ҚАЗАҚСТАН РЕСПУБЛИКАСЫ БІЛІМ ЖӘНЕ ҒЫЛЫМ МИНИСТРЛІГІ
Л.Н. ГУМИЛЕВ АТЫНДАҒЫ ЕУРАЗИЯ ҰЛТТЫҚ УНИВЕРСИТЕТІ

ЕУРАЗИЯ ҰЛТТЫҚ УНИВЕРСИТЕТІ

ЖАС ҒАЛЫМДАР КЕҢЕСІ

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СБОРНИК МАТЕРИАЛОВ XI Международной научной конференции студентов и молодых ученых **«НАУКА И ОБРАЗОВАНИЕ - 2016»**

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2016 жыл 14 сәуір
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STATISTICAL CHARACTERISTICS OF NUCLEUS ^{9}BE IN THE EXCITED STATES

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Nowadays research of light nuclei is very important because of thermonuclear fusion. One of these nuclei is the nucleus of ^9Be. Beryllium is a good neutron moderator; also it has the property of a neutron reflector in nuclear reactors and the main property of this nucleus is a neutron generation. In this section we are going to research statistical characteristics of the nucleus ^9Be in the excited states. We have used the wave function of ^9Be in the ground and excited states in the three-body 2αn model (with the αα-Ali-Bodmer potential) [1].

The RMS charge radius of ^9Be

The root mean square charge radius of ^9Be in a cluster model can be found from the calculated by us formula:

$$\left\langle r_{ch}^2 \right\rangle = \left\langle r_{ch}^2(\alpha) \right\rangle + \frac{1}{4}\left\langle x_1^2 \right\rangle + \frac{1}{81}\left\langle y_1^2 \right\rangle, \tag{1}$$

where $\left\langle r_{ch}^2(\alpha) \right\rangle$- the mean charge radius of α-particle (1,6757 fm [2]), $\left\langle x_1^2 \right\rangle$ and $\left\langle y_1^2 \right\rangle$ - matrix elements in Jacobi coordinates (x_1, y_1), which define the mean square separation of 2 α-particles and the separation of neutron from the center of mass of these 2 α-particles respectively (Jacobi coordinates (x_1, y_1) are illustrated in fig. 1.).

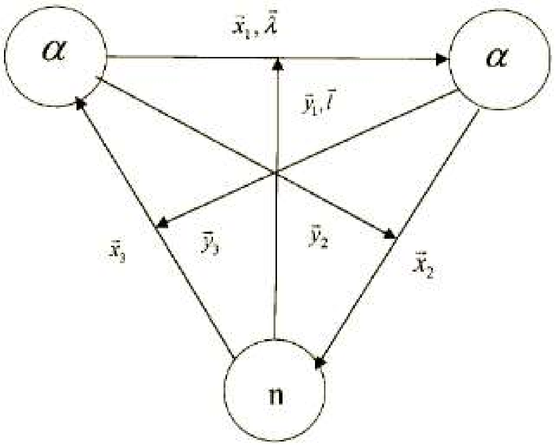

Fig. 1. Linear scheme of ^9Be in the 2αn model. x_i, y_i – Jacobi coordinates.

The value of the rms charge radius $\langle r_{ch}^2 \rangle^{1/2} = 2{,}52$ fm doesn't indicate the halo structure in ^9Be in its ground state, but in the excited states ($J^\pi = 1/2^+, 3/2^+, 5/2^+, 1/2^-$) the rms radii are greater: 2,84 fm, 3,18 fm, 3,12 fm and 3,04 fm respectively (see fig. 2.). In consequence of being excited, this nucleus increases its form and size, changes its structure to the halo. In this case neutron moves away from the center of mass of 2 α-particles (the wave function of ^9Be in its excited states drops to zero at $y_1 = 12$-18 fm [3]).

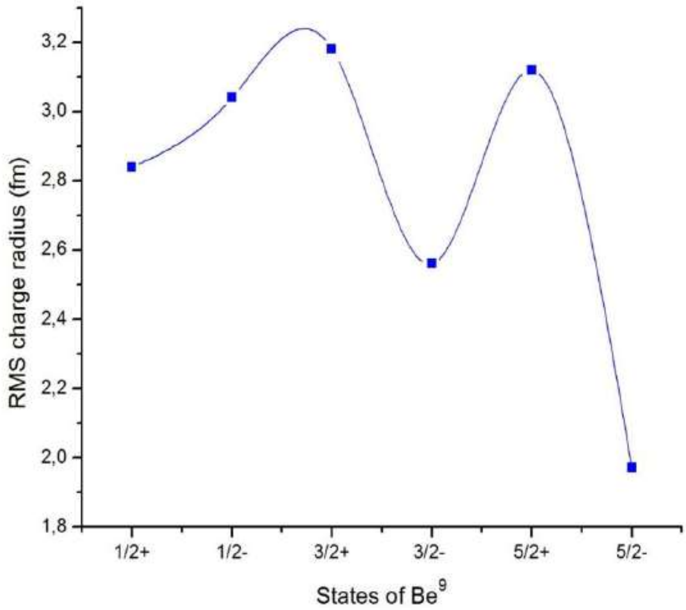

Fig. 2. The RMS charge radii of ^9Be in its ground and excited states.

The quadrupole moment of ^9Be

The quadrupole moment of ^9Be have been calculated by the next formula:

$$Q = 32\sqrt{6}Z_{\alpha}\frac{\langle JJ20|JJ\rangle}{\sqrt{[J]}}\sum_{\substack{ij\lambda l\\ i'j'\lambda'l'}} C_{ij}^{(\lambda l)}C_{i'j'}^{(\lambda'l')}\sum_{\varepsilon_1\varepsilon_2}\delta_{\varepsilon_1+\varepsilon_2.2}\left(\frac{1}{2}\right)^{\varepsilon_1}\left(\frac{1}{9}\right)^{\varepsilon_2}\frac{\left[1+(-1)^{\varepsilon_1}\right]}{2\sqrt{[\varepsilon_1]![\varepsilon_2]!}}\times \tag{2}$$

$$\times I\left(x_1^{\varepsilon_1-2},\alpha\right)I\left(y_1^{\varepsilon_2-2},\beta\right)\langle(\lambda'l')L'S':J\left\|\left[Y_{\varepsilon_1}(\hat{x}_1)\otimes Y_{\varepsilon_2}(\hat{y}_1)\right]^2\right\|(\lambda l)LS:J\rangle,$$

where Z_{α} - the electric charge of α-particle, $I\left(x_1^{\varepsilon_1-2},\alpha\right), I\left(y_1^{\varepsilon_2-2},\beta\right)$ - the Gaussian integrals, α,β and $C_{ij}^{(\lambda l)}$ - coefficients of the Gaussian function of the ^9Be wave function's radial part.

^9Be is a stable nucleus that has an enormous deformation. Quadrupole moment in its ground state $Q=$52,6 mb, but in the excited states (levels $J^{\pi}=3/2^+, 5/2^+, 5/2^-$) this nucleus has quadrupole moments with negative value ($Q=$-1.055 mb,-10.9 mb, -9,9 mb respectively). This fact means that α-particles are attracted to each other strongly, in other words there is a neutron exchange between these 2 clusters.

The magnetic moment of ^9Be

The magnetic moment of ^9Be in a cluster model can be found from the calculated by us formula:

$$\vec{\mu} = 2\mu_n\vec{J} + \left(\frac{1}{2} - 2\mu_n\right)\vec{L} - \frac{4}{9}\vec{l} \tag{3}$$

where μ_n - the magnetic moment of a neutron, $\vec{J}$, $\vec{L}$, $\vec{l}$ - angular moments of ^9Be.

We have divided this formula into two parts:

$$\mu = M_1 + M_2. \tag{4}$$

where M_1 and M_2 are defined as follows:

$$M_1 = \sum_{k=1}^{m}\left[\left(\frac{1}{4}+\mu_n\right)J + \left(\frac{1}{4}-\mu_n\right)\frac{L_k(L_k+1)-S_k(S_k+1)}{J+1}\right]\cdot P_k \tag{5}$$

where P_k - statistical weights of the state's configurations.

$$M_2 = -\frac{4}{9}\sum_{\substack{ij\lambda l\\ i'j'\lambda'l'}} C_{ij}^{(\lambda l)}C_{i'j'}^{(\lambda'l')}\langle(\lambda'l')L'S':J\|l\cdot J\|(\lambda l)LS:J\rangle\times$$
$$\times I\left(x_1^2,\alpha\right)I\left(y_1^2,\beta\right). \tag{6}$$

The octupole moment of ^9Be

The octupole moment ^9Be is an abnormal property because this nucleus has only 4 charged particles (protons), but as a fact to have this characteristic a nuclear system must have 8 charged particles [4]:

$$\Omega_{oct} = -\sqrt{\frac{4\pi}{7}} \frac{\langle JJ30|JJ\rangle}{\sqrt{2J+1}} \left\langle \Psi^{tot}_{JM_J=J} \left| \hat{M}_{30} \right| \Psi^{tot}_{JM_J=J} \right\rangle$$

$$\left\langle \Psi^{tot}_{JM_J=J} \left| \hat{M}_{30} \right| \Psi^{tot}_{JM_J=J} \right\rangle = \frac{128}{81}\sqrt{21}\mu_0\mu_n \frac{\langle JJ30|JJ\rangle}{\sqrt{[J]}} \sum_{\substack{ij\lambda l \\ i'j'\lambda'l'}} C_{ij}^{(\lambda l)} C_{i'j'}^{(\lambda'l')} \times$$

$$\times I(x_1^2,a) I(y_1^4,\beta) \left\langle (\lambda'l')L'S':J \left\| \left[Y_2(\hat{r}_k)\times\hat{S} \right]_3 \right\| (\lambda l)LS:J \right\rangle + \quad (7)$$

$$+\frac{25}{81}\sqrt{21}\mu_0 \frac{Z_a m_N}{m_a} \frac{\langle JJ30|JJ\rangle}{\sqrt{[J]}} \sum_{\substack{ij\lambda l \\ i'j'\lambda'l'}} C_{ij}^{(\lambda l)} C_{i'j'}^{(\lambda'l')} \times$$

$$\times \sum_{L_1=0}^{\lambda} \sum_{L_2=0}^{l} \sum_{j_1,j_2} \sum_{L_3=0}^{\lambda'} \sum_{L_4=0}^{l'} \sum_{j_{31},j_4} \frac{\left[1+(-1)^{\lambda+\lambda'+n}\right]}{2} A_{\lambda l j_1 j_2}^{LL_1L_2Q_2} A_{\lambda'l'j_3j_4}^{L'L_3L_4Q_2} \times$$

$$\times J(\mu x') J(\omega y') < (j_3 j_4) L'S':J \left\| \left[Y_2(\hat{y}') \times \hat{l}(\vec{y}') \right]_3 \right\| (j_1 j_2) LS:J > .$$

The octupole moment of ^{9}Be is very important because it is proportional to the magnetic differential cross section of elastic scattering of electrons on this nucleus:

$$\left(\frac{d\sigma}{d\Omega}\right)_M = \frac{\alpha^2}{4M^2}\eta^{-2} \frac{1-\sin^2\left(\frac{\theta}{2}\right)}{\sin^4\left(\frac{\theta}{2}\right)} \frac{J+1}{3J}\mu^2 * \quad (8)$$

$$*\left[1+\frac{2}{1575}\frac{(J+2)(2J+3)}{(J-1)(2J-1)}q^4\left(\frac{\Omega_{oct}}{\mu}\right)^2+\ldots\right],$$

where $\eta = 1+2\varepsilon_1\sin^2\left(\frac{\theta}{2}\right)/M$, $\varepsilon_1 -$ energy of an electron, $\theta -$ the angle of scattering, $M -$ the mass of a nucleus, α – fine-structure constant, $\Omega_{oct} -$ the octupole moment of a nucleus.

In the excited states the octupole moment of ^{9}Be is far away more than in the ground state, that is why the cross section of electron scattering on excited ^{9}Be will be more than in the ground state too. So it is better to use this nucleus in the excited states for electron scattering (in this reaction ^{9}Be is a neutron generator).

Calculated results of ^{9}Be statistical characteristics are represented in Table 1:

Table 1. Statistical characteristics of ^{9}Be

State	$\sqrt{<R_{ch}^2>}$, Fm	μ/μ_0	Q, mb	Ω, $\mu_0 \cdot Fm^2$ (spin part)
$1/2^+$	2,84	-1,87	0	0
$3/2^+$	3,18	1,51	-1,055	21,35
$5/2^+$	3,12	-1,52	-10,9	-188,49
$1/2^-$	3,04	0,82	0	0

5/2⁻	1,97	-1,21	-9,9	4,86
3/2⁻ (the ground state)	2,56	-0,85	52,6	-5,97

Conclusions

1) The nucleus of ^{9}Be in the excited states changes its structure to the halo.

2) The halo structure of ^{9}Be defines the negative value of its quadrupole moment, so in comparison with the ground state this nucleus changes its form and type of deformation.

3) The octupole moment of ^{9}Be allows to define the magnetic differential cross section of elastic scattering of electrons on this nucleus.

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ОСОБЕННОСТИ ИЗМЕРЕНИЯ УПРУГОГО РАССЕЯНИЯ ПОД БОЛЬШИМИ УГЛАМИ

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В настоящей работе представлены результаты измерения сечений упругого рассеяния ^{84}Kr на ядре ^{27}Al при энергиях 84 и 123 МэВ. Также представлены результаты анализа функции возбуждения упругого рассеяния ^{16}O+^{40}Ca в области энергий 17-50 МэВ при обратных углах в рамках оптической модели.

Введение

Упругое рассеяние – это простейшая ядерная реакция между налетающим ядром и мишенью, которая обусловлена ядро-ядерным взаимодействием. Несмотря на простоту механизма, упругое рассеяние является важным источником информации о свойствах ядер [1].

Одной из сложных экспериментальных задач является измерение упругого рассеяния под большими углами. Для этого можно использовать метод обратной кинематики.

По сравнению с прямой кинематикой, метод обратной кинематики при релятивистских энергиях имеет ряд преимуществ для систематического измерения сечений. Во-первых, все ядерные фрагменты образуются при прохождении ядра-снаряда через мишень благодаря их высоким импульсам. Таким образом, исходящие фрагменты легко