With the alpha-cluster model to explain the change of separating energy

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Abstract It was supposed that, the nucleus was composed of α -cluster, pn-pair, and nn-pair. The reciprocity of the α-cluster, pn-pair, and nn-pair caused the regular change of the separating energy to separate the nn-pair in the exotic nuclei. The regular change was that the separating energy was high behind low to separate the nn-pair in the light and exotic nuclei. This phenomenon must had more profound physical meaning.

Key words cluster model, pn-pair, nn-pair, α-cluste

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1 Introduction

From Ref. [2], we found that the binding energy of ${}^{8}_{4}$Be was lower than the theoretical value. According to the theoretical value, the binding energy of ${}^{8}_{4}$Be should be $2\epsilon_{\alpha}+\epsilon_{\alpha\alpha}=2\times 28.296$ MeV+2.425 MeV, but the experimental value was only 56.496 MeV. The explanation in the paper is that: In this case, one bond is not enough to keep two positively charged cluster close, adding one more pn-pair causes two new bonds with the pairs of two alpha-cluster with the energy $2\epsilon_{\mathrm{pnpn}}$ in the nucleus, and the clusters get closer with the distance proper for the alpha-cluster liquid.

Now, we use the explanation to explain the regular change in this text. For example, in the nucleus ${}^{10}_{4}$Be, one nn-pair is not enough to keep two positively charged cluster close, adding one more pn-pair causes two new bonds with the pair of two alpha-clusters, so the clusters and nn-pair get closer and it is more difficult to separate a nn-pair in the ${}^{12}_{5}$B than in the ${}^{10}_{4}$Be. In the nucleus ${}^{14}_{6}$C, one nn-pair is also not enough to keep three positively charge clusters, so that clusters and nn-pair are at bigger distance than in the ${}^{12}_{5}$B. In a word, the separating energy of nn-pair in the ${}^{12}_{5}$B is bigger than in the ${}^{10}_{4}$Be and bigger than ${}^{14}_{6}$C. In the end, from ${}^{6}_{2}$He to ${}^{20}_{9}$F, we found the regular phenomena just for Fig. 1.

The phenomena was also found when to separate two nn-pairs in the light and exotic nuclei from ${}^{8}_{2}$He to ${}^{18}_{7}$N just for Fig. 2.

2 The separating energy to separate a or two nn-pair

In the light and exotic nuclei, we use the function

$$E_{\Delta\mathrm{N}}=E(\mathrm{Z},\mathrm{N}+\Delta\mathrm{N})-E(\mathrm{Z},\mathrm{N}) \quad (1)$$

to calculate the separating energy to separate a nn-pair, the data come from Ref. [1]. In the Table 1 and Fig. 1 we will see the regular phenomena.

Table 1. The separating energy to separate a nn-pair.

stable nucleus	${}^{4}_{2}$He	${}^{6}_{3}$Li	${}^{8}_{4}$Be	${}^{10}_{5}$B	${}^{12}_{6}$C	${}^{14}_{7}$N	${}^{16}_{8}$O	${}^{18}_{9}$N
extoic nucleus	${}^{6}_{2}$He	${}^{8}_{3}$Li	${}^{10}_{4}$Be	${}^{12}_{5}$B	${}^{14}_{6}$C	${}^{16}_{7}N$	${}^{18}_{8}$O	${}^{20}_{9}$F
ΔE_{NN}/MeV	0.97246	902859	8.4790	14.825	13.115	13.334	12.187	17.032

Table 2. The separating energy to separate two nn-pairs.

stable nucleus	${}^{4}_{2}$He	${}^{6}_{3}$Li	${}^{8}_{4}$Be	${}^{10}_{5}$B	${}^{12}_{6}$C	${}^{14}_{7}$N
extoic nucleus	${}^{8}_{2}$He	${}^{10}_{3}$Li	${}^{12}_{4}$Be	${}^{14}_{5}$B	${}^{16}_{6}$C	${}^{18}_{7}$N
$\Delta E_{2\mathrm{NN}}$/MeV	3.1120	13.224	12.125	21.072	18.590	22.034

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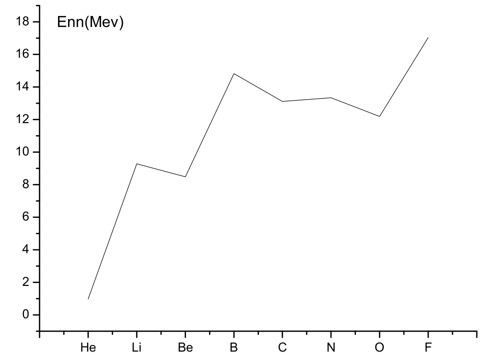

Fig. 1. The separating energy to separate a nn-pair.

We can see the change of high and low. We use the same function to calculate the separating energy to separate two nn-pairs. The same change will be seen in the Table 2 and Fig. 2. The change must have its physical signification. In this paper we use the model from Ref. [2] to explain it.

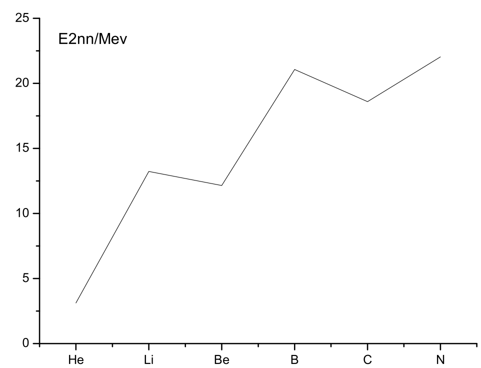

Fig. 2. The separating energy to separate two nn-pairs.

3 The alpha-cluster model in the lightest nuclei.

It used the model by the Fig. 1 in Ref. [2] to explain the light and exotic nuclei and calculated the binding energy by the following equation:

$$E^b(^4\text{He})=\varepsilon_\alpha;\quad E^b(^6\text{Li})=\varepsilon_\alpha+\varepsilon_{\text{pnpn}}+\varepsilon_{\alpha\alpha}, \qquad (2)$$

$$E^b(^{10}\text{B})=2\varepsilon_\alpha+\varepsilon_{\alpha\alpha}+2\varepsilon_{\text{pnpn}};\quad E^b(^{12}\text{C})=3\varepsilon_\alpha+3\varepsilon_{\alpha\alpha}. \qquad (3)$$

But the similar function is not right for $^8_4$Be. The distance between clusters is supposed to constant for all nuclei expect the nucleus $^8_4$Be.

4 Conclusions

We use the phenomenon of $^8_4$Be to explain the regular change of Table 1 and Table 2. For example, in the nucleus $^{10}_4$Be, one nn-pair is not enough to keep two positively charged cluster close. In nucleus of $^{12}_5$B, there is one more pn-pair than $^{10}_4$Be causes two new bonds with the pair of two alpha-clusters, so two clusters get closer because of the collective interaction of nn-pair and pn-pair, so it is more difficult to separate a nn-pair in the $^{12}_5$B than in the $^{10}_4$Be. In the nucleus $^{14}_6$C , one nn-pair is also not enough to keep three positively charge clusters, so clusters and nn-pair are at bigger distance than in the $^{12}_5$B. In a word, the separating energy of a nn-pair in the $^{12}_5$B is bigger than in the $^{10}_4$Be and bigger than $^{14}_6$C. In the end, from $^6_2$He to $^{20}_9$F , we found the regular phenomena just for Fig. 1. The same explanation was also used to explain the the regulary phenomena of Fig. 2.

We also see this phenomenon in the isotopes of H just for Fig. 3. The binding energy is small when there is only one neutron. The interaction is small because one neutron is not enough to keep the other nucleus close. When adding one more neutron, there are two neutrons become a nn-pair to keep the other nucleus close. We also can get the conclusion that odd nucleus have obstruct effect. So, the interaction of nn-pair, pn-pair and alpha-cluster make the regular phenomena of separating energy.

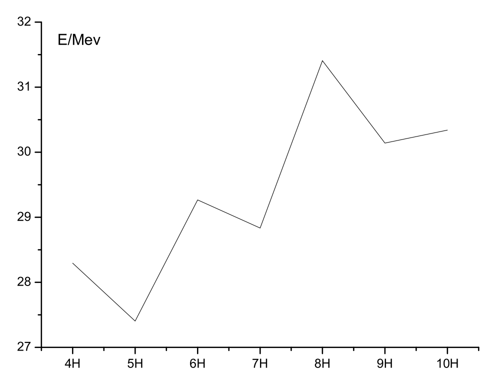

Fig. 3. The binding energy of the isotopes of H.

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