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Direct reaction mechanisms and fusion hindrance of light, weakly-bound nuclides

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Near-barrier collisions involving light, weakly-bound nuclei exhibit a diverse range of reaction phenomenon, including direct breakup, nucleon transfer, and fusion. The interplay of these different mechanisms is of great interest, since fusion reactions of 6,7,8Li, 9Be and 10,11B have been found to be significantly suppressed, by up to 35% [see 1 and refs. therein]. The root cause of this suppression is believed to be direct reaction processes, which cause disintegration of the projectile into clusters. If only part of the projectile is then captured (incomplete fusion), then complete fusion will be reduced. A strong correlation between the lowest energy direct breakup threshold QBU and the degree of fusion suppression [1], suggests that direct breakup into intrinsic clusters (e.g., 6He=α+2n, 7Li=α+t) is the culprit. The reality is more subtle: transfer reactions can also trigger projectile disintegration [2,3], and in some cases transfer dominates over direct breakup.

Here we consider stochastic classical dynamical models (SCDMs), which can treat both direct and transfer-triggered breakup simultaneously, and make predictions for above-barrier reaction outcomes [4,5]. SCDMs follow the classical trajectory of the projectile and target R(t), which is stochastically sampled to determine a location of breakup given some assumed probability function PBU(R) [4,5,6]. The resulting breakup fragments are then propagated in the field of the target-like nucleus, until they fuse or escape. By constraining PBU(R) using sub-barrier breakup, above-barrier reaction outcomes can be predicted.

The development of SCDMs has also clarified the crucial role that nuclear structure plays. Since the formation of a compound nucleus takes just 10-21 seconds, if breakup is to suppress fusion, it must occur promptly: narrow resonance states will not decay fast enough [3]. Understanding the mechanisms for prompt breakup requires careful analysis of the measured energy and angle correlations of the fragments, but suggests that (a) prompt breakup following direct excitation (e.g., 7Li to α+t) occurs quickly [6], whereas (b) prompt breakup following transfer to broad resonances is delayed, and cannot explain the observed fusion [5,7].

We discuss this key topic in near-barrier reactions via reactions of 7Li, where both direct and transfer-induced are strong, and consider whether the phenomenon is likely to persist in light exotic systems such as 6He, 7Be, and 8B.

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