DOUBLE FOLDING MODEL ANALYSIS OF THE ELASTIC SCATTERING DATA OF 9Be + 64Zn REACTION

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**DOUBLE FOLDING MODEL ANALYSIS OF THE ELASTIC SCATTERING DATA OF $^9\text{Be} + ^{64}\text{Zn}$ REACTION**

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**INTRODUCTION**

With the continuous advancement of radioactive ion beam facilities worldwide, accelerated radioactive beams including halo nuclei have become accessible for investigation. A number of detailed experimental studies have been carried out so far, for the case of light neutron halo systems like $^6\text{He}$, $^{11}\text{Li}$ and $^9\text{Be}$ (Tanihata, 1985; Canto, 2006). The isotope $^9\text{Be}$ is the only stable one, and it retains the highly deformed double-$\alpha$ shape, due to the proximity of the low-lying $2\alpha 1n$ threshold. It is a weakly-bound Borromean nucleus, i.e., three separate particles of the nucleus are bound together in such a way that if any one is removed, the remaining two become unbound, just like the rings of the Borromean family crest. The one-neutron separation energies (Wang, 2012) for $^9\text{Be}$ are 1664.54$^{+0.10}_{-0.30}$ keV.

In addition to all these, A.Di Pietro et al. (Pietro, 2010) have recently measured the angular distributions and cross sections of $^9\text{Be} + ^{64}\text{Zn}$ reaction at $E=24.5$ MeV. In the present study, we aim to make similar calculations regarding the elastic scattering data of $^9\text{Be} + ^{64}\text{Zn}$ reaction, but using the double folding model within the framework of the optical model. We will then compare the results with those in (Pietro, 2010) as well as the experimental data. This comparison justifies the reliability of the present model for the data of interest and clarifies the inter-relation between the two different approaches for the elastic scattering reaction considered.

**DOUBLE FOLDING MODEL ANALYSIS**

In the optical model approach, the total effective potential can be written as the sum of nuclear, Coulomb and centrifugal potentials

$$V(r) = V_N(r) + V_C(r) + \frac{\mu l(l+1)}{2r}$$  \hspace{1cm} (1)

Where $\mu$ is the reduced mass of the interacting pair.

The $V_C(r)$ potential (Frobrich, 1996), owing to a charge $Z_p e$ of projectile interacting with a charge $Z_T e$ of target nucleus distributed uniformly over a sphere of radius $R_C$ is

$$V_C(r) = \frac{1}{4\pi\varepsilon_0} \frac{Z_p Z_T e^2}{r} \hspace{1cm} r \geq R_C$$  \hspace{1cm} (2)

Where $R_C$ is the Coulomb radius, taken as $1.25 \left( A_p^{1/3} + A_N^{1/3} \right)$ fm in the calculations.

The nuclear potential consists of two parts, which are the real part and the imaginary part. The nuclear matter distributions of projectile and target nuclei via an effective nucleon-nucleon interaction potential $v_{nn}$ are used in obtaining the real part of the $V_N(r)$ potential. In this context, the double folding potential is given as

$$V(r) = \lambda \int \rho_p(r_1)\rho_T(r_2)v_{nn}(s)d\vec{r_1}d\vec{r_2}$$  \hspace{1cm} (3)

Where $\rho_p(r_1)$ and $\rho_T(r_2)$ the nuclear matter density of projectile $^9\text{Be}$ and target $^{64}\text{Zn}$ nuclei, respectively.

The nuclear matter density distributions for $^9\text{Be}$ is independently assumed to have a Fermi form with rms charge radius of 2.519 fm (DE.Vries, 1987)

$$\rho(r) = \frac{\rho_0}{1+\exp\left(\frac{r-R}{a}\right)}$$  \hspace{1cm} (4)

For $^{64}\text{Zn}$, nuclear charge densities are taken in the Fermi form as in eq.(4) with the parameters from (DE.Vries, 1987).

The $v_{nn}(s)$ is integrated over both density distributions. In literature, some nucleon-nucleon interaction expressions can be found for the folding model potentials. We have taken the M3Y nucleon-nucleon (Michigan 3 Yukawa) realistic interaction which is the most common one. The $v_{nn}(s)$ is given by (Satchler, 1987)

$$v_{nn}^{M3Y}(s) = \left[ 7.999 \exp(-4s) - 2.134 \exp(-2.5s) \right] + J_{00}(E)\delta(s)$$  \hspace{1cm} (5)
Where $I_{00}(E)$ is the exchange term, since nucleon exchange is possible between the projectile and the target. $I_{00}(E)$ which has a linear energy-dependence can be taken as following form

$$I_{00} = 276 \left(1 - 0.005\frac{E}{A}\right)$$

The nuclear matter densities required for the calculation of DF potential were obtained from the available nuclear charge radius in case of $^9\text{Be}$ and $^{64}\text{Zn}$, using the code DFPO, the details of which are given in (Cook,1982). The calculated real folded potentials with the renormalization constants, for $^9\text{Be}$ projectiles scattering from $^{64}\text{Zn}$ target, as a function of the radial distance $r$ are shown in (figure-1).

![Figure 1](image1.png)

**Figure 1.** The real $V_{\text{DF}}$ parts of the potential for $^9\text{Be}$, calculated using double folding model.

However, the imaginary part of the $V_N(r)$ potential has been taken as in the following the Woods-Saxon form

$$W(r) = \frac{W_0}{1 + \exp\left(\frac{r - R_W}{a_W}\right)}$$

Where $R_W = r_w\left(A_p^{1/3} + A_T^{1/3}\right)$. $A_p$ and $A_T$ denote mass numbers of projectile and target nuclei respectively. The code LOLA (Devries, 1973) has been used for the elastic scattering cross section calculations. In calculations of the present study, the parameters of the imaginary potential which give convenient results with experimental data have been searched. All the parameters obtained are shown in (table-1). The normalization factor $\lambda$ is a parameter used in double folding model calculations, which shows the achievement of the model. The most suitable value of the normalization factor is 1.1. Also, the results obtained are given in comparison with the results of (Pietro, 2010) as well as the experimental data in (figure 2). As can be seen from (figure-2), the double folding model analyzing results are in a remarkable agreement with the data in the whole domain, which obviously clarifies that double folding model explains the elastic scattering data of $^9\text{Be} + ^{64}\text{Zn}$ reaction in a perfect manner. Also, it generally shows similar behavior with the results of (Pietro, 2010).

![Figure 2](image2.png)

**Figure 2.** The ratio to Rutherford cross-section for $^9\text{Be}$ scattering from $^{64}\text{Zn}$ at $E_{\text{c.m.}} = 24.5$ MeV. The dots are the experimental values taken from (Pietro,2010), while the solid line corresponds to the DF calculations.

### Table 1

<table>
<thead>
<tr>
<th>System</th>
<th>$\lambda$</th>
<th>$W$ (MeV)</th>
<th>$r_w$ (fm)</th>
<th>$a_w$ (fm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^9\text{Be} + ^{64}\text{Zn}$</td>
<td>1.1</td>
<td>14.70</td>
<td>1.19</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Finally, we have found as 1120 mb the reaction cross section of the $^9\text{Be} + ^{64}\text{Zn}$ reaction at 24.5 MeV.

### CONCLUSION

In this study, the elastic scattering data of the reaction has been investigated. Within this context, the double folding model with reasonable potential parameters has been used. The calculation results in the present
work have been compared with the experimental data, together with the related results in the previous report (Pietro, 2010), and remarkable agreement has been observed between them. This justifies the reliability of the present technique used in this article. Once the spectroscopic factor or ANC is extracted for one nucleon transfer reaction, the cross sections for the proton or neutron capture reactions can then be computed with the radiative capture model.

References


Summary

DOUBLE FOLDING MODEL ANALYSIS OF ELASTIC SCATTERING DATA OF 9Be+64Zn REACTION


In this work, the elastic scattering data 9Be+64Zn reaction at 24.5 MeV is investigated. In order to obtain the theoretical results, the double folding model within the framework optical model is used. The results are compared with the related literature as well as the experimental date. The comparison provides information about the similarities and differences of the models used in calculations. 

Keywords: Optical model, Double folding model, Elastic scattering.