Comment on "Fusion of $^{32}S+^{27}Al$ and $^{19}F+^{40}Ca$ and the nucleus-nucleus potential"

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The purpose of the present Comment is twofold. First, we stress that the fusion cross section in region II of the critical distance model is not determined by the potential alone, but that dynamical effects (friction and deformation) play an essential role. Second, we point out that a proper single-folding potential accounts well for the fusion cross section in region I.

In a recent paper by Doukellis[1] it is pointed out that fusion cross sections for lighter systems (the examples are $^{32}S+^{27}Al$ and $^{19}F+^{40}Ca$) can well be described by three straight lines (regions I, II, and III). Region I is dominated by the interaction barrier, region II by the critical distance model,[2] and region III by a limiting angular momentum. In particular, it is claimed that the fusion cross section in region II can be determined by the nuclear potential alone and therefore gives information on the potential at large overlap. It is also stated that a single-folding potential (the author uses that of Ref. 3) cannot even account for the data close to the barrier. In the following these statements are criticized.

The critical distance model[2] was set up in order to parametrize in a simple way the fusion cross section in region II by an effective radius and the s-wave potential at this radius. This is successful to a certain extent. However, this prescription does not say anything about the mechanism which actually leads to fusion in this energy range. Therefore dynamical friction models have been proposed[3–6] to get insight into the mechanism for fusion. These models give a dynamical description of regions I, II, and III simultaneously. In the following I refer in particular to the surface friction model[6] which describes fusion excitation functions throughout the periodic table. In this model fusion is determined when trajectories with conservative and frictional forces are captured in the pocket of the potential below a certain critical angular momentum. At low energies (region I, where friction is very weak for light systems, fusion is determined essentially by the conservative potential, which in the surface friction model is a single-folding potential. Its input,[6] however, differs from the global potential of Ref. 3, which should not be used for lighter systems. In contrast to the latter, our potential[6] accounts well for the data around the fusion barrier.

We give the parameters for the systems $^{32}S+^{27}Al$ and $^{19}F+^{40}Ca$:

$$V_N(r)=-\sum_{i=1}^{5} A_i(r-R)^{i-1}\ln\left[1+\exp\left[-\frac{r-R}{a}\right]\right],$$

$$R=r_0(A_p^{1/2}+A_T^{1/3});\ a=0.61\text{fm},\quad r_0=1.30\text{ fm}.$$

	A_1	A_2	A_3	A_4	A_5
$^{32}S+^{27}Al$	16.0894	−4.1975	1.1343	−0.0282	−0.0136
$^{19}F+^{40}Ca$	15.8160	−4.0324	1.0481	−0.0183	−0.0131

This potential is entered in Figs. 3 and 4 of Ref. 1 (our Figs. 1 and 2) and compared to the potentials of Ref. 1. It is important to note that our single-folding potential describes well the onset of fusion around the barrier at ≈ 8.5 fm. At large distances it is very close to the Bass potential.

However, our potential is not consistent with the extraction from the critical distance model used to fit the data in region II. This does not mean that we use the wrong potential because in region II the potential is not the only determining factor for the fusion cross section. In this region the frictional forces start to become increasingly important (and simultaneously deformations start to play some role in the details of the fusion process also for light systems). The essential change due to friction consists in a reduction (as compared to the no friction case) of the critical l wave for fusion. This is due to the fact that a frictional trajectory loses energy and can no longer surmount the critical barrier (obtained without friction) but can only overcome a barrier with a lower l

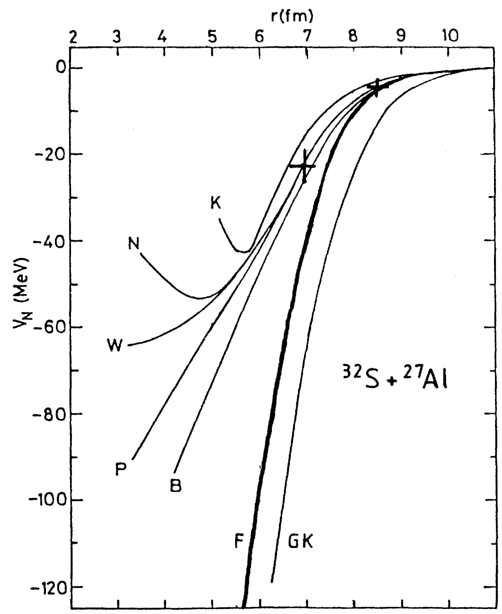

FIG. 1. The nuclear potentials of Ref. 1 are compared to the surface friction potential (F) of Ref. 6 for $^{32}S+^{27}Al$. The letters K, N, W, P, B, F, and GK refer to the Krappe-Nix, Ngo, Wilczynski, modified proximity, Bass, Fröbrich, and Gross-Kalinowski potentials, respectively. The crosses are the values extracted from the critical distance model in region I (at 8.5 fm) and II (at 7 fm).

value. The discussion shows that not only the potential determines the critical distance at which fusion is decided but that dynamical effects (friction and deformation) are of importance. More details can be found in Ref. 6. In

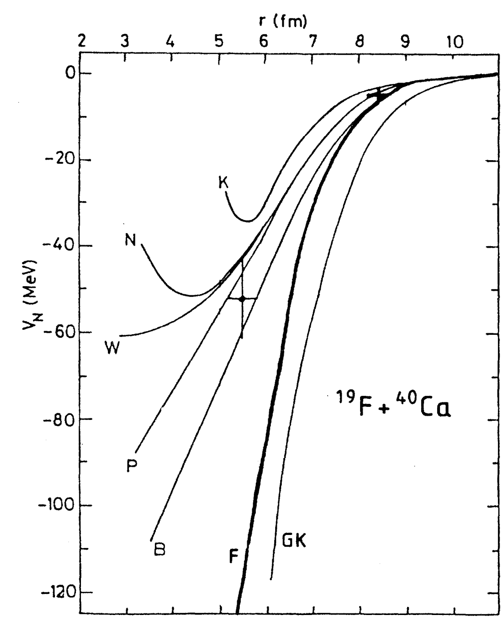

FIG. 2. The same as Fig. 1 for the $^{19}F+^{40}Ca$ system.

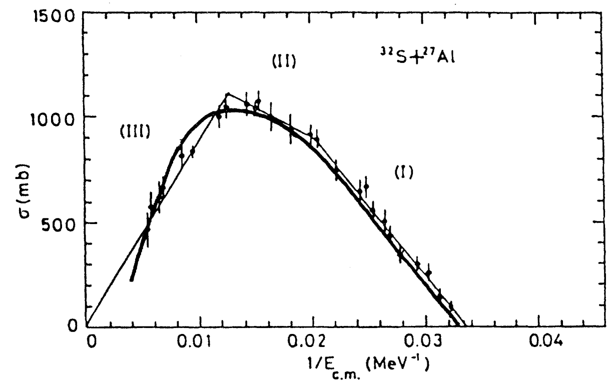

FIG. 3. Data (see Ref. 1) and the critical distance model (straight lines, Ref. 1) are compared to a dynamical surface friction model calculation (thick solid line) for $^{32}S+^{27}Al$.

our opinion, a static picture is not sufficient and it is fallacious to draw from it conclusions about the potential.

In order to show to what extent the universal dynamical surface friction model describes the data, covering automatically regions I, II, and III, we compare its results in Figs. 3 and 4 with the critical distance model of Ref. 1 and the data for the systems $^{32}S+^{27}Al$ and $^{19}F+^{40}Ca$. It is remarked that as in critical distance models the dynamical calculations in region III also determine a limiting angular momentum because with increasing energy the critical l value saturates such that the decrease of the cross section is due to the $1/E$ behavior.

The conclusions are as follows. Despite the existence of dynamical fusion models which describe the fusion excitation functions (without artificially introducing regions I, II, and III) for systems throughout the periodic table, schematic critical distance models (if their parameters are proven to be universal) can still have some value for quick estimates. However, I contend that a critical distance model (because it forgets about dynamics) can give reliable information about the nuclear potential at large overlap. It is also shown in this Comment that a single-folding potential with a proper input accounts well for the data around the fusion barrier.

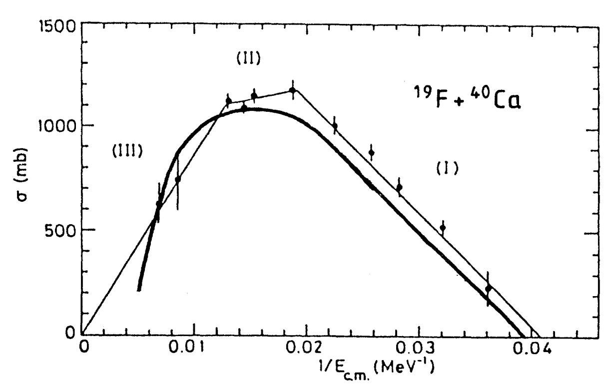

FIG. 4. The same as Fig. 3 for the $^{19}F+^{40}Ca$ system.

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