Sub-barrier fusion enhancement due to neutron transfer

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From the analysis of appropriate experimental data [1, 2, 3] within a simple theoretical model it was proved that the intermediate neutron transfer channels with positive Q-values really enhance the fusion cross section at sub-barrier energies [4]. In spite of the lower transfer probability to the states with positive Q-values compared to $Q = 0$, the penetration probability may significantly increase due to a gain in the relative motion energy for $Q > 0$. In other words, an intermediate neutron transfer to the states with $Q > 0$ is, in a certain sense, an "energy lift" for the two interacting nuclei. This looks quite different from the well-known fusion enhancement due to surface vibrations or rotation of nuclei leading to decrease of potential barrier in some channels. However, having in mind the driving potential of the nuclear system depending on neutron transfer (or mass asymmetry), the gain in the relative motion energy may be interpreted in usual way as a decrease of the driving potential in some neutron transfer channels.

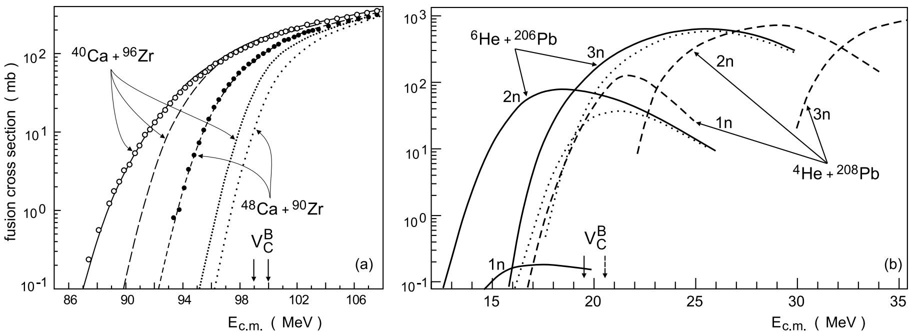

Figure 1: (a) Fusion excitation functions for ^{40}Ca+^{96}Zr and ^{40}Ca+^{90}Zr [2]. The no-coupling limits are shown by the dotted curves. The dashed curves show the CC calculations without neutron transfer, whereas the solid line was obtained with accounting for neutron transfer in the entrance channel of the ^{40}Ca+^{96}Zr reaction. (b) Excitation functions for the production of evaporation residues in the ^{6}He+^{206}Pb (solid curves) and ^{4}He+^{208}Pb (dashed curves) reactions. Dotted curves show the 2n and 3n evaporation channels in the ^{6}He+^{206}Pb fusion reaction calculated ignoring coupling with the neutron transfer channels.

New experiments are proposed, which may shed additional light on the effect of neutron transfer in fusion processes. In such experiments a direct comparison of sub-barrier fusion cross sections could be done for two projectile-target combinations leading to the same compound nucleus, one of which has a positive Q_0-value whereas another one has a negative or zero Q_0-value of neutron ground state transfer. They are ^{40,48}Ca+^{124,116}Sn, ^{16,18}O+^{42,40}Ca, ^{9,11}Li+^{208,206}Pb, and many others. The effect is found to be very large especially for fusion of weakly bound nuclei. Use of radioactive neutron-rich nuclei for production of new heavy isotopes of the elements with $Z > 100$ is discussed.

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[2] H. Timmers et al., Nucl.Phys. **A633**, 421 (1998).

[3] M. Trotta et al., Phys.Rev. C **65**, 011601(R) (2002).

[4] V.I. Zagrebaev, Phys.Rev. C **67**, 061601(R) (2003).