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Analysis of the elastic scattering measured with a 23.7 MeV ^{7}Be beam on a ^{9}Be target

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Abstract. We present new data for the reaction ^{7}Be+^{9}Be measured at E_{lab} =23.7 MeV. The elastic scattering angular distribution has been analyzed using the phenomenological optical model and the coupled-channels method. In the latter approach, we assumed a two-cluster model of the ^{7}Be nucleus, and we included explicitly the ground state and first excited state of this nucleus. The contribution of the inelastic excitation of the ^{7}Be nucleus to the quasielastic cross sections has been investigated.

Keywords: Measured elastic scattering. Optical model. Coupled channels calculations.
PACS: 25.70.Bc,24.10.Ht,24.10.Eq

INTRODUCTION

Exotic nuclei are characterized by an excess of the number of protons or neutrons when compared with stable nuclei, a fact that give rise to very remarkable properties. The production and investigation of these nuclei are of great interest, because they can help to refine our theoretical nuclear models by taking into account not only the stable isotopes, but also the exotic nuclei existing in the universe. These nuclei mainly decay by beta particle emission leading to the known stable nuclei. Therefore, the formation of the chemical elements and its amounts are determined essentially by the exotic nuclear properties.

In this work, we present new data for the scattering of the exotic nucleus ^{7}Be from a ^{9}Be target. The experiment was performed at the CRC Radioactive Beam Facility at Louvain-la-Neuve, Belgium. This facility offers a possibility to explore light nuclei with a high quality beam of ^{7}Be, which was first produced using the ^{7}Li(p,n)^{7}Be reaction. The pellet was later used in an ECR ions source to produce a 27.5 MeV beam of ^{7}Be. The average intensity of the ^{7}Be beam was about 3×10^7pps on a 0.5 mg/cm^2 thick ^{9}Be target. The main motivation of this experiment was to study excited states in the unstable

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nucleus ^{8}Be, that should be populated in this reaction. In this work, we concentrate on the analysis of the elastic data. The analysis of the one-neutron transfer channel and a more detailed description of the experiment will be given in a separate publication [1].

THEORETICAL CALCULATIONS

Optical Model Calculations

The experimental angular distribution of the elastic cross section was first analyzed using phenomenological optical potentials. The objective of this analysis is twofold. First, the optical potential extracted for the elastic channel will be useful to analyze the transfer data leading to ^{8}Be states. This part of the analysis is still in progress and will be presented elsewhere [1]. Second, the optical model analysis permitted to determine the absolute normalization of the data (elastic and transfer), which could not be obtained from the experiment.

Since there are not data in the literature for this reaction at incident energies close to the present experiment, we considered three different optical potentials obtained for the similar system ^{9}Be+^{7}Li, at energies between 24 MeV and 34 MeV [2, 3]. All these potentials use standard Woods-Saxon shapes. An optimal fit analysis was carried out, in which the depths of the real (V_0) and imaginary (W) parts, as well as the normalization of the data (N), were varied freely to minimize the χ^2. These calculations were done with the subroutine SFRESCO, that it part of the FRESCO code [4]. The parameters obtained with this procedure are listed in Table 1 and the results are shown in Fig. 1. It can be seen that all three potentials reproduce satisfactorily the data, although potentials OM1 and OM2 seem to reproduce better the shape of the data. Moreover, the values obtained for the normalization of the data are consistent to each other within a 16% deviation. So, using the theoretical calculations it was possible to estimate in a reasonable way the absolute normalization of the data that was not possible to obtain from the experiment.

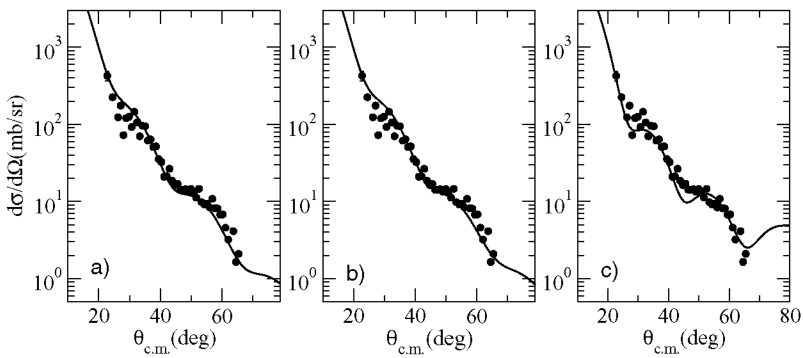

FIGURE 1. The ^{9}Be+^{7}Be elastic scattering angular distribution at E_{lab} = 23.7 MeV analyzed using the computer code SFRESCO. (a) OM1 set, (b) OM2 set, (c) OM3 set (see Table 1).

TABLE 1. Parameters obtained by automatic search for ^{9}Be+^{7}Be elastic scattering calculations. Reduced radii are converted into absolute radii as $R = r(7^{1/3} + 9^{1/3})$.

Set	V_0 (MeV)	r_0 (fm)	a_0 (fm)	W_0 (MeV)	r_i (fm)	a_i (fm)	W_D (MeV)	r_{iD} (fm)	a_{iD} (fm)	χ^2	Norm
OM1	48.6	1.28	0.88	-	-	-	13.13	1.86	0.78	36.4	37.9
OM2	12.1	2.30	0.57	7.51	2.71	0.79	-	-	-	41.3	40.0
OM3	573	1.05	0.67	6.89	2.11	0.89	-	-	-	20.9	33.3

Coupled Channel Calculations

The energy resolution of the present experiment did not allow to separate the contribution of the inelastic excitation of the first excited state of ^{7}Be ($E_x = 0.429$ MeV) from the elastic data. To estimate this contribution, we have performed coupled-channels calculations in which both the ground state and first excited state of ^{7}Be were explicitly included and coupled to all orders. In addition to this motivation, these calculations provided an additional check of the normalization of the data obtained with the optical model analysis. In this calculation, the ^{7}Be nucleus was considered as a two-body system (^{4}He+^{3}He), where the binding energy ^{3}He$-^7$Be is $E = 1.586$ MeV, and the projectile-target effective interaction was calculated from the internal wavefunction of the projectile and the fragment-target interactions as:

$$V_{ij}(\mathbf{R}) = \langle \phi_i | U_{[^3\mathrm{He}+^9\mathrm{Be}]}(\mathbf{R} + \frac{4}{7}\mathbf{r}) + U_{[\alpha+^9\mathrm{Be}]}(\mathbf{R} - \frac{3}{7}\mathbf{r}) | \phi_j \rangle \qquad (1)$$

where $\phi_i(\mathbf{r})$ is the wavefunction of the α+^{3}He relative motion in either the ground state ($i = 1$) or first excited state ($i = 2$). With this procedure the diagonal ($i = j$) as well as transition ($i \neq j$) potentials are calculated on the same footing. The coupling potentials (1) require cluster-target potentials ^{3}He+^{9}Be and α+^{9}Be, evaluated at about the beam velocity. These potentials were taken from Ref. [5].

The internal wavefunctions $\phi_i(\mathbf{r})$ were calculated using the potential model of Buck and Merchant [6]. This potential contains a central and a spin-orbit part, both of Gaussian geometry. The depths of both components were adjusted to reproduce simultaneously the separation energy of the ground and first excited states, assuming in both cases a pure $2P$ configuration for the relative motion.

The result of the coupled-channels calculations is shown in Fig. 2. The filled circles are the experimental data, with the normalization extracted with the optical potential OM1. The dashed and dotted lines correspond to the elastic and inelastic contributions, whereas the solid line is the total quasielastic cross section. The latter describes well the shape and normalization of the data. The absolute cross section provided by this calculation is fully consistent with the normalization obtained with the optical model analysis, which provides further confidence on this normalization. It can be seen also that the inelastic scattering contribution is very small, at least within the angular range of the present data.

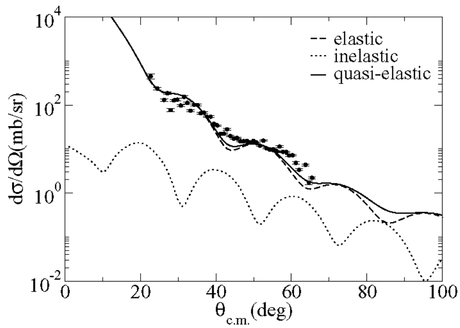

FIGURE 2. Elastic and inelastic scattering calculated within the coupled-channels method, assuming a cluster model for the ^{7}Be nucleus.

SUMMARY AND CONCLUSIONS

New data for the reaction ^{7}Be+^{9}Be, measured at 23.7 MeV at the CRC at Louvain-la-Neuve, have been presented and analyzed. The angular distribution for the elastic cross section has been analyzed in terms of the optical model and coupled-channels methods. We have obtained appropriate optical potentials for this system, using as starting point existing potentials for the nearby system ^{9}Be+^{7}Li, at energies between 24 MeV and 34 MeV. The experimental resolution did not allow to separate the data of elastic scattering from the data of inelastic scattering corresponding to the first excited state of ^{7}Be (E_x=0.4291 MeV). Coupled-channels calculations indicate that the contribution of the inelastic cross section to the quasielastic data is only significant above 60 degrees. The good agreement between optical model and coupled-channels calculations provide a good support of the absolute normalization obtained for the data. This information will be very important for the analysis of the transfer data. This work is underway [1].

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