Challenges in coupled-channels calculations of heavy-ion fusion reactions

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Heavy-ion fusion reactions are known to be sensitive probes of the structure and the size of the reacting nuclei. This is most clearly seen in coupled-channels analyses of measurements on a series of isotopes. There are uncertainties, such as model assumptions, which I would like to discuss. I will illustrate them by presenting an analysis of the fusion of ^{27}Al on a series of germanium isotopes. The measurements [1] are poorly reproduced when the calculations are based on interactions that are linear in the deformation amplitudes, but one can obtain quite reasonable fits when both linear and quadratic interactions are employed.

The sensitivity of the calculated fusion cross sections to various matrix elements and how these matrix elements can be determined or modeled will be discussed. The measured quadrupole moments, for example, can be used to determine some of the diagonal matrix elements of the linear interaction. An interesting result is that the fusion data on ^{74}Ge are best fit with a near spherical shape. This is in contrast to the preferred solution, which suggests a strong prolate deformation [2]. Another surprising result is that the extracted radius of ^{72}Ge is significantly smaller than a smooth interpolation between the radii of the other germanium isotopes.

A new challenge in coupled-channels calculations is to reproduce the steep falloff in fusion cross sections that has been observed for several heavy-ion systems at extreme sub-barrier energies [3]. In an effort to explain the ^{60}Ni +^{89}Y fusion data [3], it was realized that the calculated fusion cross sections are sensitive to the way fusion is defined, namely, either as the ingoing flux from ingoing wave boundary conditions when a real ion-ion potential is used, or as the ingoing plus absorbed flux when an additional short ranged imaginary potential is employed. Moreover, it was found that the low energy behavior becomes sensitive to the ion-ion potential at short distances, and the conventional Woods-Saxon parametrization may not be the best choice. The possible relation to the large diffuseness that is often required in fitting high precision fusion data [4] is discussed.

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