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Investigation of the elastic and inelastic scattering of ^4He from ^{11}B in the energy range 29-50.5 MeV

N.Burtebayev¹, Zh.Kerimkulov¹, M.Bakhtybayev¹, Sh.Hamada²,
Y.Mukhamejanov³, M.Nassurlla³, D.Alimov³, A.Morzabayev⁴, D.Janseitov⁴,
W.Trzaska⁵

¹ Institute of Nuclear Physics, Almaty, Kazakhstan

² Faculty of Science, Tanta University, Tanta, Egypt

³ Kazakh National University, Almaty, Kazakhstan

⁴ Eurasian National University, Astana, Kazakhstan

⁵ University of Jyväskylä, Finland

E-mail: y.mukhamejanov@gmail.com

Abstract: We have measured the angular distributions for the elastic and inelastic scattering of ^4He from ^{11}B in the isochronous cyclotron U-150 M INP RK. The extracted α -particles beam has been accelerated to energy 29 MeV and then directed to ^{11}B target. The experimental results were analyzed within the framework of both the optical model using different complex potential and the double folding potential obtained with different density-dependent NN interactions which give the corresponding values of the nuclear incompressibility K in the Hartree-Fock calculation of nuclear matter.

1. Introduction

Study of nuclear reaction is of a special interest as it could provide us with useful information about the nuclear structure, potential parameters, deformation, and transition probabilities. The α -nucleus interaction is an essential tool for the understanding of nuclear structure and nuclear reactions. The concept of the α -particle mean field has been widely used to unify the bound and scattering α -particle states in a similar way to use of the nuclear mean field to calculate the properties of bound single particle states and also the scattering of unbound nucleons by nuclei.

2. Experimental Details

The experimental angular distribution measurements for ^4He elastically and inelastically scattered from ^{11}B at energy 29 MeV were performed in the isochronous cyclotron U-150M INP located in Almaty, Kazakhstan, which allows accelerating protons up to energy 30 MeV, deuterons up to energy 25 MeV, ^3He up to energy 60 MeV and α -particles up to energy 50 MeV. Three (E - ΔE) telescopes of silicon semiconductor detectors, which cover the scattering angles of 10–70° were used in data acquisition. For optimal focusing of the accelerated ions beam on the target, two collimators of diameter 2 mm were used. The (E - ΔE) method was used in the registration and identification of reaction products. In the telescope detectors " E - ΔE ", ΔE - detector is a surface-barrier silicon detector-company ORTEC- thick active layer of 30 to 200 μm with thin inlet ($\sim 40\mu\text{g}/\text{cm}^2$ Au) and outlet



($\sim 40 \mu\text{g}/\text{cm}^2$ Al) windows. The complete absorption E detector is used as a stop detector company ORTEC high-purity silicon; thickness of 2 mm.

3. Results and discussion:

The theoretical calculations for the elastic scattering of α -particles from ^{11}B target at energies 29, 40 and 50.5 MeV were performed within the framework of code Fresco [1] using two approaches (a) phenomenological optical potential and (b) semi-microscopic double folding potential.

In the **Optical Model** calculations at energies 40 and 50.5 MeV [2] we used two different potential sets (A and B), which is a combination of real volume part plus imaginary volume part. The potential set A was used to reproduce the experimental data in the forward hemi sphere with fixed values for the parameters r_v and r_w , the potential set B was used to reproduce the experimental data in the full angular range also with the same fixed values for the parameters r_v and r_w as in set A. While, at energy 29 MeV a potential combination of real volume part plus imaginary surface part (set A) was found to be more effective to reproduce the experimental data in the full angular range at this energy.

Table 1: The optimal potential and deformation parameters obtained for elastic and inelastic $5/2^-$ (4.45 MeV) scattering of ^4He from ^{11}B at energies 29, 40 and 50.5 MeV

E MeV	Potential set	V_o MeV	r_v fm	a_v fm	Nr	W_o MeV	r_w fm	a_w fm	W_d MeV	r_d fm	a_d fm	β $5/2^-$
29	OM A full	79.55	1.2	0.743					23.65	1.76	0.438	0.46
	DF A full				1.234				37.13	1.8	0.365	0.46
	OM A short	77.85	1.245	0.856		19.01	1.57	0.7				0.42
40	OM B full	130.97	1.245	0.76		18.38	1.57	0.64				0.42
	DF A full				1.2	18.38	1.57	0.64				0.4
	DF B full				1.2	30.0	1.262	0.7				
	OM A short	77.22	1.245	0.856		16.85	1.57	0.833				0.35
50	OM B full	120.0	1.245	0.752		18.14	1.57	0.731				0.35
	DF A full				1.2	18.14	1.57	0.731				
	DF B full				1.2	30.0	1.33	0.746				0.35

In the **double folding** calculations, the real part of the potential was derived by folding the density distributions of the target nucleus and the projectile with the NN interaction potential. We used M3Y interactions which were designed to reproduce the G -matrix elements of the Reid [3] and Paris [4] free NN potentials in an oscillator basis. At energies 40 and 50 MeV two sets of potential (A and B) were used in the calculations. In potential set A, the normalization coefficient for the real part of the potential equals 1.2 and the phenomenological imaginary volume parameters were fixed to the same values used in potential set B for optical model calculations. While, at energy 29 MeV, the obtained normalization coefficient for the real part of the potential equals 1.234 and the phenomenological imaginary surface parameters were taken as free parameters.

The comparison between the experimental data and theoretical predictions for the state $5/2^-$ at energies $E_{\text{He}}^4 = 29, 40$ and 50.5 MeV are shown in figures 1. The theoretical calculations of the angular distributions for the different excited states were performed using the coupled channel method implemented in code Fresco using different potential sets.

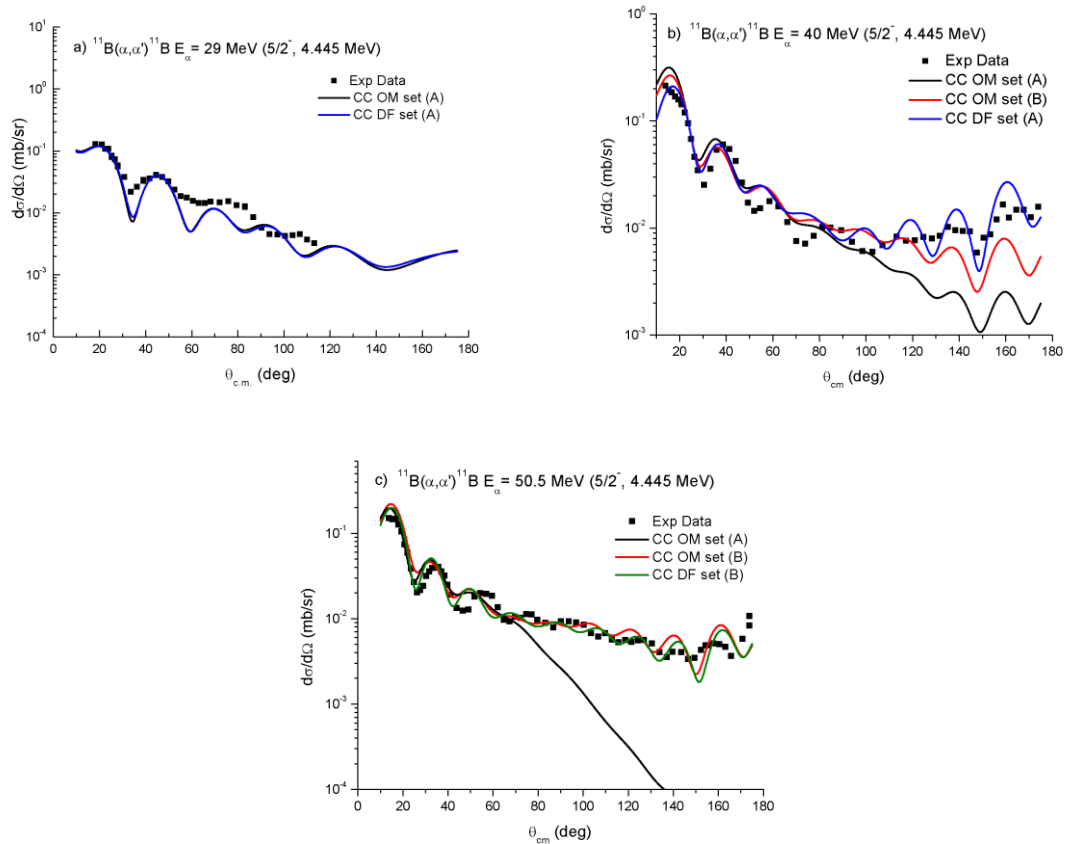


Figure 1. Comparison between the experimental data and the calculated differential cross section for inelastic scattering of ^4He from ^{11}B ($5/2^-$ state, 4.445 MeV) at energies 29, 40 and 50.5 MeV coupled channel method using different potential sets.

4. Summary

We have measured the angular distributions for the elastic and inelastic $5/2^-$ (4.45 MeV) scattering of ^4He from ^{11}B target at energy 29, 40 and 50.5 MeV. In addition to our experimental data at energy 29 MeV the elastic scattering of $^4\text{He}+^{11}\text{B}$ were studied at different energies from literature in order to clarify the position of Airy minimum and evolution of rainbow. The data on elastic scattering were analyzed using two approaches optical model (Phenomenological) and double folding (semi-microscopic). The data for the excited states were analyzed within the framework of coupled channel method, the extracted deformation parameters for $5/2^-$ state is in a good agreement with the experimental values.

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