the ^{160}Gd and ^{158}Gd targets will be finalized, in addition to completing the ^{157}Gd excitation function. Future work will consist of finishing the excitation functions for the Gd series and then performing a similar series of measurements for the reactions of ^{48}Ti with $^{164-160}$Dy. These data will then be compared to theoretical predictions to determine the effects of deformation on the survival of the compound nuclei of Rn and Ra.

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