Analysis of ^{20}Ne induced reactions and role of critical angular momentum

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Introduction

Driven by a curiosity to assess the viability of reactions aimed at generating super heavy elements, there has been a resurgence of interest in heavy-ion-induced reactions. Over the past few decades, a number of investigations have been carried out, spanning over both theoretical and experimental realms. These studies have been focused on determining fusion cross sections, both complete and incomplete, at and above barrier energies. The primary cause of this phenomenon is the significant Coulomb repulsion. Breakup of the incoming projectile at the periphery of the target acts as a doorway for incomplete fusion reaction channels. When only a portion of the projectile's breakup fragment get absorb by the target nucleus, it leads to incomplete fusion (ICF) reaction. Complete fusion (CF) involves fusion of incident projectile with the target nucleus as a single entity. The intermediate compound system formed through the CF and ICF processes can be distinguished, based on the amount of angular momentum transferred in each of the two processes. In the CF process, there is a requirement for the complete transfer of the incident angular momentum to the resulting compound system. On the other hand, the ICF process involves partial transfer of the incident angular momentum to the intermediate compound system. Experimental evidence from heavy ion-induced reactions has shown that as the incident beam energy surpasses the Coulomb barrier, the contribution from the CF process decreases. This reduction is compensated by an increased contribution from the ICF process, leading to a continuous increase in the total fusion cross section. This phenomenon is attributed to a critical angular momentum associated with the intermediate compound system. Beyond a certain limit of angular momentum, the fission barrier related to the compound system disappears, and the compound system can no longer remain intact as a single entity; instead, it breaks apart into fission fragments.

Sum-rule model: Role of critical angular momentum

Based on the study of energy dependence of reaction cross sections of the ICF channels and interpretation of these reaction channels on the basis of generalised concept of critical angular momentum (ℓ_{crt}), J. Wilczynski [1] developed the sum-rule model. This model aims to predict the reaction cross sections for both CF and all feasible ICF channels. In the CF process, it corresponds to central collisions with negligible impact parameters, resulting in angular momentum that remains below a specified threshold known as the critical angular momentum ℓ_{crt}. This critical angular momentum (ℓ_{crt}) corresponds to the input angular momentum (ℓ) value at which the pocket in the effective entrance channel potential disappears. ICF reactions, in accordance to sum-rule model, are localized in angular momentum space above the limiting value for CF reactions i.e. ℓ_{crt}, beginning with the capture of the heavier fragment of the projectile and followed by capture of the lighter fragments at subsequent higher ℓ values. Cutoff angular

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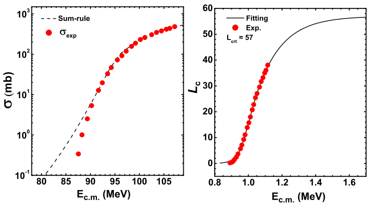

FIG. 1: (a) Comparison of experimental CF cross sections (solid bullets) with the prediction of sum-rule model (solid line). (b) Cutoff angular momentum ℓ_c (unit $\hbar$) as a function of $E_{c.m.}/V_B$ for the ^{20}Ne + ^{208}Pb system.

TABLE I: Cutoff angular momenta ℓ (unit $\hbar$) for ^{20}Ne induced reaction over ^{208}Pb and ^{165}Ho targets for different $E_{c.m.}/V_B$.

^{20}Ne + ^{208}Pb		^{20}Ne + ^{165}Ho	
$E_{c.m}/V_B$	$\ell_c(\hbar)$	$E_{c.m}/V_B$	$\ell_c(\hbar)$
0.910	1	0.988	6
0.918	2	1.077	22
0.929	3	1.186	33
0.938	4	1.335	45
0.952	6	1.452	53
0.961	7	1.589	58
0.972	9		
0.980	11		
0.993	14		
1.002	16		
1.011	18		
1.023	21		
1.031	23		
1.042	25		
1.051	27		
1.066	30		
1.076	32		
1.086	33		
1.097	35		
1.104	36		
1.114	38		

momentum ℓ_c , which is an important component in the determination of CF cross section using the sum-rule model, was estimated as per the prescription of Ref.[2]. As it can be inferred from Fig. 1, calculated CF cross sections, based on sum-rule model matches well with the experimental data at above the barrier energies. It is to be noted from Table I that observed cutoff angular momentum ℓ_c depends strongly on incident energy of the projectile and increases monotonically with increase in projectile energy for ^{20}Ne + ^{208}Pb [3] and ^{165}Ho [4] systems whereas the value of critical angular momentum ℓ_{crt} in the sum-rule model is independent of incident energy and have a specific value for a given projectile-target system.

References

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