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Investigation of interaction processes of light nuclei with ^{14}N

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Abstract. Elastic scattering of ^{3}He on ^{14}N as an example of 1p-shell nuclei at 50 and 60 MeV has been investigated within the framework of Optical Model. In the Optical Model analysis, both microscopic double-folding and phenomenological potentials for the real part of the complex nuclear potential have been used. For both microscopic double-folding and phenomenological analyses, the imaginary potential has taken to be WS volume shaped. It is noticed that while a normalization of the strength of the double-folding real potential is needed to explain the structure observed in the experimental data, a good agreement between experimental data is obtained for the phenomenological potential case.

1. Introduction

The study of the interaction of ^{3}He with ^{14}N nuclei at low energies is of interest both from the point of view of establishing reliable values of the parameters of the internuclear potential interaction of ^{3}He and to study the mechanisms of cluster effect in scattering processes [1].

The elastic and inelastic experimental data of ^{3}He+^{14}N system has been measured in INP Almaty as a part of larger experimental research program of the scattering of ^{3}He on light-heavy nuclei with a mass range between 4 and 28. Experiment on the elastic and inelastic scattering of ^{3}He ions with energies 50 and 60 MeV on ^{14}N were carried out on the extracted beam of the isochronous cyclotron U-150M in INP Almaty, Kazakhstan. The energy of the accelerated ions was determined by comparing the energy spectrum of the particles scattered from a thin Au target at a small angle, the spectra of the α - particle radioactive source. The spread of the beam energy was less than 1%. The targets were thin films and foils (1 mg/cm^{2}) of enriched isotope of corresponding elements. The thickness of the gas target was determined by weighing or by energy loss of α - particles from a radioactive source with exactly $6-9\%$. Nuclear reaction products were detected by using telescope detectors consisting of surface-barrier silicon counters with a thickness - 10, 18, 33, 50, 100 micrometers or ionization chamber, the effective thickness may be smoothly changed in a broad range. In both variants, telescopes as E-counter used diffusion-drift silicon detectors with a sensitive layer thickness of 2 mm. The angular distributions of scattered particles in the investigated nuclei were measured in the angular range of 10°-170° in laboratory coordinate system in steps of 3°. Spectrum analysis has been performed by using the program MAESTRO [2].

Experimental data of ^{3}He+^{14}N system measured at INP Almaty has been analysed within the standard optical model and microscopic double-folding potentials using the computer code FRESCO. In the next section, we present our optical model potentials and then show our results in section 3. We also present our summary and conclusion in this section.

2. The Model

We have used both phenomenological deep and double-folding real potentials with a volume type imaginary potential [3, 4, 5, 6, 7, 8, 9, 10, 14]. Our total real potential for these cases consists of the nuclear, $V_{Nuclear}$, Coulomb and centrifugal potentials, V_{Coul}, V_{Cent} respectively.

$$V_{total}(r) = V_{Nuclear}(r) + V_{Coulomb}(r) + V_{Centrifugal}(r) \tag{1}$$

The phenomenological nuclear potential is assumed to have the square of a Woods-Saxon shape and Coulomb potential [10, 11] distributed uniformly over a sphere of radius R_C, is also added.

Table 1. Phenomenological and Double Folding potential parameters with N_r.

E_b(MeV)	V_0(MeV)	r_0(fm)	a_0(fm)	W_V(MeV)	r_V(fm)	a_V(fm)	N_r	R_C(fm)
50	60	1.2	0.823	8.8	1.412	0.747		4.62
DF				8.8	1.412	0.747	0.9	
60	55	1.2	0.823	9.8	1.318	0.747		4.62
DF				9.8	1.318	0.747	0.9	

Double folding potential [12, 13] is calculated by using the nuclear matter distributions of both projectile and target nuclei together with an effective nucleon-nucleon interaction potential (ν_{NN}) are used. Thus, the double folding potential is

$$V_{DF}(\mathbf{r}) = \int d\mathbf{r}_1 \int d\mathbf{r}_2 \rho_p(\mathbf{r}_1)\rho_t(\mathbf{r}_2)\nu_{NN}(\mathbf{r}_{12}) \tag{2}$$

where $\rho_p(\mathbf{r}_1)$ and $\rho_t(\mathbf{r}_2)$ are the nuclear matter density of projectile and target nuclei, respectively. Gaussian density distributions defined as following have been used for both nuclei

$$\rho(r) = \rho_0 exp(-\beta r^2) \tag{3}$$

where β is adjusted to reproduce the experimental value for the rms radius of the ^{14}N=2.58 fm and ^{3}He=1.877 fm [14]. ρ_0 values can be obtained from the normalization condition

$$\int \rho(r) r^2 dr = \frac{A}{4\pi} \tag{4}$$

where A is the mass number. For the nucleon-nucleon interaction potential (ν_{NN}), we have used the following M3Y nucleon-nucleon realistic interaction with the relevant exchange correction term due to the Pauli principle [12, 13], given by

$$\nu_{NN}(r) = 7999\frac{exp(-4r)}{4r} - 2134\frac{exp(-2.5r)}{2.5r} + J_{00}(E)\delta(r)MeV, \tag{5}$$

where

$$J_{00}(E) = 276[1 - 0.005E_{Lab}/A_p]MeV fm^3 \tag{6}$$

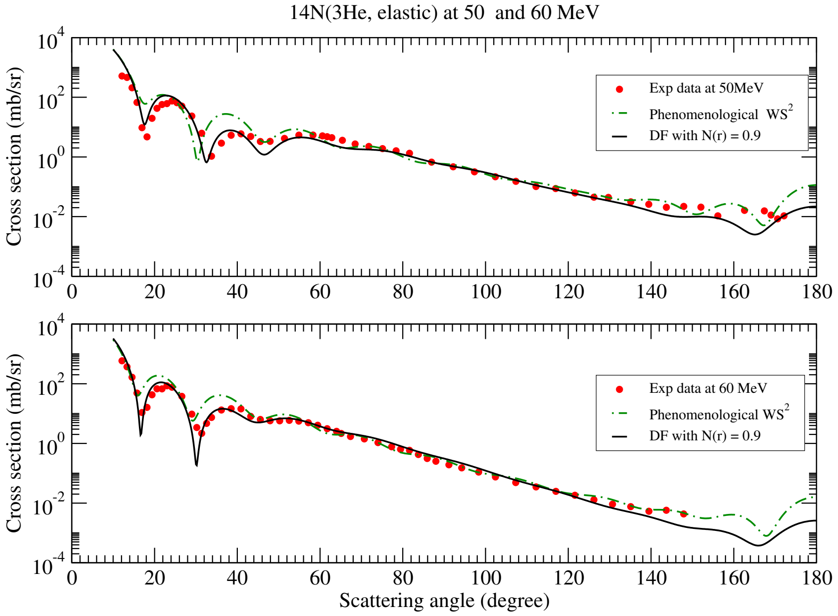

Figure 1. The results of DF and phenomenological WS^2 potentials in comparison with experimental data for ^{3}He+^{14}N system at 50 and 60 MeV.

3. The Results and Conclusion

The results obtained by using the microscopic double-folding and phenomenological nuclear potentials with the above-described models are shown in Fig.1 in comparison with the experimental data. As it can be seen from this figure that the real part of the double folding potential requires a normalization in order to obtain a reasonable result. Without this normalization, $N_r = 0.9$, we could not get an agreement with the experimental data. The phenomenological Woods-Saxon typed potential has provided a better agreement with the experimental data as seen in the same figure with dashed line.

Double-Folding analysis could effectively fit the experimental data at forward (angles lower than 70°), while phenomenological analysis could fit the experimental data at backward angles. The resulting potentials can be used for model calculations of yields of nuclear reactions necessary for astrophysical applications.

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