FUSION BARRIERS WITH FOLDING POTENTIALS FOR SYSTEMS WITH $1000 < Z_1Z_2 < 3000$

by

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Following a suggestion repeatedly stated by Vaz, Alexander, and Satchler in their recent study of fusion barriers (1), we have used two different folding models for the construction of the real nuclear potential for very heavy systems in the region $1000 < Z_1Z_2 < 3000$, and computed the corresponding s-wave barrier. A systematic description of the nuclear densities has been undertaken as a starting point for the foldings.

THE NUCLEAR DENSITY DISTRIBUTIONS have been computed as the sum of squared single-particle wave functions, ψ_i, weighted with occupation numbers. The ψ_i are initially eigenfunctions of a Woods-Saxon potential with a spin-orbit term of the Thomas type and a Coulomb repulsion for protons. later corrected for nonlocality and orthogonalized. The method has been described at length by Malaguti et al (2) and specified for our use in our previous work (3), hereafter referred to as VLM. With respect to the latter we have changed here the constant term of the depth to 50 MeV, instead of 55.7, with two exceptions: 46.7 for ^{154}Sm and 51.5 for ^{209}Bi. Table I shows the results for 17 nuclides used in this work, compared with the experimental rms radii of the charge densities.

FOLDING POTENTIALS of two different types are used here. The SL-folding, described and widely applied by Satchler and Love (4), is computed here with the proton and neutron densities obtained by the method outlined above and with the M3Y effective nucleon-nucleon interaction. The VLM-folding is based on a Gaussian density-dependent effective interaction described in ref. (3),

TABLE I **Rms radii (in fm) for the nuclear density distributions computed in this work, and experimental rms charge radius.**

Nucleus	p	n	p+n	charge	experimental
^{35}Cl	3.275	3.213	3.243	3.372	3.351
^{40}Ar	3.326	3.507	3.427	3.419	3.38 - 3.56
^{56}Fe	3.673	3.717	3.697	3.759	3.727 - 3.800
^{65}Cu	3.806	3.927	3.874	3.887	3.947(22)
^{84}Kr	4.068	4.265	4.182	4.143	
^{86}Kr	4.068	4.323	4.215	4.142	
^{90}Zr	4.197	4.300	4.255	4.271	
^{109}Ag	4.457	4.612	4.546	4.525	
^{132}Xe	4.732	4.944	4.858	4.795	
^{139}La	4.796	5.017	4.928	4.859	4.85
^{141}Pr	4.842	5.010	4.940	4.905	
^{144}Sm	4.910	5.003	4.963	4.972	
^{148}Sm	4.920	5.103	5.027	4.982	4.952 - 5.026
^{154}Sm	4.998	5.345	5.208	5.058	5.126
^{165}Ho	5.139	5.311	5.242	5.197	5.19 - 5.23
^{209}Bi	5.503	5.696	5.620	5.556	5.52
^{238}U	5.793	6.070	5.965	5.843	5.843

and uses our proton + neutron densities. In both cases only a few folding points in the relevant region of the potential have been needed to fit an analytical approximation, as explained in VLM. This has the form

$$V(r) = \begin{cases} -V_0\,(an)^n\,e^{-n} & \text{if } s < an \\ -V_0\,s^n \exp(-s/a) & \text{if } s > an \end{cases}$$

where $s = r - C_1 - C_2$, C_i are the standard half density radii, and the parameters V_0, n, a are fitted to seven points in the region $0.8 < s < 3.6$ fm. In Table II are listed the values of these parameters for SL-folding (above) and VLM-folding (below) corresponding to the 14 systems considered in this work as well as the range and depth of the (irrelevant) flat constant region introduced in this analytical expression. In the range of distances which are significant for fusion and for elastic scattering VLM-folding potential is almost twice as deep as SL-folding.

FUSION BARRIERS obtained with these potentials and their location are also listed in Table II. VLM - folding predicts lower barriers by a few percent.

TABLE II Parameters that fit SL-folding (1st line) and VLM-folding (2nd line), range and depth of flat bottom, and location and height of fusion barrier (Units: MeV and fm).

Reaction	Z_1Z_2	V_o	n	a	C_1+C_2+an	-V(0)	R_B	V_B
^{35}Cl + ^{141}Pr	1003	145.4 360.5	0.4479 0.9298	0.6569 0.5591	9.607 9.833	53.71 77.42	11.39 12.05	118.3 113.0
^{86}Kr + ^{65}Cu	1044	150.8 338.9	0.3868 0.7619	0.6711 0.5873	9.504 9.692	60.78 85.73	11.33 11.93	123.7 118.6
^{40}Ar + ^{144}Sm	1116	153.8 347.7	0.4389 0.7564	0.6666 0.5999	9.837 9.998	57.82 89.77	11.64 12.29	128.9 123.1
^{40}Ar + ^{148}Sm	1116	148.8 324.9	0.3805 0.6347	0.6986 0.6452	9.872 10.02	61.42 98.04	11.75 12.44	125.5 121.4
^{40}Ar + ^{154}Sm	1116	145.5 299.5	0.2809 0.4400	0.7817 0.7569	9.916 10.03	71.79 118.9	12.00 12.78	124.3 117.4
^{40}Ar + ^{165}Ho	1206	153.1 341.6	0.3757 0.6253	0.7025 0.6477	10.12 10.26	63.74 103.9	12.00 12.70	135.1 128.6
^{56}Fe + ^{132}Xe	1404	158.1 351.9	0.3952 0.7464	0.6684 0.5965	10.12 10.30	62.93 91.20	11.80 12.44	160.1 153.1
^{86}Kr + ^{90}Zr	1440	158.3 368.8	0.3922 0.7854	0.6634 0.5682	10.07 10.26	63.93 89.24	11.72 12.30	165.4 159.1
^{40}Ar + ^{238}U	1656	150.1 333.9	0.3183 0.4858	0.7593 0.7137	11.04 11.14	69.48 122.8	12.87 13.63	172.9 164.5
^{86}Kr + ^{109}Ag	1692	158.1 358.0	0.3254 0.6768	0.6917 0.6024	10.41 10.59	70.26 99.14	12.04 12.65	189.1 181.6
^{56}Fe + ^{165}Ho	1742	152.0 341.1	0.2907 0.5552	0.7104 0.6448	10.57 10.72	71.84 110.7	12.21 12.89	192.0 183.3
^{86}Kr + ^{139}La	2052	158.4 377.9	0.2480 0.6801	0.7101 0.5971	10.87 11.10	80.33 103.7	12.47 13.09	221.9 213.3
^{84}Kr + ^{165}Ho	2412	160.3 368.3	0.2977 0.6208	0.7243 0.6321	11.26 11.44	75.36 110.8	12.77 13.43	254.6 244.1
^{84}Kr + ^{209}Bi	2988	167.4 473.4	0.3214 0.9542	0.6978 0.5465	11.86 12.16	75.05 97.95	13.25 13.93	305.4 293.2

not only as compared with SL-folding but also with the "empirical" values reported in ref. (1) for $Z_1Z_2 < 1400$. However Vaz et al note that their technique for defining an empirical fusion barrier could possibly overestimate the barriers by 3 - 8 % for $Z_1Z_2 > 800$.

REFERENCES

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