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Fusion and neutron transfer reactions with weakly bound nuclei within time-dependent and coupled channel approaches

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The numerical solving of the time-dependent Schrödinger equation (TDSE) provides new possibilities for theoretical study of transfer reactions and the first (capture) stage of fusion reactions [1, 2]. In this model the motion of nuclei cores is described on basis of the classical physics. The small typical grid spacing (~ 0.2 fm) of TDSE method leads to correct calculations of the spatial structure of the external (valence) neutron wave function with the formation of two center (molecular) states (Fig. 1a) [3, 4]. The traditional coupled channel approach was combined with the TDSE method [2, 5]. The value of the coupling strength was determined by time-dependent two-center level populations. The coupling matrix elements were determined by the two-center wave functions of the valence neutron. They were calculated within the two-center shell model based on the Bessel series [2]. Results of the cross section calculation for the formation of the 198Au (Fig. 1b) and fusion (Fig. 1c) in the 6He+197Au reaction [6, 7] and for the formation 65Zn isotopes and fusion in 6He+64Zn reaction [8] agree satisfactorily with the experimental data near the barrier. A few additional three-body and two-body quantum models were used for more careful study the processes of neutron transfer, breakup of the weakly bound nucleus 6He and sub-barrier fusion. They are: one and two nuclear cores plus one [1] and two valence neutrons, one and two cores plus a di-neutron.

Fig. 1. a) The probability density of the valence neutrons of the 6He nucleus during a frontal collision with the 64Zn at energy in the center of mass system MeV, a scale factor is 1 fm, and radii of the circumferences equal to radii of the nuclei. b, c) The excitation functions for the formation of the 198Au isotope (b) and fusion (c) in the reaction 6He+197Au. Experimental data (circles) is from [6, 7]. Theoretical curves were calculated within the coupled channel approach (solid lines) and the TDSE method (dashed line); VB is the Coulomb barrier.

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