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Some Insights into Cluster Structure of ^{9}Be from ^{3}He + ^{9}Be Reaction

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Abstract

The study of inelastic scattering and multi-nucleon transfer reactions was performed by bombarding a ^{9}Be target with a ^{3}He beam at the incident energy of 30 MeV. Angular distributions for ^{9}Be(^{3}He, ^{3}He)^{9}Be, ^{9}Be(^{3}He, ^{4}He)^{8}Be, ^{9}Be(^{3}He, ^{7}Be)^{5}He, ^{9}Be(^{3}He, ^{6}Li)^{6}Li and ^{9}Be(^{3}He, ^{7}Li)^{5}Li reaction channels were measured. Experimental angular distributions for the corresponding ground states (g.s.) were analyzed within the framework of the optical model, the coupled-channel approach and the distorted-wave Born approximation. Cross sections for channels leading to unbound ^{5}He$_{g.s.}$, ^{5}Li$_{g.s.}$ and ^{8}Be systems were obtained from singles measurements where the relationship between the energy and the scattering angle of the observed stable ejectile was constrained by two-body kinematics. Information on the cluster structure of ^{9}Be was obtained from the transfer channels. It was concluded that cluster transfer was an important mechanism in the investigated nuclear reaction channels. In the present work an attempt was made to estimate the relative strengths of the interesting (n + ^{8}Be) and (α + ^{5}He) cluster configurations in ^{9}Be. The contributions of different exit channels have been determined confirming that the (α + ^{5}He) configuration plays an important role. The configuration of ^{9}Be consisting of two bound helium clusters (^{3}He + ^{6}He) is significantly suppressed, whereas the two-body configurations (n + ^{8}Be) and (α + ^{5}He) including unbound ^{8}Be and ^{5}He are found more probable.

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Keywords

Nuclear Reaction Mechanism, Cluster Structure, DWBA

1. Introduction

In recent years the study of light radioactive nuclei [1] [2] has intensified due to the significant progress made with radioactive beam facilities. It has led to a decrease of interest in the study of light stable nuclei such as ^{6,7}Li and ^{9}Be. It has been shown that in light nuclei the nucleons tend to group into clusters, the relative motion of which defines to a large extent the properties of these nuclei. Consequently, the cluster structure of their ground as well as low-lying excited states became the focus of theoretical and experimental studies. For example, ^{6}Li and ^{7}Li nuclei are both well described by the two-body cluster models (($\alpha + d$) and ($\alpha + t$), respectively).

Due to its Borromean structure, a special attention has been focused on the ^{9}Be nucleus, which may break up directly to $\alpha + \alpha + n$ or via one of two unstable intermediate nuclei: ^{8}Be or ^{5}He.

The breakup of ^{9}Be via ^{8}Be$_{g.s.}$ has been measured for many of the low-lying excited states of ^{9}Be [3] [4]. However, the breakup branching via the first-excited 2^{+} state of ^{8}Be and via ^{5}He remained uncertain.

The three-body configuration ($\alpha + \alpha + n$) of ^{9}Be may be of a significant astrophysical interest. The short lifetimes of ^{8}Be$_{g.s.}$, the first-excited state of ^{8}Be and ^{5}He$_{g.s.}$ suggest that the sequential capture of a neutron or an α particle is very unlikely. The formalism used to derive the ($\alpha\alpha n$) rate by Grigorenko *et al.* [5] also suggested that any broad intermediate resonances would have little effect on the ($\alpha\alpha n$) rate. However, according to another theoretical calculation [6] the stellar reaction rate for this reaction proceeding via the ^{5}He$_{g.s.}$ channel is significant for the formation of ^{9}Be.

In the measurement [7] of the ^{9}Be(^{7}Li, ^{7}Liα)αn reaction it was unambiguously established for the first time that the excited states of ^{9}Be around 6.5 and 11.3 MeV decayed into the α + ^{5}He channel.

In Ref. [8], the structure of ^{9}Be was discussed in the frame of isobaric analogue states of ^{9}B. It was found that the decay of ^{9}B had the dominant branch α + ^{5}Li implying that "the corresponding mirror state in ^{9}Be would be expected to decay through the mirror channel α + ^{5}He, instead of through the n + ^{8}Be(2^{+}) channel. The mirror state of ^{9}Be at 2.429 MeV is also reported to decay by α emission". In this case it would decay to the unstable ground state of ^{5}He producing the $n + 2\alpha$ final state. On the contrary, another experimental work claimed that this state decayed almost exclusively by n emission to the unstable first-excited state of ^{8}Be.

The excited states of ^{9}Be have been populated in various ways including among others β-decay [9]. Most experiments confirm that the 2.429 MeV state has a branching ratio to the ^{8}Be$_{g.s.}$ + n channel of only 7%, but could not determine whether the remaining strength is in the ^{8}Be(2^{+}) + n or the ^{5}He + α channel. However, it was reported in Ref. [9] that the ratio 2:1 could be assigned to these channels, respectively.

The results of Refs. [3]-[5] [7] [8] along with the qualitative breakup data discussed above suggest the necessity of obtaining quantitative branching-ratio data for the low-lying states in the Borromean nucleus ^{9}Be.

The present experiment was designed to study the breakup of ^{9}Be in the attempt to determine the contribution of ^{5}He + α and n + ^{8}Be channels. Our data are based on inclusive measurements, whereas the experimental results of Refs. [3] [4] were obtained in exclusive measurements. The exclusive measurements require fully defined kinematics with complicated detector systems allowing the complete reconstruction and identification of the breakup event. The inclusive measurements, in spite of their simplicity, may also be useful in the study of clustering phenomena. For example, in our recent paper [10] the obtained large value of the deformation parameter might be considered as the confirmation of the cluster structure of the low-lying states of ^{9}Be. However, the inclusive measurement did not allow us to give unambiguous preference to one of the possible configurations, e.g. ($\alpha + \alpha + n$) or (α + ^{5}He).

Another purpose of the present study was the attempt to obtain some information about the cluster structure of ^{9}Be and try to understand how the cluster structure influenced the nuclear reaction mechanism.

Indeed, Détraz *et al*. [11] [12] argued that multi-particle-multi-hole structures were expected to occur at rather low excitation energies in nuclei. Therefore, four-nucleon transfer reactions have been extensively studied. It is hoped that the major features of such reactions, in spite of the a priori complexity of such a transfer, may be understood assuming that the nucleons are transferred as a whole, *i.e.* strongly correlated in the cluster. The angular distributions of the ^{9}Be(^{3}He, ^{7}Be)^{5}He and ^{9}Be(^{3}He, ^{6}Li)^{6}Li reaction channels were scrupulously measured at the energy of 60 MeV for the transitions to the ground states of ^{5}He and ^{6}Li by Rudchik *et al*. [13]. The experimental data were analyzed using the coupled reaction channels (CRC) model including one- and two-step cluster transfer and cluster spectroscopic amplitudes calculated in the framework of the translation-invariant shell model. It was concluded that the cluster transfer was unimportant: in the ^{9}Be(^{3}He, ^{7}Be)^{5}He reaction channel the α-transfer dominated only at small angles while the transfer of two neutrons dominated at large angles. Nevertheless, the conclusion of Ref. [13] in general supports the idea of cluster transfer.

2. Experimental Procedure

The ^{3}He + ^{9}Be experiments were performed at the K130 Cyclotron facility of the Accelerator Laboratory of the Physics Department of Jyväskylä University and at the Nuclear Physics Institute (NPI), Řež, Czech Republic. The ^{3}He beam energy was 30 MeV. The average beam current during the experiments was maintained at 10 nA. The self-supporting Be target was prepared from a 99% pure thin foil of beryllium. The target thickness was 12 μm. Peaks due to carbon and oxygen contaminations were not observed in the energy spectra.

To measure (in) elastically scattered ions four Si-Si(Li) telescopes each consisting of ΔE_0, ΔE and E_r detectors with thicknesses 10 μm, 100 μm and 3 mm, respectively, were used. Each telescope was mounted at the distance of 45 cm from the target. Particle identification was based on the measurements of energy loss ΔE and residual energy E_r (the so-called ΔE-E method). The telescopes were mounted on rotating supports, which allowed to obtain data from $\theta_{lab} = 18^\circ$ to $\theta_{lab} = 107^\circ$ in steps of 1˚ - 2˚. The overall energy resolution of the telescopes was ~200 keV. The two-dimensional plots energy loss ΔE vs. residual energy E_r and ΔE_0 vs. ΔE are shown in **Figure 1(a)** and **Figure 1(b)**, respectively. The excellent energy resolutions of both ΔE and E_r detectors allowed unambiguous identification of *A* and *Z* of each product. The panel (a) is mainly related to the transfer from the projectile to the target, whereas the panel (b) is completely related to the transfer from the target to the projectile.

Figure 2 shows experimental spectra of the total deposited energy for the detected ^{4}He, ^{7}Be and ^{7}Li, measured at $\theta_{lab} = 18^\circ$ for the reaction ^{3}He (30 MeV) + ^{9}Be. The plotted total energies were calculated as the sum of the calibrated energy losses ΔE and the residual energy E_r. The ground and the most populated excited states of ^{8}Be, ^{5}He and ^{5}Li in the reaction channels ^{9}Be(^{3}He, ^{4}He)^{8}Be, ^{9}Be(^{3}He, ^{7}Be)^{5}He and ^{9}Be(^{3}He, ^{7}Li)^{5}Li were unambiguously identified.

Since ^{8}Be, ^{5}He, and ^{5}Li are unbound nuclei and decay into ^{4}He + ^{4}He, ^{4}He + *n* and ^{4}He + *p*, respectively, we calculated the positions in the measured spectra (**Figure 2**) of the maximum energies of ^{4}He, ^{7}Li and ^{7}Be, assuming either two bodies or three bodies in the exit channels. Calculations were performed with the aid of the NRV server [14]. The solid arrows show the maximum values of the kinetic energies of the detected ^{4}He, ^{7}Be and ^{7}Li, which correspond in the case of ^{4}He, ^{7}Be and ^{7}Li, to the two-body character of the reaction in the exit channels: ^{9}Be(^{3}He, ^{4}He)^{8}Be, ^{9}Be(^{3}He, ^{7}Be)^{5}He and ^{9}Be(^{3}He, ^{7}Li)^{5}Li, respectively. The maximum values of the

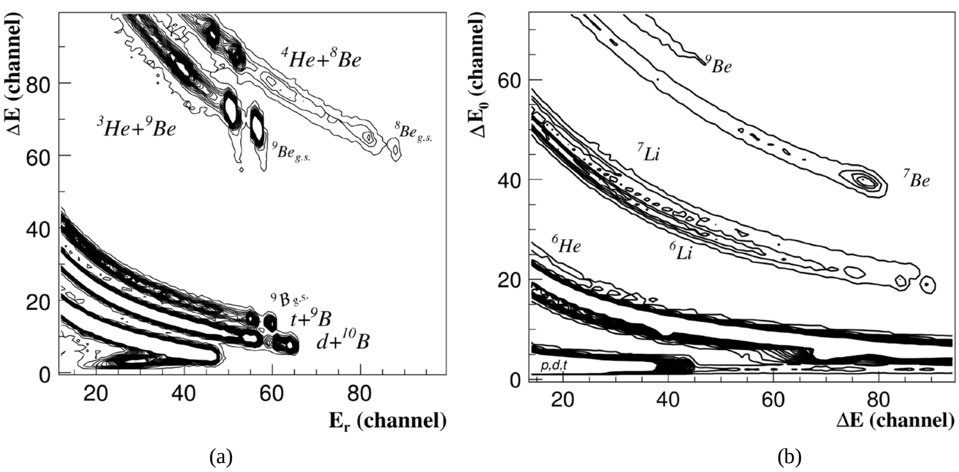


Figure 1. Particle identification plots for the products of the ^{3}He (30 MeV) + ^{9}Be reaction: (a) *p*, *d*, *t* and ^{3,4}He; (b) ^{6}He, ^{6,7}Li and ^{7,9}Be. ΔE is the energy loss and E_r is the residual energy. The loci for the products are indicated.

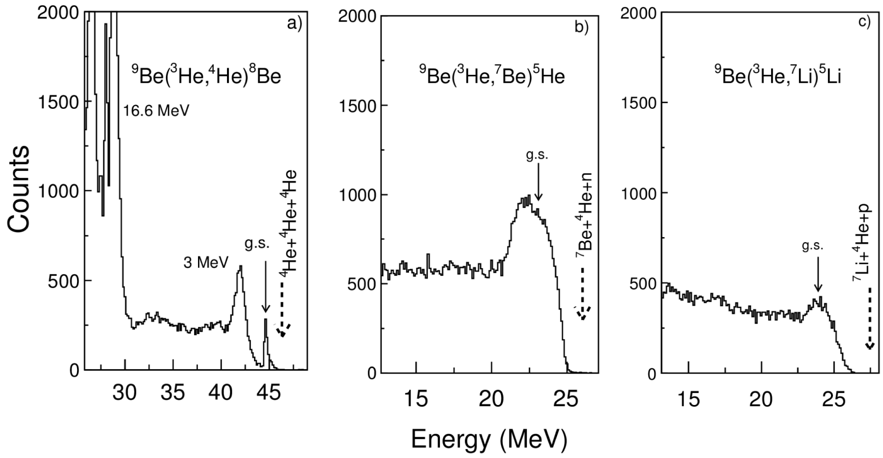


Figure 2. Spectra of the total deposited energy for the detected ^{4}He (a), ^{7}Be (b) and ^{7}Li (c), measured at $\theta_{lab} = 18^\circ$ for the reaction ^{3}He (30 MeV) + ^{9}Be.

kinetic energies in the case of three-body final states in the reaction channels ^{9}Be(^{3}He, ^{4}He + ^{4}He)^{4}He, ^{9}Be(^{3}He, ^{7}Be)^{4}He + *n* and ^{9}Be(^{3}He, ^{7}Li)^{4}He + *p* are shown by the dashed arrows. As can be seen from **Figure 2**, the local maxima at the g.s. are close to the values corresponding to the two-body exit channels in all studied reaction channels. This indicates that the two-body reaction channels dominate leading to the unbound ^{8}Be, ^{5}He and ^{5}Li in their ground states. Therefore, it may certainly be concluded that one-step multi-nucleon transfer is the main reaction mechanism leading to the binary exit channels.

The broad ground state of ^{5}He in the spectrum is overlapping with the ground and first-excited states of ^{7}Be, which explains why the peak is rather broad (FWHM ~1.5 MeV). In the case of ^{5}Li (**Figure 2(c)**) the ground state in not really prominent showing a larger value of FWHM than in the case of ^{5}He. It might indicate that ^{5}Li is a more loosely bound nucleus than ^{5}He due to the Coulomb repulsion of the additional proton from the α core.

3. Results

3.1. Elastic and Inelastic Scattering

The measured angular distributions for the reaction channels: (a) ^{3}He + ^{9}Be → ^{7}Be + ^{5}He (♦), ^{3}He + ^{9}Be → ^{7}Li$_{g.s.}$ + ^{5}Li (□), ^{3}He + ^{9}Be → ^{6}Li + ^{6}Li$_{g.s.}$ (▲), ^{3}He + ^{9}Be → ^{4}He + ^{8}Be$_{g.s.}$ (Δ), ^{3}He + ^{9}Be → ^{6}He + ^{6}Be$_{g.s.}$ (●); (b) ^{3}He + ^{9}Be → ^{4}He + ^{8}Be$_{g.s.}$ (Δ), 3.0 MeV (■) and 16.6 MeV (*) excited states of ^{8}Be are shown in **Figure 3**.

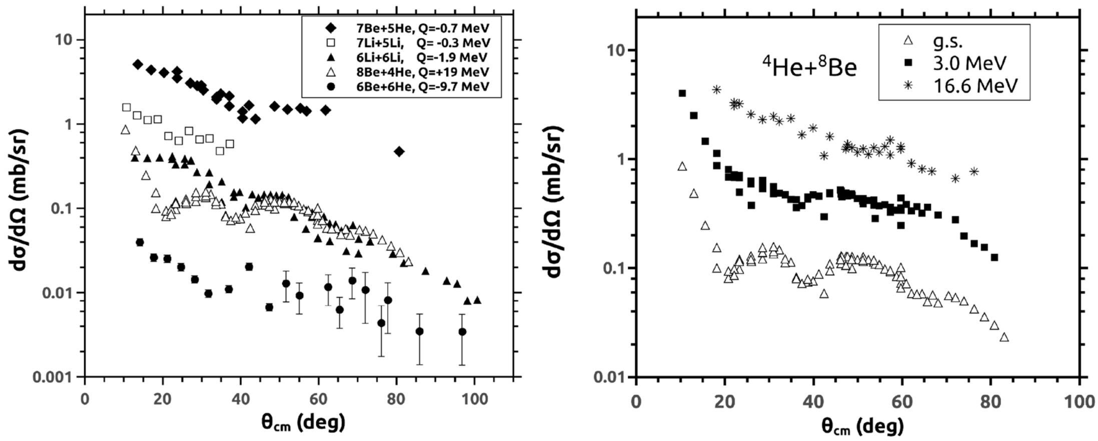
First of all, one may notice that the cross section for the case of ^{7}Be + ^{5}He is much larger than for the other reaction channels shown in **Figure 3**.

The ^{7}Be energy spectrum (**Figure 2(b)**) indicates the large probability of population of the ground state of the ^{5}He nucleus in conjunction with the 3$^-$ ground state and the 1/2$^-$ first-excited (0.429 MeV) state of ^{7}Be (unresolved in the present experiment). Therefore, the angular distribution for the ^{7}Be + ^{5}He (♦) channel corresponds to the ground state and the first-excited state of ^{7}Be.

As it was mentioned, this exit channel of the reaction has the largest cross section among the channels shown in **Figure 3(a)**. The calculated *Q*-values of the investigated channels are given in the inset of **Figure 3(a)**. It may be seen that the behavior of the cross sections does not strictly follow the famous *Q*-reaction systematics. For instance, the measured differential cross section for the channel ^{4}He + ^{8}Be$_{g.s.}$ with the maximum value of Q = +19 MeV is much less than for the channel ^{5}He + ^{7}Be ($Q = -0.7$ MeV). The lowest cross section was observed for ^{6}He + ^{6}Be$_{g.s.}$ ($Q = -9.7$ MeV).

Figure 3(b) shows the angular distributions for the ^{4}He + ^{8}Be channel populating the g.s. as well as the 3.0 MeV and 16.6 MeV excited states. It seems that the high positive *Q*-value (19 MeV) for this channel allows to excite very high-lying levels in the unbound ^{8}Be nucleus. It is clear that for this channel the cross section corresponding to the 16.6 MeV level dominates over the others.

In order to describe various reaction channels within the coupled-channel (CC) framework special attention was paid to the elastic scattering to obtain the optical model (OM) potentials. The OM potential was chosen



(a) (b)

Figure 3. Angular distributions for (a) ^{3}He + ^{9}Be → ^{5}He + ^{7}Be (♦), ^{3}He + ^{9}Be → ^{5}Li + ^{7}Li$_{g.s.}$ (□), ^{3}He + ^{9}Be → ^{6}Li + ^{6}Li$_{g.s.}$ (▲), ^{3}He + ^{9}Be → ^{4}He + ^{8}Be$_{g.s.}$ (Δ), ^{3}He + ^{9}Be → ^{6}He + ^{6}Be$_{g.s.}$ (●); (b) ^{3}He + ^{9}Be → ^{4}He + ^{8}Be$_{g.s.}$ (Δ), 3.0 MeV (■) and 16.6 MeV (*) excited states of ^{8}Be.

in the usual Woods-Saxon form $V(r) = -V_0 f(r, R_v, a_v) - iW_0 f(r, R_w, a_w)$, where the function $f(r, R, a) = (1 + e^{(r-R)/a})^{-1}$ and radii $R_i = r_i A^{1/3}$ depend on the mass of the heavier fragment A and the corresponding reduced radius r_i. In addition, a spin-orbit potential with a Woods-Saxon form has been used.

In the first step, the experimental data for the elastic scattering of ^{3}He + ^{9}Be were fitted. The obtained OM potential parameters are listed in **Table 1** in comparison with the parameters of Ref. [13]. The results of fitting are shown in **Figure 4** together with the experimental data.

The difference between the obtained parameters and those of Ref. [13] is probably due to the different projectile energies: our data were obtained at 30 MeV and the data of Ref. [13] were obtained at 60 MeV. For instance, the depths of the real and imaginary parts are smaller at the lower incident energy, whereas the radii are larger than those of Ref. [13]. Concerning the ^{9}Be(^{3}He, ^{5}He)^{7}Be reaction channel, the OM parameters of both sets do not reflect any possible peculiarities which might be expected due to the unbound nature of ^{5}He$_{g.s.}$ (for example, a larger radius of this unbound nucleus considered as the candidate for one-neutron halo structure).

In the second step of the data analysis, the cross section for the channel ^{9}Be(^{3}He, ^{4}He)^{8}Be$_{g.s.}$ was fitted and the OM potential parameters for the exit channel ^{4}He + ^{8}Be were obtained. In the fitting process, the OM potential parameters for the elastic scattering of ^{3}He + ^{9}Be obtained in the first step were used.

In the third step, the cross section for the transfer reactions ^{9}Be(^{3}He, ^{7}Be)^{5}He was fitted and the OM potential parameters for the exit channel ^{7}Be + ^{5}He were obtained (**Table 1**). In the fitting process, the OM potential parameters for the elastic scattering of ^{3}He + ^{9}Be obtained in the first step were used. In the calculations of the total cross section both transition amplitudes corresponding to the alpha-transfer mechanism (^{9}Be(^{3}He, ^{7}Be)^{5}He channel) and the 2*n*-transfer mechanism (^{9}Be(^{3}He, ^{7}Be)^{5}He channel) have been taken into account. All calculations and fitting have been performed using the FRESCO code [15] in the framework of the CC method.

By fitting the experimental angular distributions the attempt was made to determine which reaction mechanisms are the most important for the measured distributions. The results are shown in **Figure 5** for the following channels (a) ^{3}He + ^{9}Be → ^{4}He + ^{8}Be$_{g.s.}$ (Δ), (b) ^{3}He + ^{9}Be → ^{7}Be + ^{5}He (♦) and (c) ^{3}He + ^{9}Be → ^{6}Li + ^{6}Li$_{g.s.}$ (▲).

It is clear that in the case of ^{3}He + ^{9}Be → ^{7}Be + ^{5}He reaction channel the α-transfer (long-dashed curve) dominates at forward angles, whereas the transfer of the two neutrons (short-dashed curve) dominates at backward angles.

The fit for ^{3}He + ^{9}Be → ^{6}Li + ^{6}Li (solid curve) was obtained assuming *t* transfer from the target nucleus to the projectile. A good agreement between the experimental data and the calculations is observed. A similar situation may be expected for the case of ^{3}He + ^{9}Be → ^{7}Li + ^{5}Li where *d* transfer dominates. All the values of the spectroscopic amplitudes are taken from [13].

As could be seen from **Figure 5**, the main processes describing the angular distributions of the exit channels ^{4}He + ^{8}Be$_{g.s.}$, ^{7}Be + ^{5}He and ^{6}Li + ^{6}Li$_{g.s.}$ are, respectively, the neutron, α and *t* transfer from the target nucleus to the projectile.

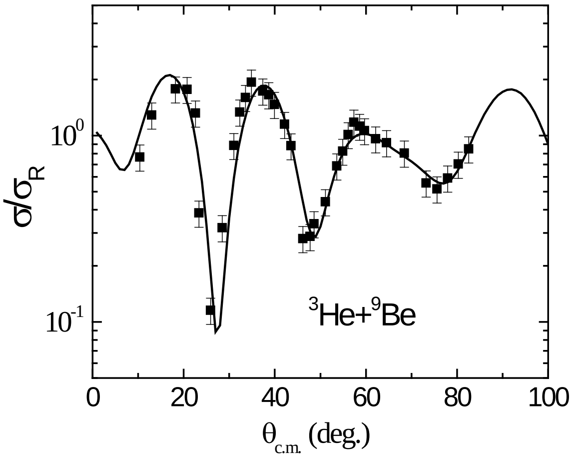


Figure 4. The ratio of the measured elastic scattering cross section to the Rutherford cross section for ^{3}He (30 MeV) + ^{9}Be at the incident energy 30 MeV in comparison with the OM fit.

Table 1. OM potential parameters used within the optical model and the CC approach for the reaction ^{3}He (30 MeV) + ^{9}Be in comparison with the parameters of Ref. [13].

Reaction channel	V_0 [MeV]	r_v [fm]	a_v [fm]	W_0 [MeV]	r_w [fm]	a_w [fm]	V_{so} [MeV]	r_{so} [fm]	a_{so} [fm]
^{3}He + ^{9}Be	108.5	1.123	0.54	15.69	1.15	0.855	13.63	1.83	0.4
^{3}He + ^{9}Be [13]	143.4	1.02	1.10	38.3	1.405	1.17			
α + ^{8}Be	90.98	1.382	0.404	12.36	1.01	0.4			
α + ^{8}Be [13]	143.4	1.024	1.35	38.3	2.539	1.67			
^{5}He + ^{7}Be	60.88	1.25	0.65	2.8	1.25	0.65	8.93	1.28	0.65
^{5}He + ^{7}Be [13]	122.5	0.9768	0.61	51.71	0.914	1.178			
^{6}Li + ^{6}Li	110.95	1.307	0.621	2.48	1.25	0.65	1.05	1.25	0.65
^{6}Li + ^{6}Li [13]	122.5	0.979	0.905	51.71	0.914	1.178			

3.2. Cluster Transfer in ^{3}He + ^{9}Be Reaction

Due to the Borromean structure of ^{9}Be the breakup of this nucleus may, in principle, proceed directly into two α particles plus a neutron or via one of the unstable intermediate nuclei: ^{8}Be or ^{5}He. The attempt was made to get some insights into (n + ^{8}Be), (^{4}He + ^{5}He), (d + ^{7}Li) and (t + ^{6}Li) cluster configurations inside of ^{9}Be and especially to estimate the relative strengths of the most interesting (n + ^{8}Be) and (^{4}He + ^{5}He) cluster configurations in ^{9}Be.

Most likely, the studied reaction channels result from the cluster transfer:

^{3}He + ^{9}Be → ^{3}He + (n + ^{8}Be) → (^{3}He + n) + ^{8}Be → ^{4}He + ^{8}Be → ^{4}He + ^{4}He + ^{4}He

^{3}He + ^{9}Be → ^{3}He + (α + ^{5}He) → (^{3}He + α) + ^{5}He → ^{7}Be + ^{5}He → ^{7}Be + ^{4}He + n

^{3}He + ^{9}Be → ^{3}He + (t + ^{6}Li) → (^{3}He + t) + ^{6}Li → ^{6}Li + ^{6}Li

^{3}He + ^{9}Be → ^{3}He + (d + ^{7}Li) → (^{3}He + d) + ^{7}Li → ^{5}Li + ^{7}Li → ^{4}He + p + ^{7}Li

^{3}He + ^{9}Be → ^{3}He + (^{3}He + ^{6}He) → (^{3}He + ^{3}He) + ^{6}He → ^{6}Be + ^{6}He.

These reaction channels are of specific interest since they provide direct information on the cluster structure of the initial and final states.

Based on the angular distributions, one may get some information about the strengths of cluster configurations in ^{9}Be. To obtain the contributions for the observed channels, the angular distributions were integrated over the solid angle. The values of the contributions were calculated as weighted integrals among the channels listed above. The obtained values are given in **Table 2**.

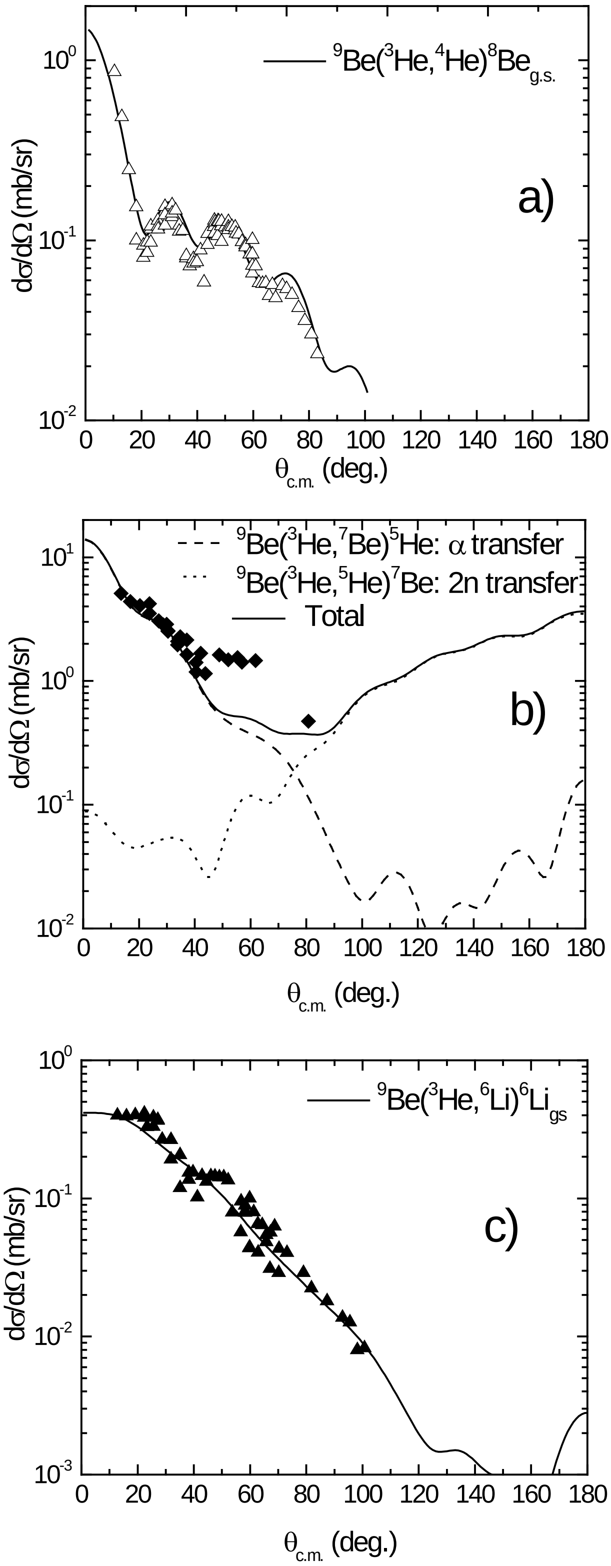


Figure 5. The angular distributions for (a) $^3He + ^9Be \rightarrow ^4He + ^8Be_{g.s.}$ (Δ), (b) $^3He + ^9Be \rightarrow ^5He + ^7Be$ (♦) and (c) $^3He + ^9Be \rightarrow ^6Li + ^6Li_{g.s.}$ (▲). Results of the optical-model and the coupled-channel calculations are shown by lines (see text).

The ratio of (n + ^{8}Be) to (α + ^{5}He) is 2.7:1, which is close to the ratio 2:1 given in Ref. [9] and contradicts the conclusion that the contribution of the (α + ^{5}He) configuration is negligible.

As for the conclusion of the more detailed experiments Refs. [3] [4] where measurements showed that the α + ^{5}He channel was not important for their consideration of the low-lying excited states of ^{9}Be, the discrepancy may be explained from the experimental point of view. Our data are based on inclusive measurements, whereas the experimental results of Refs. [3] [4] are based on exclusive measurements. The latter always requires fully defined kinematics allowing the complete reconstruction and identification of events. The values of the branching ratio given in Refs. [3] [4] were corrected by the geometrical detector efficiency obtained using a special simulating code.

Additionally, it should be noted that the values of the branching ratios given in Refs. [3] [4] are assigned especially to the excited states, whereas our values of the contributions are associated entirely with ^{9}Be without assignment of the excited levels.

The direct triton pick-up process requires that ^{9}Be has the (^{6}Li + t) cluster configuration, which seems highly unlikely compared to the (α + α + n) configuration. Also, the interpretation of any (^{3}He, ^{6}Li) reaction in terms of triton pick-up requires that ^{6}Li has the (^{3}He + t) cluster configuration, which seems equally unlikely compared to the (α + d) configuration. It has been shown in Ref. [16] that for ^{6}Li the (^{3}He + t) configuration is only slightly less probable than the (α + d) configuration. Since such cluster configurations are not mutually exclusive, one cannot judge upon the relative importance of the (^{6}Li + t) cluster configuration of ^{9}Be without making careful cluster structure calculations. Indeed, the differential cross section for the ^{7}Li in the outgoing channel is higher than for the channel leading to ^{6}Li.

4. Conclusions

The angular distributions of the ^{9}Be(^{3}He, ^{3}He)^{9}Be, ^{9}Be(^{3}He, ^{7}Be)^{5}He, ^{9}Be(^{3}He, ^{7}Li)^{5}Li, ^{9}Be(^{3}He, ^{6}He)^{6}Be and ^{9}Be(^{3}He, ^{6}Li)^{6}Li reaction channels were measured and described within the framework of the optical model, the coupled-channel approach and the distorted-wave Born approximation.

The performed analysis of the experimental data shows that the potential parameters are quite sensitive to the exit channel and hence to the cluster structure of the populated states, which allows to make general observations and conclusions regarding the internal structure of the target and exit channel nuclei.

The experimental data for ^{3}He + ^{9}Be elastic scattering were fitted. The fitting parameters were obtained and compared with the results of the previous measurements. Then, the cross sections for the transfer reactions ^{9}Be(^{3}He, ^{4}He)^{8}Be$_{g.s.}$ and ^{9}Be(^{3}He, ^{7}Be)^{5}He were fitted.

The experiment was designed to study the breakup of ^{9}Be in the attempt to determine the contribution of the n + ^{8}Be and α + ^{5}He channels in the inclusive measurements. The ratio 2.7:1 may be assigned to the contributions of these two channels, respectively. The determined contributions confirm that the ^{5}He + α breakup channel plays an important role. The inclusive experimental method used has the advantage of its experimental simplicity in comparison with the exclusive one.

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Table 2. Contribution of the observed exit channels and the corresponding cluster configurations in the ^{9}Be nucleus.

Exit channel	^{9}Be cluster configuration	Contribution (%)
^{4}He + ^{8}Be	(n + ^{8}Be)	68.7 ± 10
^{5}He + ^{7}Be	(α + ^{5}He)	25.1 ± 5
^{6}Li + ^{6}Li$_{g.s.}$	(t + ^{6}Li)	3.3 ± 2
^{5}Li + ^{7}Li$_{g.s.}$	(d + ^{7}Li)	2.7 ± 2
^{6}Be + ^{6}He$_{g.s.}$	(^{3}He + ^{6}He)	0.2 ± 0.7

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