International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:7, No:7, 2013

New Investigation of the Exchange Effects Role on the Elastic and Inelastic Scattering of α-Particles on ^{9}Be

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***Abstract*—**Elastic and inelastic scattering of α-particles by ^{9}Be nuclei at different incident energies have been analyzed. Optical model parameters (OMPs) of α-particles elastic scattering by ^{9}Be at different energies have been obtained. Coupled Reaction Channel (CRC) of elastic scattering, inelastic scattering and transfer reaction has been calculated using Fresco Code. The effect of involving CRC calculations on the analysis of differential cross section has been studied. The transfer reaction of (^{5}He) in the reaction ^{9}Be(α,^{9}Be)α has been studied. The spectroscopic factor of ^{9}Be≡α+^{5}He has been extracted.

***Keywords*—**Elastic scattering of α-particles, Optical model parameters, Coupled Reaction Channel, the transfer reaction of (^{5}He), the spectroscopic factor of ^{9}Be≡α+^{5}He.

I. Introduction

THE measurements of inelastic scattering of nucleons at the low energies on nuclei are very important information source regarding the parameters of deformation and densities distribution in the nucleus. Beryllium nucleus is one among the nuclei of 1p-shell relates to the most deformed nuclei. In this connection, since some of low-lying levels of these nuclei have the pronounced collective nature for this reason we will perform an analysis of experimental data on scattering of α-particles on ^{9}Be at Eα=50.5, 45, 40 and 18 MeV from literature.

It is known that by the interaction of the complex particles with light nuclei the specific effect called as an anomalous large-angle scattering (ALAS), which is impossible to explain in the framework of the standard optical model is often observed. The nature of this phenomenon can by different, but in certain cases for ^{6}Li and ^{7}Li targets, having the pronounced (α+d) and (α+t) cluster structure, increasing in angular distributions at large angle is observed. It is almost entirely connected with the transfer exchange mechanism, and superimposed on potential scattering [1]. The results of DWBA analysis of the transfer cross sections are typically highly sensitive to changing of the optical potential parameters. The calculated angular distribution of the nucleon transfer reaction can vary significantly even through the used OM parameters fit well the elastic scattering in the entrance and exit reaction channels. Moreover, different optical potential parameterizations can provide spectroscopic factors (SF) different up to factor 3. Consequently, it is very important to fix these values as long as is possible. The ability to extract the SF from transfer reaction data depends on the place of reaction, on the surface or more in the interior of the nucleus. It is common to obtain the empirical SF by direct comparison of theoretical calculations with the experimental data, fitting up to the first maximum of the angular distribution of the outgoing particles.

It has been pointed out that nuclear deformations may be expected to have magnitudes roughly equal to the number of particles outside closed shells divided by the total number of particles. Of all available nuclear targets, ^{9}Be is then expected to have the greatest quadrupole deformation. In the standard expression for the nuclear radius:

$$R=R_0(1+\beta_2 Y_{20}(\theta, \varphi))$$

β_2 is the deformation parameter of ^{9}Be [2].

II. Elastic Scattering Analysis of α-Particles on ^{9}Be Using Optical Model

Elastic scattering analysis was performed on the optical model using the phenomenological, which has a standard Woods-Saxon parameterization for the real and imaginary parts. In this model the influence of inelastic channels is accounted with introducing the imaginary part into phenomenological potential of interaction. The elastic scattering is described by complex potential with radial dependence in Woods-Saxon form:

$$U(r)=-Vf(x_V)-i\left[Wf(x_W)-4W_D a_D\frac{df}{dr}(x_d)\right]+V_C(r) \quad (1)$$

where $f(x_i)=(1+\exp(x_i))^{-1},\ x_i=(r-R_i)/a_i$

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$R_i = r_i A^{1/3}$, and V_C (r) is Coulomb potentialof uniformly charged spherewith radius ofR = 1.25 $A^{1/3}$ fm. Previous experience of studying the scattering of α-particles on nuclei of lithium clearly showed that the standard optical model cannot explain the behavior of cross sections at large angles. Therefore in the present study attempt had been made to get good description at large angles.

It was assumed that the potential scattering dominates in the forward hemisphere (θ<80-90o) and it is here carried out a fit. Found parameters of optical potentials describing the elastic scattering of α-particles on 9Be are shown in Table I.

TABLE I
OPTICAL PARAMETERS FOR α-PARTICLES ELASTICALLY SCATTERING BY ^{9}BE

E, MeV	set	*V*,MeV	r_V,fm	a_V,fm	*W*,MeV	r_W,fm	a_W,fm	J_V,Me·fm^3	J_W,MeV·fm^3	χ^2/N
50.5	A	81.05	1.389	0.731	33.41	1.051	1.084	371.2	139.1	31.66
	B	96.02	1.245	0.791	18.35	1.570	0.910	372.7	128.8	37.84
45	A	81.83	1.389	0.731	34.06	1.051	0.990	374.9	125.5	45.65
	B	95.50	1.245	0.791	16.79	1.570	0.910	370.6	120.1	17.82
40	A	91.07	1.389	0.731	44.23	1.051	0.849	403.9	121.5	18.52
	B	90.43	1.245	0.791	16.03	1.570	0.910	351.0	114.8	28.16
18.4	A	93.60	1.389	0.731	13.68	1.051	1.003	428.9	51.2	38.82
	B	104.5	1.245	0.791	6.55	1.570	0.910	405.6	53.6	32.78

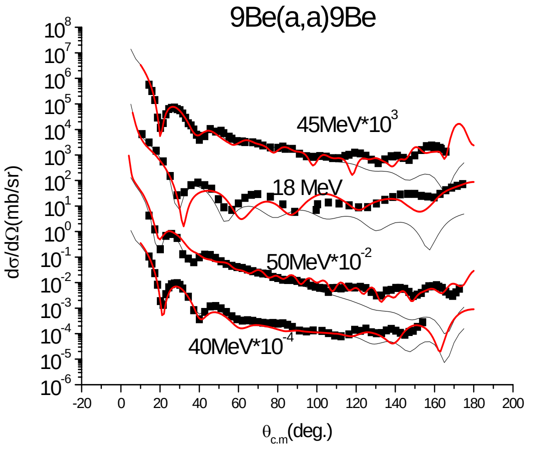

Fig. 1Comparison between experimental data and theoretical calculations using optical model, black lines are OMPs where red lines represent ^{5}He transfer

It is known that higher beam energy increase the sensitivity of the potential inside the nucleus which removes the discrete ambiguity. That is why the search for optimal potentials began with an analysis of experimental data at 50 MeV. At sufficiently high energies one can expect that the effects of exchange and transfer channels will be small and consequently, the potential scattering is pure [3], [4]. The optimal potential parameters describe well the experimental cross sections shown in Table I. They were starting the fit of the theoretical cross sections to experimental data obtained at energies of 18-50 MeV. All geometrical parameters were fixed and V and W were varied only. The results of the calculations are shownin Fig. 1. In this part we evaluate the mechanisms which may influence upon the cross sections of the ^{9}Be(α,^{9}Be)α reaction. Here we exclude from consideration the compound process as well as two-step processes, probability of which as expected will be small. So we consider, together with the elastic and inelastic scattering, only one-step reactions with transfer of the ^{5}*He*.The diagrams of these processes are displayed schematically in the Fig.2.

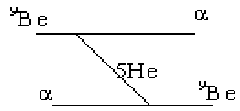

Fig. 2 Diagram of the 9Be (α, 9Be) α reaction and clusters exchange mechanism

All calculations by the CRC method were performed with the optical potentials parameters presented in the Table II. The extraction of spectroscopic factors in all calculations with FRESCO code was made.

TABLE II
OPTICAL POTENTIAL PARAMETERS OBTAINED FOR THE TRANSFER REACTION ^{9}BE(α,^{9}BE)α

E, MeV	*V*,MeV	r_V,fm	a_V,fm	*W*,MeV	r_v,fm	a_v,fm
50.5	76.37	1.453	0.73	27.01	1.306	1.012
45	79.39	1.453	0.71	29.26	1.306	0.89
	82.51	1.389	0.731	36.83	1.051	0.995
40	85.035	1.453	0.608	34.63	1.306	0.652
	81.83	1.389	0.731	34.06	1.051	0.990
18.4	103	1.453	0.824	20.44	1.306	0.757
	93.60	1.389	0.731	13.68	1.051	1.003

Deformation parameter of ^{9}Be and extracted spectroscopic factor of ^{9}Be≡^{5}He+α determined from the description of experimental data by CRC jointly with literature data are presented in Table III.

TABLE III
DEFORMATION PARAMETER AND SPECTROSCOPIC FACTOR OF 9BE

Nucleus	E_i(MeV)	Set OP	β_2	S-factor
^{9}Be	40.0 50.0	B (Table II)	0.6	1.25

According to the table, such combined analysis of experimental data has significantly allowed to restrict the spread of β_2 value for ^{9}Be nucleus [5].

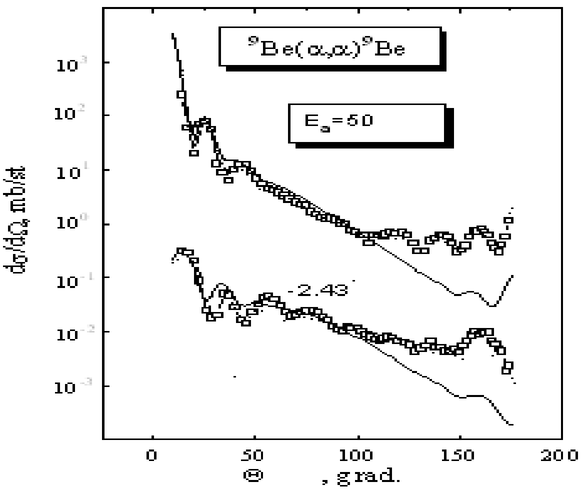

Fig. 3 Comparison between experimental data and theoretical calculations where dots represent experimental data and solid line is calculation

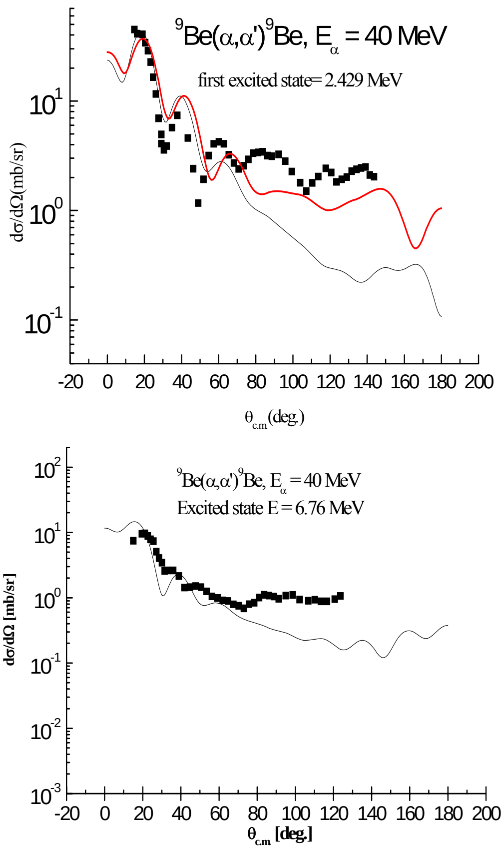

Fig. 4 Comparison between experimental data and theoretical calculations where dots represent experimental data and solid line is calculation

It was shown in [6] that the first excited state ½$^+$, 1.68 MeV of ^{9}Be located at ~ 15 keV above a neutron emission threshold and occupying the s-state might have abnormally large radius typical to neutron halos. This conclusion was drawn from the analysis of the ^{9}Be + α inelastic diffraction scattering at 35.5 MeV [2]. Elastic and inelastic scattering of α by ^{9}Be have been measured at 29 MeV in order to get independent confirmation of this result at *Institute of Nuclear Physics, Almaty, Kazakhstan*. The diffraction radii R_{dif} of the ^{9}Be states were extracted from the measured positions of the minima and maxima of the relevant angular distributions. The "real" (say, *rms*) radii R* of the excited states can be obtained [7] by adding the difference $[R_{dif}^* - R_{dif}(0)]$ to the *rms*radius of the ground state. The analysis of the measurements at 29MeV is taken place nowadays.The calculations will be published at near future. Energy spectra were measured by the Enge type magnetic spectrograph. A typical spectrum is shown in Fig. 1. The states of two cluster α + α + n rotational bands: $3/2^-(0.00)$ – $5/2^-(2.43)$ – $7/2^-(6.38)$ and $1/2^+(1.68)$ – $5/2^+(3.05)$ – $3/2^+(4.70)$, are seen. Analysis of all the data is not yet completed (May 2013).

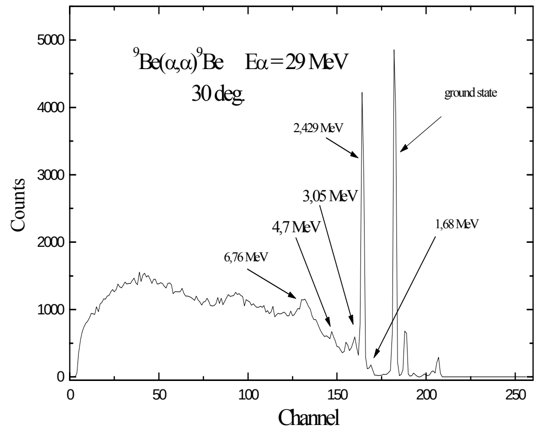

Fig. 5 Energy Spectrum of alpha elastically scattered by ^{9}Be at 30 degree

III. Conclusion

Elastic scattering of alpha-particles by ^{9}Be nuclei at $E_α$ = 18, 40, 45 and 50MeV have been analyzed. New sets of OMPs have been obtained as shown in TablesI and II. Coupled reaction channel CRC method has been used allowing the angular distributions description of ^{4}He scattered on ^{9}Be nuclei over the total angular range. The difference between two OMPs sets appear as a result from Coupled Reaction Channel. As regards to data on α-particles scattering on these nuclei, there is occurred a significant improvement of description in the range of intermediate angles in comparison when coupled reaction channel is neglected.

References

[1] N. Burtebayev, MarzhanNassurlla, MaulenNassurlla, Zh. K. Kerimkulov and S. B. Sakuta Optical Model Potential Parameters for p, d, ^{3}He and Alpha-Particle Scattering on Lithium Nuclei, American Institute of Physics (AIP) Conference Proceedings (2008) 203 -208.
[2] R.J. PETERSON, Nuclear Physics A377 (1982) 41-52.
[3] N. Burtebaev, A.D.Duisebaev, G. N. Ivanov, V. I. Kanaschevich, S. V.

Laptev, Izv.Akad.NaukKaz. SSR, ser. Fiz.-Mat.,No 4, 176 (1978)
[4] K. Baktybaev et al., Thesises of 50th Inter. Conf. On Nuc. Phys., Sankt-Peterburg, 326 (2000).
[5] N. Burtebaev, A.D.Duisebaev, B.A.Duisebaev G. N. Ivanov, R. J. Peterson, S. B. Sakuta,Inter. Nuc. Phys. Conf., August, 24-28, 1998,Paris, France, P.289.
[6] A.A.Ogloblin et al., AIP Conf. Proc. 1224 (2010) 100; Int. J. Modern Phys. E 20 (2011).
[7] A.N.Danilov et al., Phys. Rev.C 80, (2009) 054603.