Dependence of absorption effects on simultaneous variation of nuclear surface diffuseness and central depression parameter in Coulomb excitation process

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Introduction

Coulomb excitation is a process in which a nucleus is excited by electromagnetic interaction of another nucleus [1]. For the reliable extraction of nuclear properties, the maintenance of purity of the Coulomb excitation process is an essential requirement. The purity of Coulomb excitation process means that the excitation takes place only due to electromagnetic interactions while the influence of strong nuclear interactions is absent. The effects caused by the nuclear interactions are commonly termed as absorption effects. The absorption effects, if present, need to be accounted properly. Minimum value of the impact parameter (b_{min}) is an important factor which decides whether the absorption effects will come into play or not. In the analysis of the Coulomb excitation data, the absorption effects can be accounted through the concept of survival probability $|S(b)|^2$ of the projectile [2-3].

Theoretical Formalism

The $|S(b)|^2$ can be calculated in terms of imaginary part of projectile target optical potential $U_{PT}(\boldsymbol{r})$, as given below [2]

$$|S(b)|^2 = exp\left[\frac{2}{\hbar v}\int Im[\,U_{PT}(\boldsymbol{r})]dz\right]. \quad (1)$$

The $U_{PT}(\boldsymbol{r})$ can be constructed by employing the double folding of nucleon-nucleon interaction $v_{nn}(s)$ over the nuclear matter densities of the projectile $\rho_1(r_1)$ and the target $\rho_2(r_2)$. The expression for the $U_{PT}(\boldsymbol{r})$ is given by [4]

$$U_{PT}(\boldsymbol{r}) = \int \rho_1(r_1)\rho_2(r_2)v_{nn}(r)d^3r_1 d^3r_2. \quad (2)$$

Out of various types of available nucleon-nucleon interactions, we have used M3Y type realistic interaction along with Fermi type 2pF and 3pF matter density distributions in the present work to construct the $U_{PT}(\boldsymbol{r})$. The expression for the 3pF matter density distribution is given by [5]

$$\rho(r) = \frac{\rho_0\left(1+\frac{wr^2}{R^2}\right)}{\left(1+\exp(\frac{r-R}{a})\right)}. \quad (3)$$

here ρ_0, R, a and w are central density, radius, surface diffuseness and central depression parameter respectively. The R, a and w form a set of three parameters of the 3pF matter density distribution, for w=0 the 3pF distribution reduces to 2pF distribution. Out of the three parameters only a and w are taken as free parameters, for every value of a and w, the value of R is determined by a condition which ensures that root mean square radius of the projectile stays constant and the details for the same may be found elsewhere [6].

It is clear from the earlier studies that individually a as well as w have been found to be the sensitive parameters. Therefore, it is interesting to see the effect of simultaneous variation of a and w on the absorption effects and on the reaction cross section also. In present work, a recently studied projectile target system ^{80}Kr+^{197}Au [7] is chosen as a representative case for the same.

Results and discussion

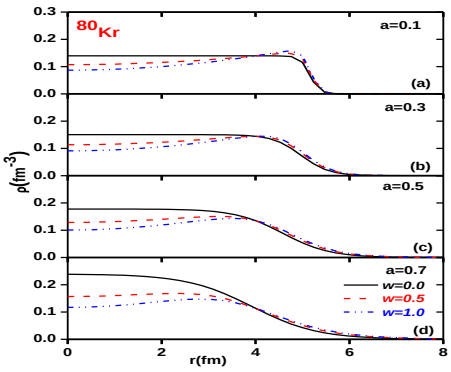

Fig. 1 Comparison of 2pF and 3pF matter density distribution for ^{80}Kr nucleus for various values of a and w.

In Fig. 1, the 2pF and 3pF type matter density distribution for ^{80}Kr have been plotted for various values of a and w ranging from 0.1 to 0.7 fm and 0.0 to 1.0 respectively. The matter density distributions are found to be significantly different from each other for various values of a and w. For a fixed value of a the Fermi density

distribution extends spatially in the peripheral region for various value of central depression parameter w and the feature of spatial extension is found to be most pronounced for $a = 0.7\ fm$. Thus the simultaneous increase a and w lead to spatial extension of the matter density distribution of the projectile. This observation becomes more clear from Fig. 2, where only the peripheral regions is plotted for ^{80}Kr for $a = 0.7\ fm$.

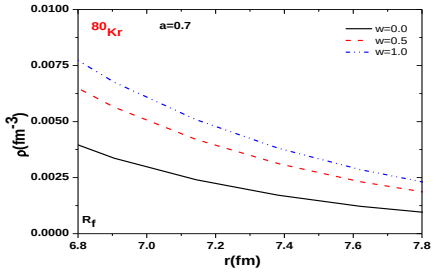

Fig. 2 Plot of the peripheral density distributions of ^{80}Kr for $a = 0.7\ fm$ and various value of w.

The spatial extension may affect the absorption effects significantly which are commonly mentioned by the quantity denoted by $\left(\frac{\sigma-\sigma^{|S(b)^2|}}{\sigma}\right)$% [3]. Here, σ and $\sigma^{|S(b)^2|}$ represents the Coulomb excitation cross section calculated without and with inclusion of the $|S(b)|^2$ respectively. Hereafter, the quantity $\left(\frac{\sigma-\sigma^{|S(b)^2|}}{\sigma}\right)$% shall be denoted by $\boldsymbol{\varepsilon}$% for the sake of brevity.

In order to calculate the absorption effects $\boldsymbol{\varepsilon}$% for various simultaneous values of a and w, the value of b_{min} needs to be fixed and in the present work it is fixed to be equal to $R_P + R_T$, $R_P + R_T + 2$ and $R_P + R_T + 3\ fm$. The quantitative estimate of the absorption effects $\boldsymbol{\varepsilon}$% are listed in Table 1 in columns 4, 5, 6 and 7. It is evident from the Table 1 that for a fixed value of the b_{min}, the absorption effects depend upon the value of a and w. For the projectile target system being considered here, the absorption effects are found to be maximum ~31% for the lowest value of b_{min} $(R_P + R_T)$ and the highest value of a $(0.7fm)$ and $w(1.0)$. At $R_P + R_T$ the absorption effects are significant for each and every value of the a and w and also have appreciable variations from ~15% to 31%. With increase in the value of b_{min} from $R_P + R_T$, to $R_P + R_T + 2$ and to $R_P + R_T + 3\ fm$ the significance of the absorption effects reduces to moderate and to weak respectively and the variations w.r.t a and w also follows the same trend.

Table 1: Estimation of the absorption effects for different values of b_{min}, surface diffuseness a and central depression w.

$a(fm)$			0.1	0.3	0.5	0.7
b_{min} (fm)	Density Type	w	$\boldsymbol{\varepsilon}$%	$\boldsymbol{\varepsilon}$%	$\boldsymbol{\varepsilon}$%	$\boldsymbol{\varepsilon}$%
$R_P + R_T$	2pF	0.0	15.2	16.6	19.7	24.3
	3pF	0.5	15.8	17.6	22.1	29.4
		1.0	16.2	18.2	23.2	31.2
$R_P + R_T + 2$	2pF	0.0	0.8	1.1	2.0	4.5
	3pF	0.5	0.9	1.3	2.9	8.1
		1.0	1.0	1.4	3.4	9.6
$R_P + R_T + 3$	2pF	0.0	0.1	0.2	0.6	1.3
	3pF	0.5	0.2	0.2	0.7	2.8
		1.0	0.2	0.2	0.8	3.5

It is pertinent to mention here that for the calculations of the Coulomb excitation cross sections the σ and $\sigma^{|S(b)^2|}$ and the absorption effects $\boldsymbol{\varepsilon}$% the code DWEIKO has been used [8] but with 2pF and 3pF type matter density distributions.

Conclusions

In conclusion the simultaneous variations in the values of a and w have been found to be affecting the absorption effects significantly.

References

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