Measurement of the ^{208}Pb(^{51}V,xn)$^{259\text{-}x}$Db Excitation Function

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Recently, a program to measure decay properties and excitation functions of coupled reaction pairs leading to odd-Z compound nuclei has been started by our group [1]. Studying two different reactions with an odd proton in either the target or the projectile is expected to yield information on the entrance channel of cold fusion reactions. The more asymmetric target-projectile combinations have smaller Coulomb barriers, which are expected to result in larger evaporation residue cross sections. However, in many of these pairs, only the reaction with the odd proton in the target has been studied. One such pair contains the $^{209}_{83}\mathrm{Bi}(^{50}_{22}\mathrm{Ti},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ and $^{208}_{82}\mathrm{Pb}(^{51}_{23}\mathrm{V},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ reactions. In 1985 Heßberger et al. first produced $^{258}_{105}\mathrm{Db}$ and $^{257}_{105}\mathrm{Db}$ in the reaction $^{209}_{83}\mathrm{Bi}(^{50}_{22}\mathrm{Ti},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ [2]. This experiment measured 1n and 2n excitation functions with maximum cross sections of 2.9±0.3 and 2.1±0.8 nb at excitation energies of 8.9 MeV and 16.9 MeV, respectively. More recent results suggest that the maximum cross sections for ^{258}Db and ^{257}Db using the $^{209}_{83}\mathrm{Bi}(^{50}_{22}\mathrm{Ti},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ reactions are closer to 4.3±0.4 and 2.4±0.3 nb at excitation energies of 15.8 and 22.3 MeV, respectively [3].

The analogous reaction, $^{208}_{82}\mathrm{Pb}(^{51}_{23}\mathrm{V},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$, was studied at the Lawrence Berkeley National Laboratory's 88-Inch Cyclotron in order to further understand these pairs, and to investigate a new production reaction for ^{258}Db. During the experiment, a total of six projectile energies were investigated. The laboratory frame energies were 236.2, 239.9, 243.6, 247.4, 251.1 and 254.8 MeV at the center of the 470 μgcm^{-2} ^{208}Pb target. Upon fusing, ^{258}Db and ^{257}Db were produced when the compound nucleus de-excited by the evaporation of 1-2 neutrons. The evaporation residues (EVRs) were formed with the momentum of the beam and recoiled out of the target. They were separated from the un-reacted beam, transfer products and fission fragments using the Berkeley Gas-filled Separator (BGS) [4] and were implanted in a silicon strip focal plane detector. The separation factors from un-reacted beam during transport through the BGS was approximately 10^{18} and separation from transfer products was 10^5. Alpha energy, position, time signatures for implantation and decay of Db and Lr allowed for the unambiguous identification of events through genetic correlation.

Fig. 1 shows the measured excitation functions for the 1n and 2n reactions. Cross sections of $1.6^{+0.4}_{-0.3}$ and $1.6^{+0.6}_{-0.4}$ nb were observed for the 2n excitation function at laboratory frame center-of-target beam energies of 247.4 and 251.1 MeV, respectively. These beam energies correspond to excitation energies of 22.2 and 25.2 MeV in the compound nucleus. Given the similarity of the two values, the maximum cross section was estimated to be $1.8^{+0.5}_{-0.4}$ nb at 23.7 MeV excitation energy, similar in magnitude to the maximum 2n cross section published for the $^{209}_{83}\mathrm{Bi}(^{50}_{22}\mathrm{Ti},2\mathrm{n})^{257}_{105}\mathrm{Db}$ reaction. For the 1n cross section, a maximum of $1.2^{+0.8}_{-0.5}$ nb was observed at a laboratory frame energy of 239.9 MeV in the center of the target, corresponding to a compound nucleus excitation energy of 16.2 MeV. This cross section is approximately 3.5 times smaller than the cross section for the 1n reaction in the analogous reaction $^{209}_{83}\mathrm{Bi}(^{50}_{22}\mathrm{Ti},\mathrm{n})^{258}_{105}\mathrm{Db}$.

Maximum cross sections for the 1n and 2n excitation functions were observed at 16.2 and 23.7 MeV excitation energies for the $^{208}_{82}\mathrm{Pb}(^{51}_{23}\mathrm{V},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ reaction at LBNL. For the $^{209}_{83}\mathrm{Bi}(^{50}_{22}\mathrm{Ti},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ reaction, maximum cross sections were observed at 15.8 and 22.3 MeV excitation energies, respectively, at GSI [3]. A difference in reported energies is expected due to differences in the accelerators and the methods for determining beam energy at the two institutions. Further studies are necessary to determine whether the difference in excitation energy at which the cross section peak is observed occur as a result of systematic errors or due to the spread of beam energies within the target.

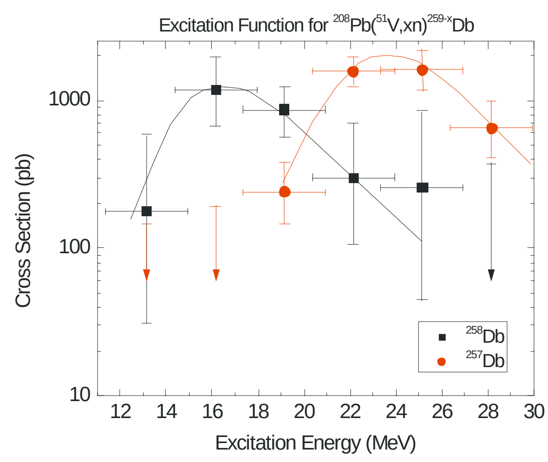

FIG. 1: Excitation function for the $^{208}_{82}\mathrm{Pb}(^{51}_{23}\mathrm{V},\mathrm{xn})^{259-x}_{105}\mathrm{Db}$ reaction, where x = 1, 2. Lines are drawn to guide the eye.

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