Determination of diffuseness parameter to estimate the survival probability of projectile using Woods-Saxon formula at intermediate beam energies

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The scattering processes have been playing a pivotal role in the progress of nuclear physics since its beginning. In order to study the scattering processes, the concept of scattering (S) matrix has been found to be very useful which is being used in variety of ways [1-6]. One out of several such ways is to evaluate the survival probability ($|S|^2$) of a projectile in case of experiments performed at intermediate beam energies. The S-matrix, as a function of impact parameter b, can be evaluated by an oversimplified Woods-Saxon formula given by [4, 6-8]

$$S(b) = \frac{1}{1 + \exp\left(\frac{b_{min} - b}{\Delta}\right)}$$

Here b_{min} is the minimum value of impact parameter and Δ is the free diffuseness parameter. Once the value of b_{min} is fixed, the Δ plays the role of the only ingredient which decides the value of S-matrix. The value of Δ usually varies from $0.3fm$ to $1.5fm$ [4, 8]. Unfortunately, there exists no method in principle, to decide the value of Δ for a particular projectile target system at any incident beam energy. Due to this fact the simplicity of the Woods-Saxon formula in no way serves the useful purpose unless one has the fixed value of Δ.

Another method available for evaluation of S-matrix, which is a realistic but more involved, is in terms of integral of the projectile-target interaction along the straight-line trajectories and is given by [9]

$$S(b) = exp\left[\frac{i}{\hbar\vec{v}}\int V_{PT}(b^2 + z^2)dz\right]$$

with V_{PT} as nucleus-nucleus potential. It is clear that the evaluation of realistic S-matrix by this method requires the nucleus-nucleus potential, which in turn needs the understanding of nuclear matter density distribution of the projectile and the nucleon-target potential [9].

Here, two parameter Fermi (2pF) matter density distribution for projectile [10] and nucleon-target potential due to R L Varner et al [11] have been used.

In present work, the S-matrix has been evaluated by using simple Woods-Saxon formula as well as the realistic expression for a number of projectiles varying from ^{26}Ne to ^{76}Ge at intermediate incident beam energies ranging from 30 MeV/A to 300 MeV/A. The target is ^{197}Au in each and every case. The realistic S-matrix is compared with that of obtained by using the simple Woods-Saxon formula. The motive of this comparison is to fix the value of otherwise free Δ so that the much involved evaluation of realistic S-matrix can be replaced by the simple Woods-Saxon formula.

In table 1 the fixed values of Δ have been mentioned, which ranges from 0.6 fm to 1.4 fm, for various projectile target systems at intermediate incident beam energies being considered here. The value of Δ for ^{26}Ne at 30 MeV/A is found to be 1.1 fm which increases to 1.4 fm for ^{76}Ge. In other words, at particular incident beam energy the value of Δ increases for heavier projectile. Similar trend prevails for rest of the systems also as evident from table 1.

The variation of Δ with incident beam energy has been plotted in fig. 1 for ^{26}Ne+^{197}Au system. The value of Δ decreases with increase in incident beam energy, for ^{26}Ne its value decreases to 0.6 fm from 1.1 fm as the incident beam energy increases from 30 MeV/A to 300 MeV/A. It is worth to mention here that a significant decrease in the value of Δ is evident with increase in incident beam energy from 30 MeV/A to 200 MeV/A, in case of each and every projectile target system.

Table 1. A comparison of diffuseness parameter for various projectile target systems at 30 MeV/A-300 MeV/A.

	Diffuseness parameter $\Delta(fm)$				
Projectile +Target System	30 (MeV/A)	50 (MeV/A)	100 (MeV/A)	200 (MeV/A)	300 (MeV/A)
^{26}Ne+^{197}Au	1.1	0.9	0.8	0.7	0.6
^{38}Si+^{197}Au	1.2	1.1	0.9	0.8	0.7
^{56}Ti+^{197}Au	1.3	1.2	1.0	0.8	0.8
^{76}Ge+^{197}Au	1.4	1.4	1.2	0.8	0.8

However, the same is not case with increase in incident beam energy from 200 MeV/A to 300 MeV/A where the variation in the value of Δ is found to be almost insignificant.

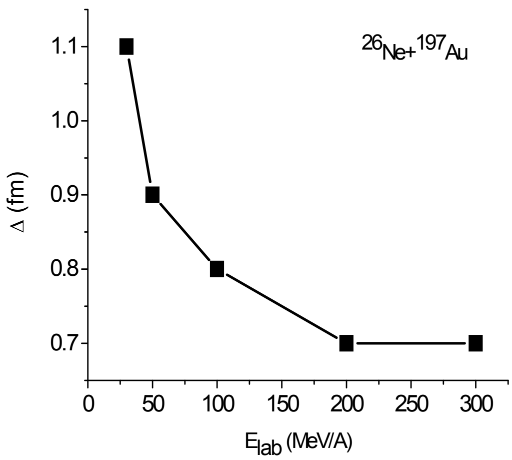

Fig. 1 The variation of diffuseness parameter with incident beam energies for ^{26}Ne+^{197}Au system.

From the discussion of table 1 and fig. 1 it is concluded that the value of Δ increases for heavier projectile and decreases with increase in incident beam energy. Further, it becomes clear that S-matrix can be evaluated, for a variety of projectile target systems at intermediate beam energies, with the help of simple Woods-Saxon formula, provided the fixed value of Δ is available.

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