Systematic Study of Heavy Element Production in Compound Nucleus Reactions with ^{238}U Targets

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Reactions between heavy ions up to ^{27}Al and actinide targets have been used to produce neutron-rich isotopes of heavy elements up to Z=108. Recent reports of cross sections as large as several picobarns for production of superheavy elements (SHE) from Z=112 to Z=118 in the reaction of ^{48}Ca projectiles with actinide targets [1-3] challenge our understanding of the heavy element formation reaction mechanisms. Understanding these SHE formation cross sections is limited by the small number of reports involving actinide targets and projectiles heavier than Ne. To provide information on formation of heavy elements by complete fusion with actinide targets, we have undertaken a systematic study of heavy element formation in the reaction of neutron-rich projectiles from ^{18}O through ^{30}Si with ^{238}U targets.

Beams of ^{22}Ne, ^{23}Na, ^{26}Mg, ^{27}Al, and ^{30}Si were accelerated by the LBNL 88-Inch Cyclotron to several near Coulomb barrier energies. Compound nucleus evaporation residues recoiling from ^{238}UF$_4$ targets were separated from scattered beam and other reaction products with the Berkeley Gas-filled Separator (BGS). Atoms of heavy element products were identified by measuring their implantation and decay (and the decay of the resulting daughter products) in the Si-strip detector array at the BGS focal plane. Excitation functions for evaporation residues from the 4n, 5n, and 6n exit channels were determined. In addition, excitation functions resulting from radiochemical measurements in the reactions of ^{18}O, ^{19}F, and ^{22}Ne with ^{238}U targets were considered [4].

Armbruster has noted [5] a steep decrease in heavy element formation cross sections with increasing effective fissility of the fusing system [6], and has interpreted this decrease as being due to a hindrance in compound nucleus formation. Fig. 1 shows the peak cross sections for the 4n, 5n, and 6n exit channels from this series of reactions as a function of the effective fissility. In each of the seven reactions studied, the 5n exit channel was the largest. The peak of the 6n exit channel, where available, was approximately a factor of two smaller, and the peak of the 4n exit channel was several times smaller still. Parallel lines indicating an exponential trend in the peak cross sections are drawn in Fig. 1. Examination of the peak cross sections relative to the trend lines shows a strong odd-Z/even-Z effect in the 4n peak cross sections, and a weaker odd-Z/even-Z effect in the 5n peak cross sections. This odd/even effect is expected because the Q-values for compound nucleus formation (relative to the Coulomb barriers) are approximately 5 MeV less favorable in the odd-Z systems.

Also shown in Fig. 1 are reported cross sections and limits for reaction of heavier projectiles with ^{238}U targets [7-13]. If the exponentially decreasing compound nucleus formation trend continues to higher effective fissilities, observation of multi-picobarn cross sections for SHE must be explained by unexpectedly large enhancements in the survival against fission during deexciation (Γ_n/Γ_f).

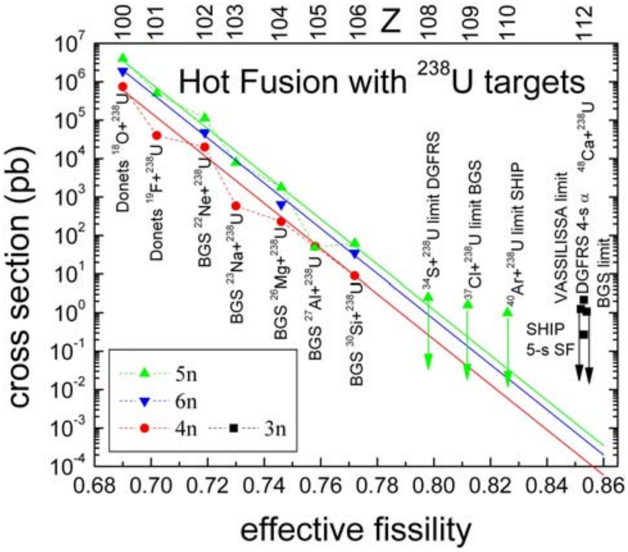

FIG. 1: Systematics of 4n, 5n, and 6n exit channels from compound nucleus reactions of heavy ion projectiles with ^{238}U targets.

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