Deciphering the influence of optical model parameters in heavy ion induced reactions

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During the last few decades, research in the field of heavy ion induced nuclear reactions has been exploring various interesting features of complex nuclear structure and reaction dynamics. Out of many nuclear reaction mechanisms, fusion reactions, namely, complete fusion (CF) and incomplete fusion (ICF) play a significant role in nuclear reaction dynamics [1]. In addition to characteristics like fractional linear momentum transfer and entirely distinct spin distribution patterns for CF and ICF residues, an enhancement in the fusion cross-section for α-emitting channels is an important characteristic of ICF.

In the present work, comparative study has been done for available experimental data of evaporation residues (ERs) obtained for the systems ^{12}C + ^{165}Ho and ^{14}N + ^{163}Dy [2,3] with theoretical predictions made by statistical model based computer code PACE4 [4]. The fusion evaporation code is based on Hauser-Feshbach (HF) theory of compound nucleus decay and calculates cross-section using Bass formula. The code calculates transmission coefficients (TC) for neutron (n), proton (p) and alpha particles (α) using the optical model potentials (OMP).

Optical model has inbuilt mass number, charge and energy dependence and is capable of describing reactions induced by heavy ions. The OMP, as defined by Perey et al [5] has many parameters which are phenomenologically determined from elastic scattering fittings. As such, the choice of parameters is not global / unique. Several sets of OMP parameters have been reported for different ranges of mass numbers and energies.

In the present work, cross-sections calculated using default (systematic) set of OMP parameters have been compared with modified set of OMP parameters in “manual mode” of PACE4. Both the sets of OMP parameters are enlisted in table-1

Table-1

OMP parameter	PACE4 default Values for		PACE4 modified Values for	
	neutron	proton	neutron	Proton
V(MeV)	47.01	55.982	51.711	53.775
*E[re]	-0.267	-0.55	-0.267	-0.22
*E^2[re]	-0.002	0.000	-0.002	0.00
r_0(fm)	1.268	1.25	1.268	1.16
a_D	0.66	0.65	0.66	0.75
W_D(MeV)	9.520	13.50	9.52	7.112
*E[img]	-0.053	0.00	-0.053	-0.05
r_D(fm)	1.30365	1.25	1.30365	1.37
a_D	0.48	0.47	0.48	0.928†

† Incident energy (E) dependent

On changing the OMP parameters, a considerable change in cross-sections for xn/pxn channels has been observed for the chosen systems. In Figs-1&2, experimental data of EFs for 3n, 4n, 5n channels of chosen systems have been plotted along with PACE4 predictions for default and modified set of OMP parameters. Level density free parameter ‘K’, another important parameter of PACE4, has been taken ‘10’ in all cases. As can be seen, experimental cross-sections fairly match with modified set of OMP parameters for 4n and 5n channels but the match is not good enough for 3n channel. It appears that the choice of parameter systematics does affect the end results.

Further, cross-sections other than xn and pxn channels, predicted by PACE4 have been summed and plotted for the two systems for default as well as modified set of OMP parameters [Fig-3]. It can be seen clearly that the modification in OMP parameters decreases the sum total of such cross-sections of by 15-30%. This in turn, when compared with experimental data will influence the fractional ICF contribution.

Figures

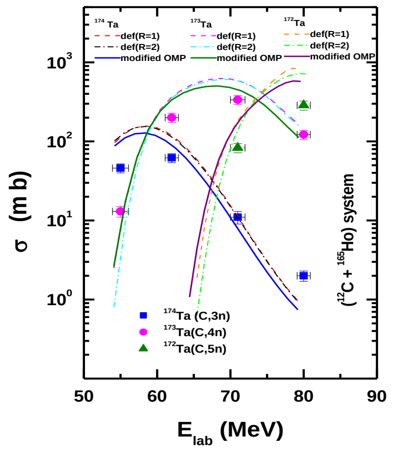

Fig-1

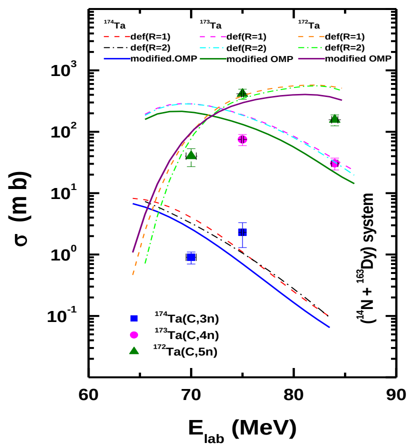

Fig-2

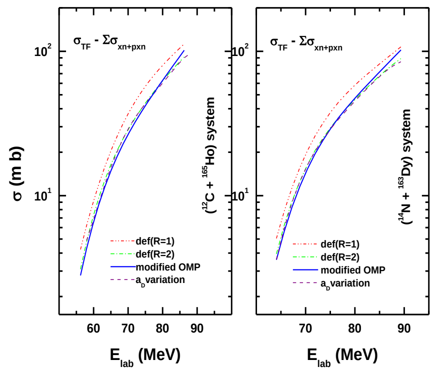

Fig-3

Conclusions

OMP parameter systematics, affects the end results to appreciable extent. The presence of such effects can be deduced on comparing the experimental data with the predictions of systematic parameter studies. As such, the parameters selected for certain range of mass number and energy may not be adequate over some other mass number and energy range. Thus instead of using OMP systematics established over large range of energies and mass numbers (default), it may be better to use a different parameter set, systematically determined for small range of mass number and energies in the region of interest.

References

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