Outstanding problems in fusion and quasi-elastic barrier distributions

N. Rowley

1 UMR 7500, Institut de Recherches Subatomiques/Université Louis Pasteur, 23 rue du Loess, F-67037 Strasbourg Cedex 2, France

The introduction [1] of the notion of an “experimental” barrier distribution:

$$D(E) = \frac{d^2(E \sigma)}{dE^2}$$  \hspace{1cm} (1)

stimulated many new measurements of fusion cross sections (strictly speaking capture cross sections) with sufficient precision to be able to extract this quantity in a meaningful way from the data. The initial choice of systems for such studies (see, for example, Ref. [2]) was influenced by the fact that the width of the barrier distribution was expected to vary as $\beta Z_1 Z_2$, where $\beta$ is an appropriate deformation parameter for the system and $Z_1$ and $Z_2$ are the target and projectile atomic numbers. Theory and experiment could be best compared if the width was significantly greater than that for penetration of a single barrier (that is, greater than the quantal “tunelling width” of around 3 MeV). Thus to test our understanding of the underlying reaction mechanisms in nucleus-nucleus collisions, systems with relatively large deformations (static and/or vibrational) had to be studied. In addition, of course, $Z_1 Z_2$ also had to be reasonably large, but not so large that the measurement of the capture cross section was complicated by processes such as fission, quasi-fission and deep-inelastic scattering.

The results for judiciously chosen systems showed beautifully the dramatic role of collective inelastic excitations in capture. For example in Ref. [3] one sees the predicted “fingerprint” of fusion of an inert $^{16}$O projectile with a $^{154}$Sm target possessing both quadrupole and hexadecapole deformations, and Ref. [4] shows the remarkable effect of complex surface vibrations arising from the multiple, mutual excitation of quadrupole phonons in the $^{58}$Ni + $^{60}$Ni system.

Outside the limits of these classic “textbook” cases other complications arise and some outstanding problems will be discussed, including

- What happens for heavier systems, where other channels will intervene and other phenomena may emerge?
- How useful are quasi-elastic barrier distributions?
- What happens in systems where transfer is important, and can we simply predict for which systems this will be the case?

References