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

Alpna Ojha1, Sunita Gupta1, Mohd Shuaib2, Pushpendra P. Singh3, Abhishek Yadav4, Mohd Shariq Asnain2, B.P.Singh2 and R.Prasad2
1Department of Physics, Agra College, Agra-282002, INDIA
2Nuclear Physics Laboratory, Physics Department, A.M.U. Aligarh-202002, INDIA
3Department of Physics, Indian Institute of Technology, Ropar, Punjab- 140 001, INDIA
4Department of Physics, Faculty of Natural Sciences, Jamia Millia Islamia, New Delhi-110 025, INDIA
*E-mail - iwa2008@rediffmail.com

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 12C + 160Ho and 14N + 160Dy [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>
<thead>
<tr>
<th>OMP parameter</th>
<th>PACE4 default Values for neutron</th>
<th>PACE4 default Values for proton</th>
<th>PACE4 modified Values for neutron</th>
<th>PACE4 modified Values for proton</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(MeV)</td>
<td>-0.267</td>
<td>-0.267</td>
<td>-0.267</td>
<td>-0.22</td>
</tr>
<tr>
<td>*E[ref]</td>
<td>0.002</td>
<td>-0.002</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>r0(fm)</td>
<td>1.268</td>
<td>1.268</td>
<td>1.268</td>
<td>1.16</td>
</tr>
<tr>
<td>aD</td>
<td>0.66</td>
<td>0.65</td>
<td>0.66</td>
<td>0.75</td>
</tr>
<tr>
<td>W[ref(MeV)]</td>
<td>9.520</td>
<td>9.520</td>
<td>7.112</td>
<td>7.112</td>
</tr>
<tr>
<td>*E[img]</td>
<td>-0.053</td>
<td>-0.053</td>
<td>-0.053</td>
<td>-0.053</td>
</tr>
<tr>
<td>rD(fm)</td>
<td>1.30365</td>
<td>1.30365</td>
<td>1.30365</td>
<td>1.37</td>
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<tr>
<td>aD</td>
<td>0.48</td>
<td>0.47</td>
<td>0.48</td>
<td>0.928</td>
</tr>
</tbody>
</table>

† 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 by 15-30%. This in turn, when compared with experimental data will influence the fractional ICF contribution.

Figures

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

5- C.M.Perey et al, At. data and Nucl.data Tables 17, 1-101 (1976).