Angular momentum limit to fusion for reactions of weakly bound ^{6,7}Li and ^{6}He nuclei with heavy mass targets

M.K. Pradhan[1],* A. Mukherjee[1]
[1]Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata -700064, INDIA
* email: mukeshk.pradhan@saha.ac.in

The idea of maximum angular momentum called the critical angular momentum, l_{cr} for fusion was proposed long time ago to explain the difference between the total and fusion cross sections for normal systems at relatively high energies above the barrier [1,2]. Since practically fusion saturates the total reaction cross sections at near-barrier energies for many heavy-ion systems, Wong's formula of barrier penetration which provides a simple analytic formula to calculate reaction cross sections of two nuclei, has been successfully used to describe the corresponding fusion data. However, for weakly bound systems including halo systems, other reaction channels may favorably compete with the fusion even in the near-barrier region. In this case Wong's model is still suitable to characterize the total reaction data [2,4], but a suitable model is desirable which can simultaneously characterize the total reaction and fusion cross sections. It is well known that

$$\sigma_{capture} = \pi\lambda\!\!\!^{-2} \sum_{l=0}^{l=\infty} (2l+1) T_l P_l ,$$

where T_l is the transmission coefficients and P_l is the probability for capture once the barrier is crossed. For maximum angular momentum l_{cr} corresponding to fusion when the barrier crossed is

$$\sigma_{fus} = \pi\lambda\!\!\!^{-2} \sum_{l=0}^{l=lcr} (2l+1) T_l .$$

An analytic expression [5] thus obtained by extending the Wong's model is given by

$$\sigma_{fus} = [\hbar\omega_0 R_b^2 /(2E)] \ln[(1+e^{-y_0})/(1+e^{-z})],$$

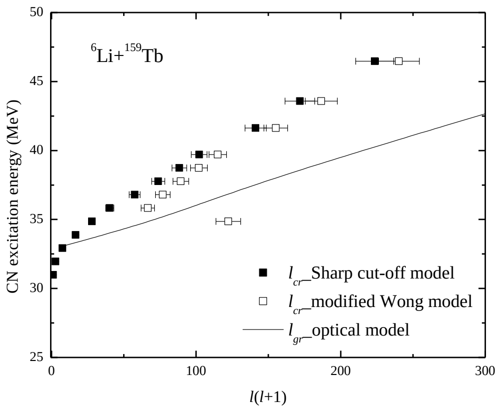
where $z = y_0 + [\pi\hbar/(\omega_0 \mu R_b^2)] l_{cr}(l_{cr}+1)$,

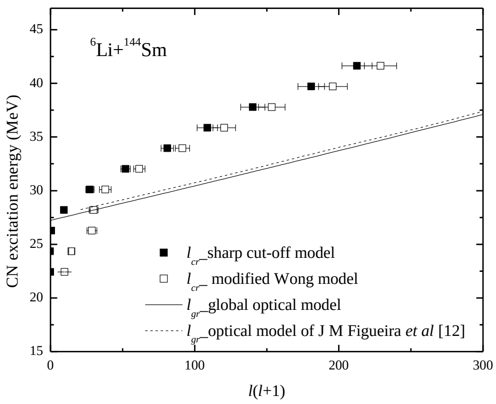
and $y_0 = 2\pi(V_b - E)/(\hbar\omega_0)$.

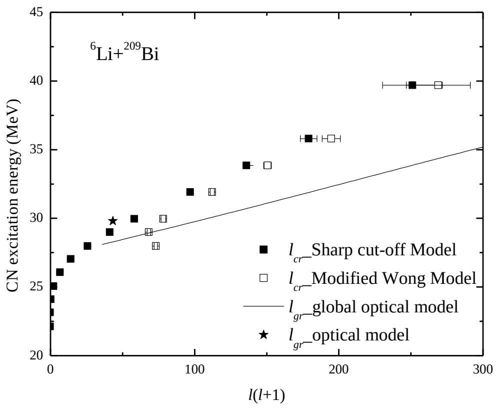
Here V_b, R_b and $\hbar\omega_o$ are the potential barrier parameters. Using this simple model E.F. Aguilera and J.J. Kolata [5] have worked on the fusion data for reactions of weakly bound nuclei ^{6,7}Li and ^{6}He with the targets ^{58}Ni, ^{59}Co, ^{64}Zn, ^{209}Bi. In the present work, we have used this modified Wong's model to study our measured fusion cross section data for the systems ^{6,7}Li+^{159}Tb [6,7]. Also we have studied other systems ^{6,7}Li+^{209}Bi [8], ^{6}Li+^{144}Sm [9] and ^{6}He+^{209}Bi [5] in the heavy mass systems. From the measured fusion excitation functions, we have extracted the value of l_{cr} using this model. The barrier parameters used in the calculations are from the Akyüz-Winther potential. Also we have extracted the critical angular momentum l_{cr} related to fusion in the sharp cut off model and compare it with l_{cr} obtained from the modified Wong's formula. In addition, grazing angular momentum l_{gr} was also determined for these reactions. The l_{cr} can be extracted from the measured fusion cross section (σ_{fus}) in the sharp cutoff approximation for a particular system at a given energy according to the relation,

$$\sigma_{fus} = \pi\lambda\!\!\!^{-2} (l_{cr}+1)^2 .$$

For simplicity, we have used this model in the present work since the qualitative features of the angular momenta are expected to remain unchanged. The l_{gr} which is essentially the angular momentum corresponding to the grazing collision of the two interacting nuclei represents the angular momentum for which the transmission through the potential barrier is 50% at a given centre of mass energy E_{cm}. The l_{gr} is extracted by determining the T_l from the optical model calculations, then finding the value of l for which T_l is 0.5. To determine T_l and hence to find l_{gr} for the systems ^{6,7}Li+^{159}Tb, ^{6,7}Li+^{209}Bi, and ^{6}Li+^{144}Sm, global optical model potential of J. Cook [10] have been used in the optical model calculations carried out using the code FRESCO [11]. For the system ^{6}Li+^{144}Sm, we have also obtained l_{gr} using the phenomenological optical model potential of Ref. [12].







In Figs. 1-4, the dependence of compound nucleus excitation energy E_{ex} with the derived various angular momenta are shown for the systems ^{6}Li+^{159}Tb, ^{6}Li+^{144}Sm and ^{6}Li+^{209}Bi and ^{6}He+^{209}Bi. It is found that for all the systems studied here the l_{cr} derived using the modified Wong's model and the sharp cut-off model

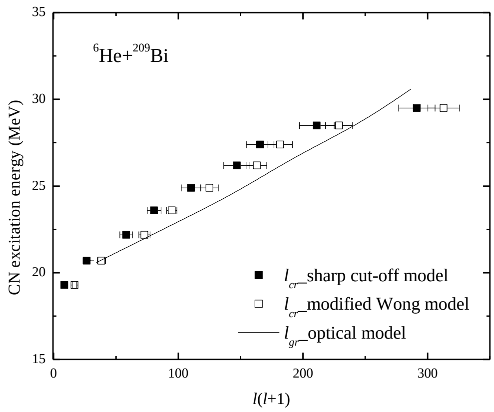


Fig. 1-4: $l_{\rm cr}$ and $l_{\rm gr}$ as a function of the compound nucleus excitation energy for the systems ^{6}Li+^{159}Tb, ^{6}Li+^{144}Sm, ^{6}Li+^{209}Bi and ^{6}He+^{209}Bi.

respectively are nearly the same and $l_{\rm gr}$ is found to diverge away from the l_{cr} except for the halo systems ^{6}He+^{209}Bi. Detailed calculations and discussions will be presented during the symposium.

References

[1] L. Kowalski *et al.*, Phys. Rev. **169**, 894 (1968).
[2] J. B. Natowitz, Phys. Rev. C **1**, 623 (1970).
[3] E. F. Aguilera *et al.*, Phys. Rev. C **83**, 021601 (R) (2011).
[4] J.J. Kolata and E.F. Aguilera, Phys. Rev. C **79**, 027603 (2009).
[5] E.F. Aguilera and J. J. Kolata, Phys. Rev. C **85**, 014603 (2012).
[6] A. Mukherjee *et al.*, Phys. Lett. B **636**, 91 (2006).
[7] M.K. Pradhan *et al.*, Phys. Rev. C **83**, 064606 (2011).
[8] M. Dasgupta *et al.*, Phys. Rev. C **70**, 024606 (2004).
[9] P.K. Rath *et al.*, Phys. Rev. C **79**, 051601(R) (2009).
[10] J. Cook, Nucl. Phys. A **388** 153-172, (1982).
[11] I.J. Thompson, Comput. Phys. Rep. **7**, 167 (1988).
[12] J. M. Figueira *et al.*, Phys. Rev. C **81**, 024613 (2010).