Transfer at sub-barrier energies and its role in understanding the suppression of fusion

M. Evers[a], M. Dasgupta[a], D.J. Hinde[a], C. Simenel[b]

[a] *Department of Nuclear Physics, Research School of Physics and Engineering, Australian National University, Canberra, Australian Capital Territory 0200, Australia*

[b] *CEA, Centre de Saclay, IRFU/Service de Physique Nucleaire, F-91191 Gif-sur-Yvette, France*

Fusion cross section measurements in nuclear reactions of heavy nuclei consistently fall below model predictions at energies both well below and above the fusion barrier. Understanding the physical mechanisms leading to this fusion suppression has been one of the major challenges in nuclear reaction physics [6, 7, 1]. It is crucial for a consistent understanding of nuclear reactions involving both light nuclei (e.g. in astrophysical scenarios) and heavy nuclei (e.g. in the formation of super-heavy elements). The suppression of fusion at *above-barrier energies* has been associated with deep inelastic collisions (DIC) [3, 7]. Kinetic energy dissipation into nucleonic degrees of freedom as part of the DIC is believed to lead to a reduction of the fusion probability. Fusion at energies *well below and close to the fusion barrier* occurs through quantum tunnelling of the projectile nucleus through the fusion barrier, which in turn is affected by couplings to few inelastic and/or transfer channels which are most dominant at these energies [2]. We expect in reality a smooth transition from nucleon transfer to low-lying discrete states in sub-barrier nuclear reactions on one end, to (multi-)nucleon transfer leading to highly excited nuclei in DIC at energies above the barrier on the other end.

Detailed measurements of the back-scattered projectile-like fragment (PLF) yields in the reaction $^{16}O+^{208}Pb$ will be presented [4]. They suggest that energy dissipation may play a significant role already at energies below the fusion barrier [5]. Results indicate that (i) the transfer of two protons ($2p$) occurs with probabilities $\sim 10\%$ at energies near the fusion barrier, (ii) the $2p$ transfer probabilities are significantly enhanced compared to TDHF calculations, and (iii) $2p$ transfer leads to excitation energies as high as ~ 13 MeV in the residual nuclei. These results show that experimental and theoretical work on multi-nucleon transfer, particularly cluster transfer, may be a key towards developing a complete understanding of both fusion and scattering in low energy heavy-ion collisions, how these processes may be linked to the suppression of fusion at sub-barrier energies, and how processes leading to large excitation energies in the residual nuclei may be included in future nuclear reaction models.

References

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