Transmission efficiency of the gas-filled separator AGGIE and measurement of the ^{158,160}Gd(^{48}Ti, xn)$^{208-x}$Rn and ^{164}Dy(^{48}Ti, xn)$^{212-x}$Ra excitation functions

J.A. Mildon,[1,2] C.M. Sehring,[1,2] and C.M. Folden III1[1,2]
[1]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843*
[2]*Department of Chemistry, Texas A&M University, College Station, Texas 77843*

AGGIE (Al Ghiorso's Gas-filled Ion Equipment) has been installed at the Cyclotron Institute at Texas A&M University and is in active use for research [1]. The 2.5 m separator utilizes a $D_vQ_hD_v$ magnet configuration to deliver fusion-evaporation products, also known as evaporation residues (EvRs), to the focal plane array positioned immediately downstream of the separator. The detector setup currently employs two adjacent double-sided silicon strip detectors (DSSDs), each with 60 vertical and 40 horizontal strips with a pitch of 1 mm in each direction, spanning a total area of 120 mm x 40 mm. A recently installed Mesytec 16-input VMMR measures the pulse height in each strip individually and interfaces to the established data acquisition system. Such a setup, with a characterized separator, enables accurate cross section determination for fusion-evaporation reactions. The current work establishes the first preliminary separator transmission efficiency for AGGIE in its present configuration. In addition, we present the most recent analysis using these efficiency measurements of reactions recently studied with AGGIE.

The ^{164}Dy(^{40}Ar, xn)$^{204-x}$Po reactions were utilized to determine AGGIE's transmission efficiency since the excitation function has been previously reported [2]. We define the separator transmission efficiency (ε_{trans}) as the likelihood of an EvR produced in the target reaching the infinitely large focal plane. In addition, we defined three efficiencies related to the DSSDs. First, the geometric distribution of the measured beam spot on the DSSDs was fit to quantify the fraction of fusion-evaporation products that were within the 120 mm x 40 mm of the focal plane array (ε_{geom}), as this distribution provides for a direct examination of how well the beam is centered onto the detector. Second, the fraction of EVRs that implanted in an electrically functioning strip (ε_{elec}) was estimated with a Monte Carlo simulation of the previous fit. Third, the single-event energy discrepancy tolerance (the difference between the "vertical energy" measured on the front of the DSSD and the "horizontal energy" measured on the back of the DSSD) was limited to improve energy resolution. The actual value was estimated by projecting a plot of vertical energy versus horizontal energy onto an axis perpendicular to a line through the data. The fraction of events satisfying this criterion established the data analysis efficiency (ε_{anal}).

We corrected for the geometric probability that an alpha particle is emitted into the DSSD rather than out of the focal plane ($\varepsilon_{emission}$), the live time ($\varepsilon_{livetime}$), and the relevant alpha branching ratio (b_α). The luminosity N_tIt in each experiment was determined using Coulomb ("Rutherford") scattering into two Si detectors mounted at ±30° to the beam axis, where N_t is the areal density of the target, I is the average beam intensity, and t is the length of irradiation. $\varepsilon_{emission}$ was assumed to be ~52%, and the measured efficiencies were ε_{geom} = 89.6%, ε_{elec} = 71.1%, and ε_{anal} = 97.7%. These data were combined with the known excitation function to determine ε_{trans}:

$$\sigma_{rxn} = \frac{N_{obs,rxn}}{\varepsilon N_t I t} \quad \text{(Eq. 1)}$$

where σ_{rxn} is the known reaction cross section, $N_{obs,\ rxn}$ is the number of observed reaction products, and $\varepsilon = \varepsilon_{trans}\varepsilon_{geom}\varepsilon_{elec}\varepsilon_{anal}\varepsilon_{emission}\varepsilon_{livetime}ba$ is the total efficiency. An energy shift was required to bring the data into alignment agreement with the literature data. These analyses resulted in ε_{trans} = 15.4% for a product to reach the infinitely large focal plane in a reaction with this mass asymmetry.

In August and December of 2023, experiments were performed to measure the excitation functions for ^{48}Ti + $^{156\text{-}158,160}$Gd, and ^{48}Ti + $^{162\text{-}164}$Dy. These experiments were carried out using the K150 cyclotron at the Cyclotron Institute with a beam of 6.5 MeV/u ^{48}Ti^{11+}. The energy was reduced by a 10 or 15 µm Al window separating AGGIE from the evacuated beamline, a variable Al degrader (0 – 6.3 µm Al), and the 2 µm Ti target backings that the target material was deposited onto. The products were separated using AGGIE, which was set for magnetic rigidities from 1.58–1.61 T m. Finally, the products were then focused onto the same DSSD and VMMR setup as previously described.

Using the measured transmission, preliminary results for the reactions of ^{48}Ti + Gd are shown in Fig. 1. A full analysis of these results is still ongoing, but it is apparent that the cross section is reduced when changing from ^{160}Gd targets to the more neutron-deficient ^{158}Gd. This is to be expected as the compound nucleus is more neutron deficient. There is another sharp decrease in the reaction cross section for the reaction of ^{48}Ti + ^{164}Dy, which effectively adds an alpha particle to ^{160}Gd. It appears that an increase

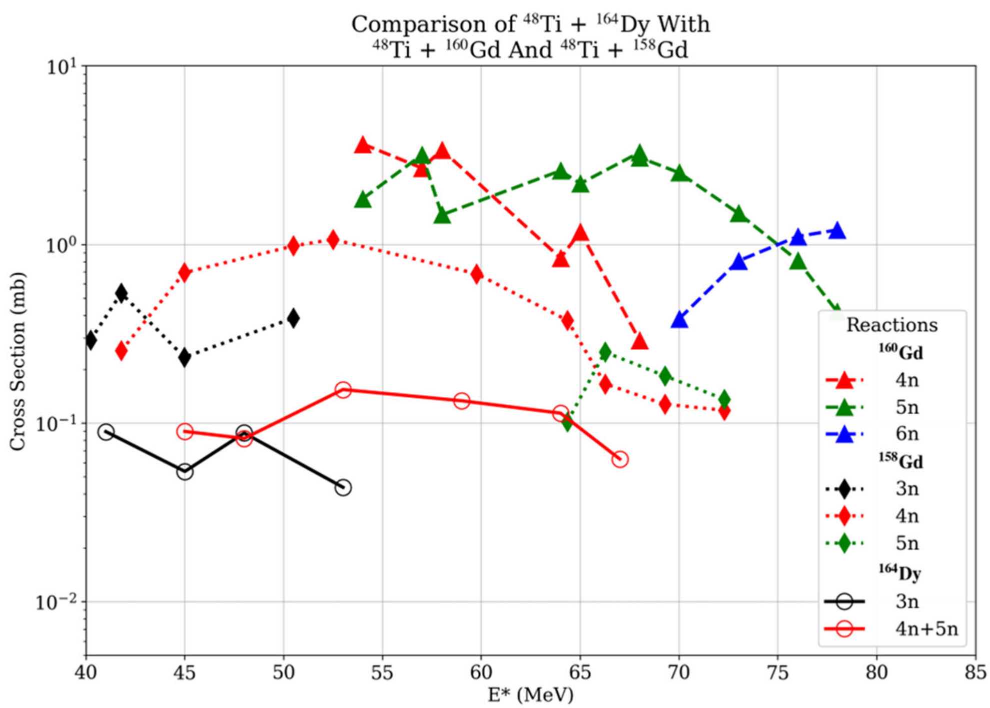

Fig. 1. Preliminary cross sections for the reactions of ^{48}Ti on ^{158,160}Gd and ^{164}Dy. The shape of the markers shows the reaction while the color shows the exit channel.

in the level density of the compound nucleus for neutron emission is not sufficient to counteract an even greater increase in fissility. In the future, we hope to be able to compare data on ^{48}Ti + ^{162}Dy, another reaction that we studied, to a recent paper on the ^{51}V + ^{159}Tb reaction [3] which produces the same compound nucleus.

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