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EFFECTS OF DYNAMIC ASPECTS ON FUSION EXCITATION FUNCTIONS

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Abstract

As an extension of the macroscopic theory, the nucleus- nucleus fusion has been described in terms of the chaotic regime dynamics (liquid drop potential energy plus one body dissipation).Three milestone configurations are attended : the touching , the conditional saddle point and the unconditional saddle one. We would like to deduce the associated extra push and extra-extra push energy values required to carry the system between these configurations, respectively. The next step is to light on the effect of these limiting values on the fusion excitation functions and their significance for accurate fitting of the measured functions for larger values of the angular momentum. It is found that there is a limiting values of excitation energy and angular momentum for each interacting pair, over which these aspects must be considered to fit the excitation functions of different nucleus –nucleus fusion .These values were found to be in relation with the limiting angular momentum for fusion in major cases.

Key words: Barrier / configuration /liquid drop/ extra push energy / fissility
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INTRODUCTION

Nuclear Dynamics

In the chaotic regime, if the nuclear configuration is free of symmetries, the static potential energy considered as a function of shape must be described by a liquid drop type and the resulting shape dynamics is predicted to be severely over-damped: the nucleus should behave like viscous fluid. On the other hand when the nuclear system is dominated by symmetries, the single - particle level structure of the nucleons acquires special features (bunching and crossings or near crossings of levels) and the nucleus becomes more like a visco-elastic solid. In addition the striking pair correlation effects associated with time reversal symmetry (responsible for superconductivity and super fluidity in macroscopic bodies) it is clear that nuclear dynamics is a fascinatingly rich and complex field for study of which we can possess an approximate understanding of a few especially simple limiting cases [1].

Dynamic Aspects

It is clear that the significance of dynamic aspects of fusion process as well as the role of deformation in the entrance channel influences the probability of that process .For heavy ion fusion system below a critical size and /or angular momentum, the fusion process is well described using a static one- dimensional interaction potential with inclusion of entrance – channel angular momentum dissipation. Where heavier reaction partners and/or high angular momentum are involved, the dynamical aspects of fusion become important. This comes about as a result of the of the regression of the conditional saddle point to more compact shape , eventually to the situation where it lies inside the radial distance corresponding to the sharp – surface contact point between the reaction partners. The resulting additional radial energy necessary to force the reaction pair past the contact point and over the conditional saddle constituent a dynamic inhibition to fuse, pushing the observed fusion yields to higher energies with increasing entrance channel angular momenta. Also in comparison to predictions of the static one- dimensional potential, the fusion data were observed to be strikingly lower in magnitude, and exhibit dependence with energy consistent with data that an additional energy is required to induce fusion, thus skewing the fusion excitation functions to higher energies [2]. In terms of the proximity potential between two deformable liquid drops, Swiatecki introduced a simple model based on multidimensional dynamics calculation with one body dissipation and the effect of neck formation between the interacting nuclei .The model introduces three configurations in the dynamical evolution of a nucleus-nucleus collision, defining three associated threshold energies: the contact configuration where the two nuclei come into contact and the growth of a neck between them becomes energetically favorable, the configuration of conditional equilibrium because of that its energy is stationary only when the asymmetry be held fixed and is limited by losing its physical significance when the shape is convex everywhere and the last is configuration of unconditional equilibrium or the fission saddle point shape where the associated fission barrier ensures the existence of a compound nucleus and guards it against disintegration [1] .

In this work, we are interesting on distinguishing the conditions of these configurations, defining when they are necessary, and on calculating the energies required for reproducing a wide variety of measured fusion excitation functions for different interacting pairs of ($240 \leq \mathbf{z_p z_t} \leq 1640$), from intermediate to very heavy systems where the one dimension potential model fail [3].

CALCULATIONS

The single-barrier penetration model [4], or (BPM), sums the reaction cross section over all partial waves [4, 5] or channels of energy E as:

$$\sigma_{rec}(E) = \pi\lambda^2 \sum_{\ell=0}^{\infty} (2\ell+1)\tau_\ell(E)\mathrm{P}_\ell(E)$$

or

$$\sigma\mathbf{fus}(E) = (\hbar\omega R^{2}/ 2E)\, \boldsymbol{lin}\{ 1+ \exp[(2\pi/\hbar\omega)(E - V\boldsymbol{B}(\mathbf{r}))]\} \tag{1a}$$

where λ is the asymptotic wave length ,P_1(E) is the probability of a specific process to take place and $T_l(E)$ *is* the transmission coefficient . For fusion, ($\sigma_{rec} \approx \sigma_{fus}$ at P_1(E) $\approx$ 1), and the higher limit becomes 1_{max} , deduced [6] due to that

$$E_{cm} = V(R_{fus}, 1max) = \max\{V(r, 1max)\}, \text{ where}$$

$$V(r,l) = V_B(r) + V_l(r) = V_n(r) + V_C(r) + \{\hbar^2\, l(l+1) / (2\mu r^2)\} \qquad (1b)$$

For sharp cut - off approximation eq.[1a] reads :

$$\sigma_{fus}(E_{cm}) = \pi\, (R_{fus})^2 (1 - V_B(r)/E_{cm}) \qquad (1c)$$

and the critical angular momentum 1_{cr} , which is defined as a specific value at which the partial level width for fission is equal to that for evaporation [7] , and calculated from measured data by

$$\sigma_{fus}(\exp) = (\pi\, \hbar^2 / 2\, \mu\, E_{cm})\, (1_{cr} + 1)^2 \qquad (1d)$$

For asymmetric systems there are two saddle points, the conditional where the potential is not stationary and the unconditional or fission saddle point. For heavy asymmetric systems the first one is more extended than the second. The dynamical influence of the saddle points leads to the requirement that the projectile energy be above that necessary to reach the spherical touching point if the system is to move behind the saddle point. These additional energies are called the extra push E**x**(l) to move the system behind the conditional saddle and the extra extra push E**xx**(l) to move the system behind the unconditional saddle . In these both cases the barrier height will read

$$B_I = V(r,l) \quad B_{II} = V(r,l) + Ex(l) \quad B_{III} = V(r,l) + Exx(l) \qquad (2)$$

The important parameter in the determination of both of ***Ex(l)*** and ***Exx(l)***, is the effective fissility

$$\xi_{eff} = 4 z_p z_t / (A_p^{1/3} A_t^{1/3} (A_p^{1/3} + A_t^{1/3})) \qquad (3)$$

and its threshold value , below which the extra push energy is zero , is given by

$$\xi_{effth} = b\{1 - 1.7826\ I^2\} \qquad (4)$$

where b is the surface energy coefficient of the nuclear matter and I is the relative neutron excess $I = (N_p - Z_p + N_t - Z_t)/(A_p + A_t)$ and the critical fissility is

$$\xi_{crit} = 40\pi\gamma r_0^3 / 3e^2 = 50.883\{1 - 1.7826\, I^2\} \qquad (5)$$

the corresponding (characteristic energy unit of) the system is given by

$$E_{ch} = \frac{0.072047}{A_p A_t} \ell_{ch}^2 \xi_{crit}^2 \qquad (6)$$

$$\ell_{ch} = 0.1027132(A_p^{2/3} A_t^{12/3}(A_p^{1/3} + A_t^{1/3}) / \sqrt{A_p + A_t} \quad (7)$$

where l_{ch} is the characteristic angular momentum number of the system in units of $\hbar$ values . The extra push energy is given by

$$E_x(\ell) = \begin{cases} 0 \; for \; \xi_{eff}(\ell) \le \xi_{effth} \\ K[\xi_{eff}(\ell) - \xi_{effth}]^2 \; for \; \xi_{eff}(\ell) > \xi_{effth} \end{cases}$$ where $\xi_{eff}(\ell) = \xi_{eff} + (\frac{fl}{lch})^2$ and

$$K = 0.07205 \frac{(a\ell_{ch})^2}{A_p A_t} \quad (8)$$

The other parameter of interest is

$$X_{eff} = \xi_{eff} / \xi_{crit} \quad (9)$$

is a measure of the relative importance of electric and nuclear forces for necked-in configurations near contact, namely neck scaling parameter or the effective fissility parameter, its threshold value is given by :

$$X_{th} = \xi_{effth} / \xi_{crit} \quad (10)$$

The parameters a and b are two parameters deduced empirically [1] to the values a = 12 ± 2 , b =35 ±1 and ***f*** is the fraction of the entrance channel angular momentum remaining in the orbital motion after contact , of different values for both of the sliding , rolling and sticking collision [8] . The fusion excitation functions where the extra push energy is nonzero are deduced by:

$$\sigma_{fus}(E) = \frac{\pi R_B^2}{E}\{[(\frac{\alpha_x \beta_x + 1/2}{\beta_x^2})^2 - \frac{\alpha_x^2 + V_B - E}{\beta_x^2}]^{1/2} - \frac{\alpha_x \beta_x + 1/2}{\beta_x^2}\} \quad (11)$$

where $\alpha_x = K^{1/2}(\xi_{eff} - \xi_{effth}) and \beta_x = 6.8056 K^{1/2} f^2 /(A_p^{1/3} A_t^{1/3})$

On the other hand, the energy above the spherical touching barrier required to reach the unconditional saddle has been parameterized in a compatible manner point limited by the value

$$\xi_m = \xi_g - K\xi(1 - \frac{\xi_g}{\xi})^2, \xi_g = \sqrt{\xi \xi_{eff}}, \xi = (z^2 / A) \quad (12)$$

the associated extra –extra push energy is given by:

$$E_{xx} = \begin{cases} E_x \; for \; \xi_m \le 0.84 \xi_{crit} \\ K[\xi_m - \xi_{effth}]^2 \; for \; \xi_m > 0.84 \xi_{crit} \end{cases} \quad (13)$$

and the fusion excitation function has been deduced by the same formula (11) with the corresponding parameters α_{xx} and β_{xx} instead of α_x and β_x respectively where :

$$\alpha_{xx} = K^{1/2}(\xi_m - \xi_{effth}) and \beta_{xx} = 6.8056\, K^{1/2} f_m^2 /(A_p^{1/3} A_t^{1/3})$$

$$f_m = [\eta(x)]^{1/4} f^{1/2} (25/24)(A_p^{2/3} A_t^{12/3} (A_p^{1/3} + A_t^{1/3})^{1/2} (A_p + A_t)^{-5/6} \qquad (14)$$

In case of asymmetric systems and assuming the di-nuclear and mononuclear regimes we can revert to using one and the same angular momentum fraction, i.e. $f_m = f$. We are interested here in case of symmetric systems where the extra-extra push exceeds the extra push energies. It was concluded, as an initial verdict [9], that the dynamical extra-extra push energy does not play a significant role in the fusion of two heavy nuclei and the reduction of the empirical extra-extra push energy to a value explicable in terms of Coulomb polarization means that the experimental fusion cross sections in heavy massive reactant region are no longer in contradiction with the observation of super-heavy elements yields at energies around barrier . So we will restrict our work on the effect of extra push energy on the fusion excitation functions.

RESULT AND DISCUSSION

Table (I) gives radius, height and curvature of fusion barriers calculated by the extended Thomas Fermi model (x^a) for more recently studied pairs [10] of wide range ($240 \le z_p z_t \le 1640$), in comparison with those calculated recently (x^b) .For same interacting pairs , Table (II) indicates the limiting variables for fusion, concerning the lighted point of view with the same names $x_y^{(i)}$ in the corresponding equations of number (i) in the text . We would like to notice that all of the extra push energies $E_x(l)$ are calculated due to excitation energy ranges more extended than those used in equation (1b) as shown on the last columns . The values are fitted for angular momentum values, maintaining the associated extra push energies less than 3.5 Mev . This indicates that it is not necessary to concern the effect of the extra push energy for energies lower than those used to define the maximum angular momentum (eq.1b). Another set of interacting pairs ($496 \le z_p z_t \le 1540$), studied early by Udagawa [11] are taken into account. Table (III) presents the barrier heights Vb_1 by proximity potential in comparison with Vb_2 calculated by optical model potential [11] **,** at the same r_F . The parameters l_{ch} , E_{ch} (eqs. 6,7) indicate the initial limit for dynamic effect on fusion excitation functions . As shown on the last two columns the extra push energies E_x (from eq.8), using the corresponding l values don't exceed 3Mev for excitation energies approaching 3 times of the barrier heights. It is clear the large differences between $l(\hbar)$ ***and*** l_{max} **.** The last table (IV) include four pairs chosen to indicate the effect of dynamic aspects on the fusion excitation functions calculated

Table (I)

Proj.	*Target*	*ZpZt*	R_{fus} [a]	V_B [a]	$\hbar\omega_0$ [a]	R_{fus} [b]	V_B [b]	$\hbar\omega_0$ [b]
C12	Zr92	240	9.75	33.34	2.10	9.93	33.38	2.69
O16	Ge70	256	9.25	36.52	2.84	9.65	36.52	2.65
O16	Ge72	256	9.5	36.27	2.37	9.70	36.32	2.64
O16	Ge73	256	9.5	36.16	2.44	9.73	36.22	2.63
O16	Ge74	256	9.5	36.08	2.50	9.76	36.12	2.62
O16	Ge76	256	9.5	35.80	2.63	9.81	35.94	2.59
C12	Te128	312	10.25	40.98	2.50	10.49	41.15	2.88
O16	Zr92	320	9.75	43.88	2.86	10.05	43.86	2.83
O16	Cd112	384	10.0	51.12	3.19	10.35	51.14	3.03
Al27	Ge70	416	9.75	57.37	3.26	9.98	57.15	2.90
Al27	Ge72	416	9.75	57.05	3.39	10.03	56.84	2.88
Al27	Ge73	416	9.75	56.87	3.46	10.06	56.69	2.87
Al27	Ge74	416	9.75	56.72	3.51	10.09	56.55	2.86
Al27	Ge76	416	10.0	56.31	3.01	10.14	56.26	2.84
Cl35	Fe54	442	9.5	61.89	3.67	9.84	61.53	2.91
O16	Nd144	480	10.5	61.35	3.27	10.76	61.46	3.33
Ci12	Pb204	492	11.0	59.80	3.19	11.31	60.16	3.54
O16	Sm144	496	10.5	63.62	3.27	10.73	63.63	3.41
O17	Sm144	496	10.5	63.26	3.41	10.80	63.16	3.36
O16	Sm147	496	10.5	63.31	3.37	10.78	63.35	3.39
O16	Sm148	496	10.5	63.20	3.41	10.80	63.26	3.39
O16	Sm149	496	10.5	63.08	3.46	10.82	63.17	3.38
O16	Sm150	496	10.5	62.96	3.49	10.83	63.08	3.37
O16	Sm154	496	10.75	62.43	3.07	10.90	62.74	3.34
O16	Er166	544	10.75	67.83	3.45	11.01	68.06	3.52
Si28	Zr92	560	10.0	74.20	3.97	10.35	74.08	3.24
O16	W186	592	11.0	72.26	3.52	11.23	72.61	3.65
S32	Y89	624	10.25	82.31	3.76	10.38	82.12	3.34
S32	Zr90	640	10.25	84.12	3.87	10.38	84.19	3.38
S32	Zr92	640	10.25	83.74	3.97	10.43	83.83	3.70
O16	Pb208	656	10.25	78.46	3.54	11.43	78.96	3.85
Cl35	Zr92	680	10.25	88.61	4.14	10.51	88.25	3.41
F19	Au197	711	10.25	85.21	3.69	11.42	85.39	3.88
O16	Th232	720	11.5	84.47	3.68	11.64	85.01	4.04
S32	Pd110	736	10.5	94.00	4.13	10.69	93.92	3.58
S36	Pd110	736	10.5	92.85	4.28	10.86	92.30	3.46
F19	Pb208	738	11.25	87.44	3.87	11.53	87.77	3.94
Ca40	Zr90	800	10.25	103.74	4.31	10.53	103.33	3.64
Ca40	Zr96	800	10.5	102.22	4.28	10.66	102.06	3.60

Table (I) continued

Proj.	*Target*	*ZpZt*	R_{fus} [a]	V_B [a]	$\hbar\omega_0$ [a]	R_{fus} [b]	V_B [b]	$\hbar\omega_0$ [b]
Ti50	**Zr90**	**880**	**10.5**	**111.16**	**4.49**	**10.80**	**110.40**	**3.66**
S32	**Sm154**	**992**	**11.0**	**120.22**	**4.47**	**11.18**	**120.35**	**4.18**
Si28	**Hf178**	**1008**	**11.25**	**120.65**	**4.41**	**11.34**	**120.73**	**4.36**
Si29	**Hf178**	**1008**	**11.25**	**120.31**	**4.42**	**11.38**	**120.15**	**4.32**
Si30	**W186**	**1036**	**11.5**	**122.14**	**4.24**	**11.51**	**121.97**	**4.33**
P31	**Lu175**	**1065**	**11.25**	**126.97**	**4.46**	**11.38**	**126.72**	**4.40**
Si28	**Pt198**	**1092**	**11.5**	**128.04**	**4.38**	**11.53**	**128.40**	**4.56**
S32	**Ta181**	**1168**	**11.25**	**138.15**	**4.56**	**11.42**	**138.15**	**5.16**
S32	**W186**	**1184**	**11.25**	**140.02**	**4.52**	**11.42**	**139.96**	**5.21**
Sn132	**Ni64**	**1400**	**11.5**	**162.75**	**4.61**	**11.14**	**161.16**	**4.81**
Ca40	**Pb208**	**1640**	**11.75**	**186.57**	**4.62**	**11.75**	**185.45**	**5.94**
Ca48	**Pb208**	**1640**	**12.0**	**183.17**	**4.43**	**12.02**	**180.34**	**5.60**

Table (II)

Zeff	$L_{cr}^{(1d)}$	$l_{max}^{(1b)}$	$E_{cm}^{(1b)}$	$X_{eff}^{(9)}$	$l_{ch}^{(7)}$	$E_{ch}^{(6)}$	$E_X(l)^{(8)}$	$l^{(8)}$
13.652	**56.33**	**52.54**	**79.85**	**0.2748**	**7.31**	**8.62**	**2.54**	**90**
14.847	**63.9**	**59.58**	**87.57**	**0.2944**	**7.93**	**10.30**	**3.29**	**71**
14.623	**64.0**	**59.46**	**86.40**	**0.2917**	**8.04**	**10.15**	**3.50**	**73**
14.514	**64.23**	**59.70**	**86.31**	**0.2905**	**8.09**	**10.07**	**2.12**	**73**
14.408	**64.5**	**59.93**	**86.22**	**0.2895**	**8.14**	**9.98**	**2.27**	**74**
14.201	**64.9**	**60.38**	**86.05**	**0.2878**	**8.24**	**9.79**	**2.66**	**76**
14.758	**64.5**	**62.3**	**98.25**	**0.3061**	**8.47**	**7.82**	**2.40**	**128**
15.996	**75.76**	**69.1**	**104.76**	**0.3215**	**8.99**	**9.81**	**2.39**	**88**
17.228	**86.84**	**78.12**	**122.74**	**0.3483**	**9.83**	**9.51**	**2.46**	**104**
18.899	**105.6**	**95.1**	**138.0**	**0.3749**	**11.35**	**12.48**	**2.09**	**75**
18.620	**106.1**	**95.37**	**136.75**	**0.3714**	**11.51**	**12.34**	**2.28**	**77**
18.485	**106.55**	**95.79**	**136.63**	**0.3699**	**11.59**	**12.26**	**2.42**	**78**
18.354	**106.98**	**96.22**	**136.5**	**0.3685**	**11.67**	**12.18**	**2.59**	**79**
18.097	**107.42**	**96.41**	**135.25**	**0.3661**	**11.82**	**12.00**	**3.00**	**81**
20.281	**113.4**	**101.85**	**148.76**	**0.3994**	**11.73**	**13.53**	**2.13**	**68**
18.730	**102.13**	**90.04**	**147.38**	**0.3835**	**10.99**	**9.01**	**2.40**	**130**
17.860	**93.93**	**81.99**	**143.01**	**0.3738**	**10.38**	**7.23**	**0.84**	**201**
19.354	**103.8**	**91.25**	**152.23**	**0.3913**	**10.99**	**9.25**	**2.25**	**129**
18.842	**107.3**	**94.46**	**151.88**	**0.3819**	**11.49**	**9.45**	**2.37**	**131**
19.133	**104.32**	**91.75**	**151.98**	**0.3898**	**11.09**	**9.08**	**2.30**	**132**
19.060	**104.49**	**91.91**	**151.90**	**0.3895**	**11.13**	**9.02**	**2.33**	**133**
18.988	**104.65**	**92.07**	**151.82**	**0.3891**	**11.16**	**8.96**	**2.36**	**134**
18.918	**104.50**	**91.70**	**150.74**	**0.3888**	**11.19**	**8.90**	**2.40**	**135**
18.641	**105.1**	**92.33**	**150.43**	**0.3879**	**11.32**	**8.66**	**2.08**	**138**
19.602	**111.7**	**97.32**	**162.92**	**0.4049**	**11.70**	**8.71**	**2.34**	**148**

Table (II) continued

Zeff	$L_{cr}^{(1d)}$	$l_{max}^{(1b)}$	$E_{cm}^{(1b)}$	$X_{eff}^{(9)}$	$l_{ch}^{(7)}$	$E_{ch}^{(6)}$	$E_X(l)^{(8)}$	$l^{(8)}$
21.640	133.8	117.34	178.34	0.4330	13.30	12.36	2.25	86
20.008	119.0	102.85	173.74	0.4197	12.30	8.33	2.04	164
23.050	149.6	130.24	198.24	0.4598	14.33	13.06	2.45	84
23.502	152.3	132.55	204.0	0.4675	14.41	13.13	2.81	84
23.230	152.9	132.93	202.69	0.4643	14.57	13.00	2.14	85
20.811	128.0	109.7	189.1	0.4392	12.92	8.11	2.09	182
23.659	164.3	142.16	213.53	0.4738	15.47	13.35	2.76	87
21.582	145.1	123.96	205.73	0.4518	14.30	8.98	2.02	165
21.468	137.1	116.6	204.23	0.4578	13.55	7.83	1.74	201
24.294	171.5	147.34	227.33	0.4915	15.89	12.62	2.48	93
22.992	181.0	155.57	224.08	0.4709	17.22	12.86	2.23	100
21.727	149.4	127.27	211.75	0.4592	14.64	8.75	2.01	173
26.424	189.3	162.17	251.50	0.5249	16.72	14.18	2.12	80
25.548	192.3	164.63	248.4	0.5148	17.27	13.79	2.44	86
26.111	218.1	185.34	269.84	0.5254	19.32	14.76	2.22	88
27.320	216.1	181.35	293.18	0.5630	18.61	11.92	2.17	103
27.251	210.0	175.85	294.44	0.5629	18.08	11.08	2.07	116
26.824	213.6	178.8	293.02	0.5555	18.54	11.19	2.06	119
26.503	222.14	185.56	297.67	0.5548	19.38	11.07	2.14	125
27.756	226.8	186.31	309.8	0.5733	19.30	11.59	2.15	112
27.839	223.3	185.64	313.13	0.5830	18.97	10.66	2.13	121
29.457	184.6	201.91	337.8	0.6082	20.04	11.72	2.15	102
29.771	186.1	203.48	342.41	0.6127	20.09	11.79	2.24	101
30.243	261.4	283.376	399.14	0.6420	27.66	14.48	2.03	79
34.643	254.8	272.93	460.5	0.7213	25.02	12.51	2.02	80
31.870	278.74	298.77	450.9	0.6761	28.45	12.98	2.01	78

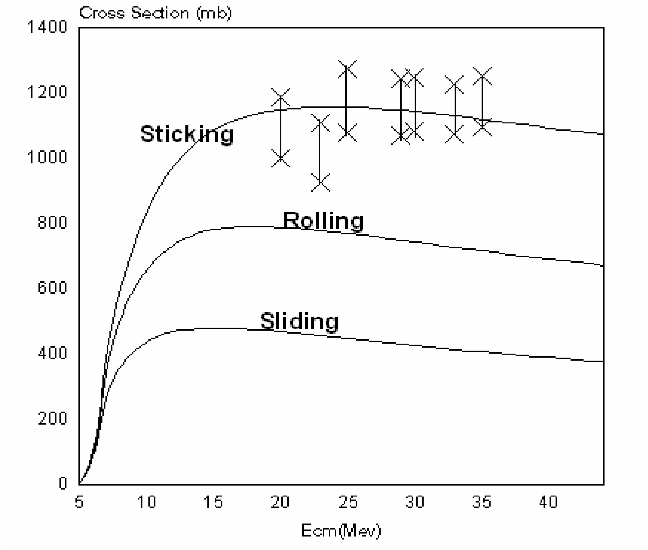
Table (III)

Proj.	Target	Vb_1	Vb_2	L_{ch}	E_{ch}	E_X	E_{cm}	$l(\hbar)$	l_{max}
O16	Sm148	60.42	59.5	11.13	9.02	2.33	159.02	133	92
O16	Sm154	59.9	59.1	11.32	8.66	2.08	156.66	138	93
O16	Pb208	75.74	73.8	12.92	8.11	2.09	196.11	182	110
Ar40	Sn122	107.04	108	19.45	13.17	2.51	279.17	101	183
Ni58	Sn124	163.03	165	25.12	15.20	2.13	421.20	60	264
Ni64	Sn118	162.09	164	26.09	15.62	2.02	419.61	68	272
Br81	Zr90	163.82	154	26.01	16.39	2.25	424.39	61	274
Br81	Zr94	162.61	153	26.66	16.17	2.07	421.17	66	278
Br81	Mo94	171.37	161	26.66	16.53	2.00	443.53	51	285
Br81	Ru104	177.04	166	28.23	16.33	2.02	457.33	50	300

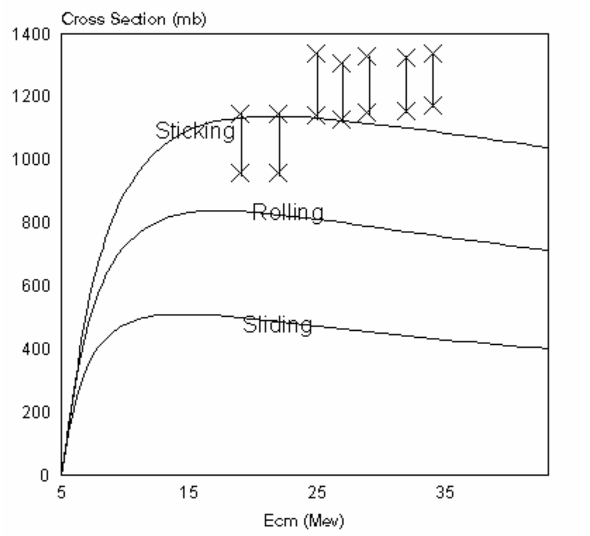
Table (IV)

Fusion excitation functions of some pairs calculated recently , taking into account the effect of dynamic aspects and compared with the experimental data imported from the mentioned references .

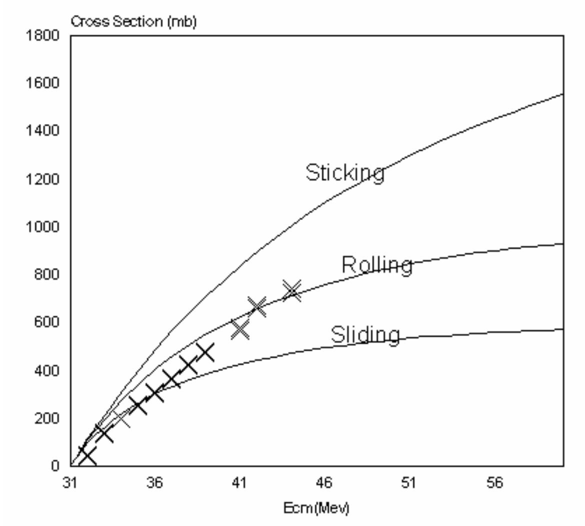
Fig. No.	*Proj.*	*Target*	*ZpZt*	*Zeff*	*Extra push (Mev)*	*Energy range Ecm(Mev)*	*Ref. Of exp. data*
1	**Li 6**	**Al 27**	**39**	**5.941**	**4.77**	**19-35**	**12**
2	**Li 7**	**Al 27**	**39**	**5.533**	**3.21**	**19-35**	**12**
3	**C 12**	**Zr 92**	**240**	**13.652**	**2.54**	**30-45**	**13**
4	**Li 6**	**Bi 209**	**249**	**11.915**	**2.09**	**30-50**	**14**



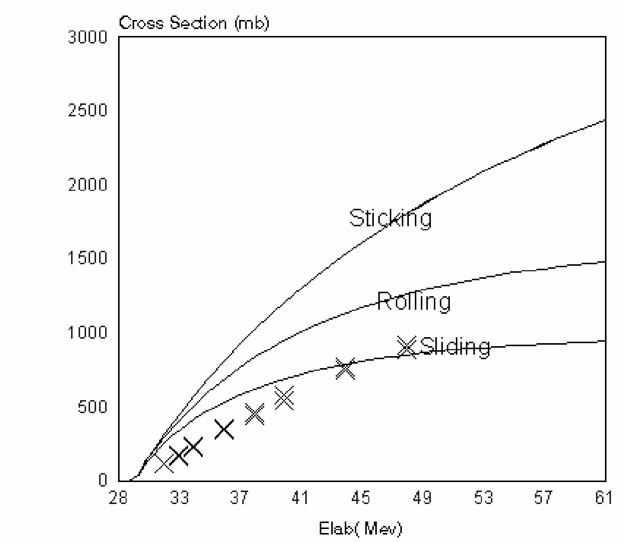
fig(1)



fig(2)



fig(3)



fig(4)

recently , taking into account the effect of dynamic aspects and compared with the experimental data imported from the mentioned references . From these cases it is noticed that for small values of $\mathbf{z_{eff}}$ the extra push energy required is higher than those for large values of $\mathbf{z_{eff}}$ and also it is noticed that the agreement with the experimental data is due to the mode of sticking collision whereas it is shifted to the other modes, the rolling and then to the sliding collision modes . We can deduce that the recently calculated excitation functions (figures 1-4), when displayed in comparison with corresponding measured data and as similar to those in figs. 4,5 and figs.14-16 of ref. (3) for heavier pairs, will point out the same note. That is that even when taking into account the effects of dynamic aspects, not only is it very problematic that a compound nucleus can be formed, but the high probability of fission makes the likelihood of producing super heavy nuclei by heavy ion reactions very small. Finally, we can point out the following results:

1- The extra push energy takes values, but so smaller to be concerned , for all values of bombarding energies $Ecm \geq Ech$ and these values are so small to be effective for all values of $Ecm \leq Vb$

2- It is clear that extra push energy shows very slow rise with increasing the bombarding energy and gets values $E_X <$ 3.5 Mev for all values E$cm < 3\ Vb$

3- The dynamic effects , in terms of extra push energy , has been clearly affecting the fusion excitation functions when the angular momentum values approach the maximum values l_{max}.

4- The theory of dynamic aspects will be only of interest for reproducing a wide variety of measured fusion excitation functions for very heavy systems where the one dimension potential model fail. For heavier reaction partners and as the high angular momentum values involved , the dynamical aspects of fusion become important .

REFERENCES

[1] S. Bjornholm and W.J.Swieatecki , nucl.phys. A391,471-504,(1982)
[2] R.A. Esterlund et al , Nucl. Phys. A435,597-620, (1985)
[3] J.R.Birkelund and J.R.Huizenga , Ann.Rev.Nucl.Part.Sci.,33,265-322,(1983)
[4]M.Dasgupta,etal,Ann.Rev.Nucl.Part.Sci.,48,401-61,(1998) .
[5] M. Beckerman, Rep. Prog. Phys.,51,1047,(1988), L. C. Vaz and J. M. Alexander, Phys. Rep. 69,5, (1981), and R. Satchler and W. G. Love, Phys. Lett. B65, 415, (1976)
[6]G.S. Hassan, Bull. Russian Acad. Sci. , (2002)
[7] H. Kusawake et al, Radiochemica Acta 69, 65-75, (1995) .
[8]M. Farid,Z. Mahmoud and G.S.Hassan,Nucl.Phys.A691,671.690,(2001).
[9]D. J. Hinde and M. Dasgupta , Nucl. Phys. ,A787, 176c-183c, (2007)
[10] M. Liu et al, Nucl. Phys. ,A768, 80-98, (2006)
[11] T. Udagawa et al, Phys. Rev. C32,1,124-135,(1985)
[12] P. R. S. Padron , et al, Phys. Rev. ,C66, 044608, (2002)
[13] G. O. Newton ,et al, Phys. Rev. ,C64, 64608, (2001)
[14] M. Dsagupta ,et al, Phys. Rev. C70,024606, (2004)