Measurement of the ^{208}Pb(^{55}Mn, *n*)^{262}Bh Excitation Function

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So-called "cold" nuclear fusion reactions have been successfully employed in the production of transactinide elements, most notably in the discoveries of elements 107-111 (see [1] for a review) and the reported production of elements 112 [2] and 113 [3]. In this series, the odd-*Z* members were first produced by irradiating ^{209}Bi targets with even-*Z* projectiles because the lower effective fissility [4] of these systems is expected to lead to larger reaction cross sections relative to the analogous odd-*Z*-projectile reactions, which use ^{208}Pb targets. Recently, our group has shown that an odd-*Z*-projectile reaction can have a cross section comparable to that of the corresponding even-*Z*-projectile reaction [5]. We continued this study by measuring the excitation function of the ^{208}Pb(^{55}Mn, *n*)^{262}Bh (Z = 107) reaction using the Berkeley Gas-filled Separator (BGS) at the Lawrence Berkeley National Laboratory 88-Inch Cyclotron.

The ^{55}Mn + ^{208}Pb reaction had previously been studied by Oganessian *et al*. [6] using a rotating-drum technique. Their experiments were unable to conclusively identify ^{262}Bh so we chose to re-examine this reaction using the improved sensitivity of the BGS. The initial projectile lab-frame energy in the center of the 470-µg/cm^2 ^{208}Pb targets was 264.0 MeV, chosen using the "Optimum Energy Rule" proposed by Świątecki, Siwek-Wilczyńska, and Wilczyński [7]. Additional energies of 260.0 MeV and 268.0 MeV were also studied and the measured excitation function is shown in Fig. 1.

Of the 33 total ^{262}Bh decay chains observed at all three projectile energies, 22 were assigned to ^{262}Bh^g and 11 were assigned to ^{262}Bh^m. Production of ground state ^{262}Bh was favored at all three energies. The observed decay chains are in good agreement with previously reported data on the decay of ^{262}Bh^{g,m} [8]. A slightly improved half-life of 84^{+21}_{-16} ms was measured for ^{262}Bh^g. A new alpha group from ^{262}Bh^g with energy 9657 keV was also observed. Neither ^{262}Bh^g nor ^{262}Bh^m was observed to decay by spontaneous fission (SF), leading to upper limit SF branches of < 11% and < 24%, respectively, and lower-limit partial SF half-lives of > 640 ms and > 30 ms, respectively (84% confidence level in all cases). At 268.0 MeV, two additional decay chains were observed and attributed to ^{261}Bh, the 2*n* product of complete fusion. The observed magnetic rigidity of all Z = 107 evaporation residues was 2.16 ± 0.03 T m (statistical uncertainty only), corresponding to an average evaporation residue charge-state of approximately +8.0.

Also shown in Fig. 1 is a theoretical prediction for the ^{208}Pb(^{55}Mn, *n*)^{262}Bh excitation function, calculated with the "Fusion by Diffusion" theory described in [7]. The measured excitation function has a greater peak cross section and is shifted to higher projectile energies than the prediction. These observations are correlated and may be indicative of the late onset of second-chance fission in the fused system. This may be caused by the fission barrier in ^{262}Bh being several hundred keV larger than expected.

The maximum cross section of 540^{+180}_{-150} pb measured for the ^{208}Pb(^{55}Mn, *n*)^{262}Bh reaction at 264.0 MeV is much larger than that of 163 ± 34 pb reported for the analogous ^{209}Bi(^{54}Cr, *n*)^{262}Bh reaction [8]. The ^{54}Cr + ^{209}Bi reaction may have been studied at projectile energies too high for optimum production of the 1*n* product, and the current results suggest that the complete excitation function of this reaction should be measured. The large cross section of the ^{55}Mn + ^{208}Pb reaction suggests that it may be possible to perform detailed nuclear structure studies of the decay of ^{262}Bh using alpha-gamma correlation techniques.

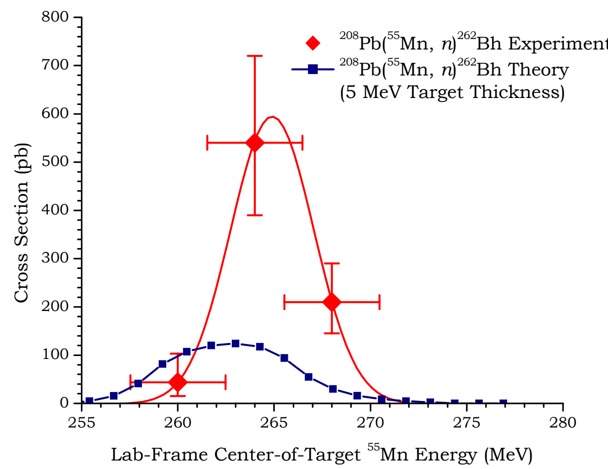

FIG. 1. Measured excitation function for the ^{208}Pb(^{55}Mn, *n*)^{262}Bh reaction (red diamonds). Vertical error bars represent 1σ (68%) limits and horizontal error bars represent the range of energies covered by the projectiles while traversing the targets. A Gaussian fit to the data is shown. Also shown is a prediction of the "Fusion by Diffusion" theory [7] for this reaction (blue squares). In both cases, the production of ^{262}Bh^g and ^{262}Bh^m has been summed.

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