SIX QUARK CLUSTER EFFECTS AND Λ-BINDING ENERGY DIFFERENCE BETWEEN $A = 6$ MIRROR HYPERNUCLEI ${}^{6}_{\Lambda}$He–${}^{6}_{\Lambda}$Li

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The contribution of the six quark cluster formation of the overlapping nucleons to the Λ-binding energy difference between the mirror hypernuclei pair ${}^{6}_{\Lambda}$He–${}^{6}_{\Lambda}$Li has been estimated in the hybrid quark nucleon model. The contribution is small and model dependent. It makes the neutron rich nucleus ${}^{6}_{\Lambda}$He more bound compared to its proton rich partner ${}^{6}_{\Lambda}$Li.

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1. Introduction

The study of binding energy difference between mirror nuclei has been a subject of interest since long [1–4]. With the availability of reliable experimentalal data on Λ-binding energies such studies have also been extended to mirror hypernuclei [5, 6]. The most important comtribution to this binding energy difference of mirror pair originates from the Coulomb energy, but as is well known the Coulomb energy contribution is not sufficient to explain the observed difference in the energy. The discrepancy which is non Coulombic in origin is known as Nolen-Schiffer(NS) anomaly [1]. In the traditional nuclear theories origin of NS anomaly has been attributed to different aspects of theoretical charge symmetry breaking NN interaction [7] or ΛN interaction [8]. With the realization that strong nucleon–nucleon interaction has its ultimate origin in quark and gluon interaction provided by quantum chromodynamics, an alternative approach has emerged to understand the NS anomaly through incorporating explicit quark degrees of freedom in the nuclear wave functions. First few studies in this direction are of Greban and Thomas [9], Köch and Miller [10], and Wang *et al.* [11]. In [9] and [10] contribution of six quark cluster formation of the overlapping nucleons on the binding energy difference of mirror nuclei has been estimated in the hybrid quark model [12]. In [11] calculations have been made in the framework of resonating group method. In the above studies it has been observed that quark effects make the neutron rich nucleus more bound compared to its proton rich partner and reduce the NS anomaly for lighter nuclei. Nag and Sural [13] have extended such studies to s-shell mirror hypernuclei pair ${}^{4}_{\Lambda}$He$-{}^{4}_{\Lambda}$H. Experimental binding energy of Λ-particle is more in ${}^{4}_{\Lambda}$He (proton rich partner) than in ${}^{4}_{\Lambda}$H (neutron rich partner) by nearly 360 keV. According to the calculations made in [13] quark cluster formation effects are of right sign and can account for nearly 15-20% of the NS anomaly. In the present work we have studied the effect of six quark cluster formation on the binding energy difference of lightest p-shell mirror hypernuclei pair ${}^{6}_{\Lambda}$Li$-{}^{6}_{\Lambda}$He. Our work is closely related to that of [9] and [13]. Our aim is to estimate the quark effect contribution to the binding energy difference of mirror pair ${}^{6}_{\Lambda}$Li$-{}^{6}_{\Lambda}$He and to check whether it is in the right direction to account for the observed NS anomaly. Experimental data [14–16] show that the Λ-binding energy in ${}^{6}_{\Lambda}$Li is more than in ${}^{6}_{\Lambda}$He by nearly 250 keV. Coulomb contribution, when added, will increase this discrepancy.

Our calculations are based on the hybrid quark model employed in the earlier studies. According to this model two nucleons maintain their identity as long as the distance between them is greater than a certain cutoff radius r_0. For distances smaller than r_0 the two baryons overlap and form a six quark bag. The quark contribution to the binding energy difference depends on (a) the probability of the formation of six quark bags and (b) the energy difference between the six quark bags of overlapping nucleons (or hyperon and nucleon) than that of isolated nucleons (or hyperon and nucleon). In both ${}^{6}_{\Lambda}$He and ${}^{6}_{\Lambda}$Li there is a valence nucleon outside a closed core of nucleons and Λ-particle. We have calculated the six quark bag probability of the valence particle with the core nucleon and the corresponding contribution to the binding enegy difference of the pair ${}^{6}_{\Lambda}$He and ${}^{6}_{\Lambda}$Li. We have also estimated the six quark cluster formation of the valence nucleon with the hyperon and its effect on the binding energy difference. ΛN bag formation effects are known to make significant contribution to the Λ-nonmesonic decay rates in the finite nuclei [17]. This effect was not included in the work of Nag and Sural [13]. In Section 2 we give the formalism. Calculations are discussed in Section 3 and conclusion in Section 4.

2. Formalism

Lambda particle binding energies in the ground states of ${}^{6}_{\Lambda}$Li and ${}^{6}_{\Lambda}$He hypernuclei with respect to the free particle system ${}^{4}_{2}$He$+\Lambda+n$ can be defined as (${}^{5}_{3}$Li and ${}^{5}_{2}$He are resonant states)

$$M({}^{6}_{\Lambda}\mathrm{Li}) = M({}^{4}_{2}\mathrm{He}) + m_\Lambda + m_p - \mathrm{B.E.}({}^{6}_{\Lambda}\mathrm{Li})\,, \tag{1}$$

$$M({}^6_\Lambda\mathrm{He}) = M({}^4_2\mathrm{He}) + m_\Lambda + m_n - \mathrm{B.E.}({}^6_\Lambda\mathrm{He})\,. \tag{2}$$

If we neglect core contribution which is irrelevant for the binding energy difference and consider only the effect of six quark cluster formation of the valence nucleon with the core nucleon and the hyperon, an additional contribution to the binding energies of the hypernuclei results as shown below. If the probabilites that the valence nucleon forms a six quark bag with any of the core nucleons and hyperon are P^{6q}_{NN} and $P^{6q}_{\Lambda N}$ respectively and P_0 is the probability that it does not overlap with any of the nucleons or hyperon, then

$$P_0 + P^{6q}_{NN} + P^{6q}_{\Lambda N} \cong 1\,. \tag{3}$$

(The probability of formation of nine or higher quark bags is neglected). We can rewrite the mass of core plus one additonal nucleon as

$$\begin{aligned} M'({}^6_\Lambda\mathrm{Li}) \;=\; & M({}^4_2\mathrm{He}) + P_0 m_p + \frac{1}{2}P^{6q}_{NN}(m_{pp} - m_p) \\ & + \frac{1}{2}P^{6q}_{NN}(m_{pn} - m_n) + m_\Lambda + P^{6q}_{\Lambda N}(m_{p\Lambda} - m_\Lambda) \\ & - [(\mathrm{B.E.}({}^6_\Lambda\mathrm{Li}) + \Delta V_c({}^6_\Lambda\mathrm{Li})]\,, \end{aligned} \tag{4}$$

where m_{pp} , m_{pn} and $m_{p\Lambda}$ represent the masses of six quark bags formed of two protons, a proton and a neutron, and a proton and a hyperon. $\Delta V_c({}^6_\Lambda\mathrm{Li})$ measures how much coulomb repulsion is lost by cuttting the two proton integral off at distances $r < r_0$. Due to this the binding energy in ${}^6_\Lambda\mathrm{Li}$ increases by $\Delta V_c({}^6_\Lambda\mathrm{Li})$. We may rewrite (4) as

$$M'({}^6_\Lambda\mathrm{Li}) \;=\; M({}^4_2\mathrm{He}) + m_\Lambda + m_p - [\mathrm{B.E.}({}^6_\Lambda\mathrm{Li}) + \delta B({}^6_\Lambda\mathrm{Li})]\,, \tag{5}$$

where

$$\begin{aligned} \delta B({}^6_\Lambda\mathrm{Li}) \;=\; & P^{6q}_{NN} m_p + P^{6q}_{\Lambda N} m_p - \frac{1}{2}P^{6q}_{NN}(m_{pp} - m_p) \\ & - \frac{1}{2}P^{6q}_{NN}(m_{pn} - m_n) - P^{6q}_{\Lambda N}(m_{p\Lambda} - m_\Lambda) + \Delta V_c({}^6_\Lambda\mathrm{Li})\,. \end{aligned} \tag{6}$$

Comparision of equation (5) with equation (1) shows that the six quark cluster formation of the valence nucleon with the core nucleons and the hyperon increases the binding energy of Λ-particle in ${}^6_\Lambda\mathrm{Li}$ by $\delta B({}^6_\Lambda\mathrm{Li})$. Similarly,for ${}^6_\Lambda\mathrm{He}$ the additional contribution to the binding energy is

$$\begin{aligned} \delta B({}^6_\Lambda\mathrm{He}) \;=\; & P^{6q}_{NN} m_n + P^{6q}_{\Lambda N} m_n - \frac{1}{2}P^{6q}_{NN}(m_{np} - m_p) \\ & - \frac{1}{2}P^{6q}_{NN}(m_{nn} - m_n) - P^{6q}_{\Lambda N}(m_{n\Lambda} - m_\Lambda)\,, \end{aligned} \tag{7}$$

where m_{nn} , m_{np} and $m_{n\Lambda}$ are the masses of six quark bags of two neutrons, a neutron and a proton, and a neutron and a hyperon respectively. Concentrating on the effect of six quarks cluster formation only on the binding energy difference (denoted by ΔB_{6q}), we get

$$\begin{aligned}(\Delta B)_{6q} &= \delta B({}^6_\Lambda\mathrm{He}) - \delta B({}^6_\Lambda\mathrm{Li}) \\ &= \frac{1}{2}P^{6q}_{NN}(2m_n - 2m_p) - \frac{1}{2}P^{6q}_{NN}(m_{nn} - m_{pp}) \\ &\quad + P^{6q}_{\Lambda N}(m_{p\Lambda} - m_{n\Lambda}) + P^{6q}_{\Lambda N}(m_n - m_p) - \Delta V_c({}^6_\Lambda\mathrm{Li})\,. \end{aligned} \tag{8}$$

In the spirit of independent particle model the ground state of the hypernucleus with $A+1$ nucleons can be written as

$$\begin{aligned}\Psi^0(1,2,\ldots A+1,\Lambda) &= \Phi_0^\Lambda \Psi_0^N \\ &= \Phi_{\alpha_0}(\Lambda)\mathcal{A}\left\{\prod_{i=1}^{A+1}\Phi_{\alpha_i}(i)\right\}\,, \end{aligned} \tag{9}$$

where $\Phi_{\alpha_i}(i)$ are normalized single particle states with quantum numbers α_i,Φ_{α_0} is the hyperon state and $\mathcal{A}$ is the antisymmetrization operator.We may define a wave function

$$\Psi^v_N(1,2,\ldots A+1,\Lambda) = \Phi_{\alpha_0}(\Lambda)\mathcal{A}\left\{\prod_{\alpha_i<\alpha_v}[1-\theta(r_0 - r_{\alpha_i\alpha_v})]\prod_{i=1}^{A+1}\Phi_{\alpha_i}(i)\right\}\,, \tag{10}$$

where

$$\begin{aligned}\theta(r_0 - r_{\alpha_i\alpha_v}) &= 0 \text{ for } r_{\alpha_i\alpha_v} > r_0 \\ &= 1 \text{ otherwise}\,. \end{aligned}$$

Ψ^v_N is written to ascertain that the valence particle in quantum state α_v does not form a six quark bag with any of the nucleons. Thus

$$P^{6q}_{NN} = \langle\Psi^0|\Psi^0\rangle \;-\; \langle\Psi^v_N|\Psi^v_N\rangle \tag{11}$$

is the probability of the valence particle being part of one or more six quark bags with the core nucleons and gives us the amount of six quark admixture in the nuclear wave function.The overlap probability P^{6q}_{NN} can be expressed as a sum of single particle term [9] to lowest order in correlation function $\theta(r_0 - r_{ij})$ as

$$P^{6q}_{NN} = \sum_{\alpha_m=\alpha_1}^{\alpha_A} P_{\alpha_m}(r_0)\,, \tag{12}$$

where

$$P_{\alpha_m}(r_0) = \langle \Phi_{\alpha_v}(1)\Phi_{\alpha_m}(2)|\theta(r_0 - r_{12})|\Phi_{\alpha_v}(1)\Phi_{\alpha_m}(2) - \Phi_{\alpha_m}(1)\Phi_{\alpha_v}(2)\rangle \,. \tag{13}$$

α_v and α_m define the quantum states of the valence and the core nucleons respectively. Equation (12) in turn can be written as

$$\begin{aligned} P_{NN}^{6q}(r_0) &= \sum_{\alpha_m=\alpha_1}^{\alpha_A} P_{\alpha_m}(r_0) \\ &= \sum_{n_i l_i j_i \tau_{z_i}} (2j_i + 1) P_{n_i l_i j_i \tau_{z_i}}(r_0) \,. \end{aligned} \tag{14}$$

$P_{n_i l_i j_i \tau_{z_i}}(r_0)$ can be interpreted as the probability for the valence particle to be within a distance r_0 of a specified core particle with quantum numbers $n_i l_i j_i \tau_{z_i}$ and is

$$\begin{aligned} P_{n_i l_i j_i \tau_{z_i}}(r_0) &= \frac{1}{(2j_v + 1)(2j_i + 1)} \\ &\times \sum_{m_v m_i} \langle \Phi_{\alpha_v}(1)\Phi_{\alpha_i}(2)|\theta(r_0 - r_{12}|\Phi_{\alpha_v}(1)\Phi_{\alpha_i}(2) - \Phi_{\alpha_i}(1)\Phi_{\alpha_v}(2)\rangle \,, \end{aligned} \tag{15}$$

where the sum is over the magnetic substates. If we assume that the difference between neutron and proton orbits can be ignored, the isospin index can be suppressed.Thus from equations(14) and (15) $P_{NN}^{6q}(r_0)$ can be expressed as a combination of a direct term $P_{n_i l_i j_i}^{d}(r_0)$ and an exchange term $P_{n_i l_i j_i}^{e}(r_0)$ as

$$P_{NN}^{6q}(r_0) = \frac{1}{(2j_v + 1)} \sum_{n_i l_i j_i} \left[2P_{n_i l_i j_i}^{d}(r_0) - P_{n_i l_i j_i}^{e}(r_0) \right] \,, \tag{16}$$

where

$$P_{n_i l_i j_i}^{d}(r_0) = \sum_{m_v m_i} \langle \Phi_{\alpha_v}(1)\Phi_{\alpha_i}(2)|\theta(r_0 - r_{12})|\Phi_{\alpha_v}(1)\Phi_{\alpha_i}(2)\rangle \tag{17}$$

and

$$P_{n_i l_i j_i}^{e}(r_0) = \sum_{m_v m_i} \langle \Phi_{\alpha_v}(1)\Phi_{\alpha_i}(2)|\theta(r_0 - r_{12})|\Phi_{\alpha_i}(1)\Phi_{\alpha_v}(2)\rangle \,. \tag{18}$$

In equation (16), factor 2 in the $P^d_{n_i l_i j_i}(r_0)$ stems from identical proton and neutron direct contribution. Similarly

$$P^{6q}_{\Lambda N}(r_0) = P'_{n_0 l_0 j_0}(r_0)$$

with

$$\begin{aligned} P'_{n_0 l_0 j_0}(r_0) &= \frac{1}{(2j_v+1)(2j_0+1)} \\ &\quad \times \sum_{m_0 m_v} \langle \Phi_{\alpha_0}(1)\Phi_{\alpha_v}(2)|\theta(r_0 - r_{12}|\Phi_{\alpha_0}(1)\Phi_{\alpha_v}(2)\rangle \,. \end{aligned} \tag{19}$$

There is no exchange term for ΛN overlapping. Φ_{α_0} is the single particle orbital for hyperon. Our calculations for $P^{6q}_{NN}(r_0)$ and $P^{6q}_{\Lambda N}(r_0)$ are based on equations (14) to (19).

3. Calculations

To calculate the six quark probability $P^{6q}_{NN}(r_0)$ we have used the harmonic oscillator wave function with a uniform oscillator constant $\mathcal{V} = 0.41\mathrm{fm}^{-2}$ for $1s$ and $1p$ nucleons.This value of $\mathcal{V}$ has been fixed in the study of 1s shell hypernuclei by Gal *et al.* [18] and gives a good fit to the experimental value of charge radii measured from charge scattering experiment [19]. Using standard techniques of angular momentum algebra matrix elements in equation (15) are transformed to relative and centre-of-mass basis, the transformation coefficients being Moshinsky brackets [20,21]. The final expression for the direct term in equation (16) simplifies to

$$\begin{aligned} P^d_{n_i l_i j_i}(r_0) &= \sum_{\substack{\lambda S n l N L \\ J M}} A^2 \begin{bmatrix} l_i & 1/2 & j_i \\ l_v & 1/2 & j_v \\ \lambda & S & J \end{bmatrix} \\ &\quad \times \langle nlNL, \lambda | n_i l_i n_v l_v; \lambda\rangle^2_{MB} \langle nl||\theta(r_0 - r)||nl\rangle \,, \end{aligned} \tag{20}$$

where

$$\langle nl||\theta(r_0 - r)||nl\rangle = \int_0^{r_0} R^2_{nl}(r)dr \,,$$

$R_{nl}(r)$ are normalized radial functions. The quantum numbers $nlSJ$ and NL refer to the relative and center-of-mass (CM) state of the overlapping pair respectively. The angular momentum J is the result of coupling l and S and λ is the result of coupling l and L. $\langle nlNL, \lambda | n_i l_i n_v l_v; \lambda\rangle_{MB}$ are the

Moshinsky brackets. The expression for the exchange term is similar to (20) with an additional phase factor of $(-1)^{\lambda+S+l_i+l_v+1}$. In the calculation of $P^{6q}_{\Lambda N}(r_0)$, to facilitate Moshinsky transformation to relative basis in the matrix elements in equation (19), we have chosen $\mathcal{V}_\Lambda = (m_\Lambda/m_N)\mathcal{V}_N$. With $\mathcal{V}_N = 0.41\mathrm{fm}^{-2}$, $\mathcal{V}_\Lambda$ is fixed at $0.49\mathrm{fm}^{-2}$. This prescription has been used earlier by others in the study of hypernuclei [22, 23]. With this ansatz matrix elements in equation (19) can be expanded in relative and center-of-mass basis, the expansion coefficients being Smirnov coefficients. Thus equation (19) can also be simplified to an expression similar to (20) with Moshinsky bracket replaced by Smirnov bracket $\langle nlNL,\lambda|n_0l_0n_vl_v,\lambda\rangle_{SM}$ [24]. The Coulomb energy difference of $^6_\Lambda$Li and $^6_\Lambda$He is

$$\begin{aligned} V_c \;=\; & \frac{(2j_i+1)}{(2j_v+1)} \sum_{\substack{\lambda SnlNL\\ JM}} A^2 \begin{bmatrix} l_i & 1/2 & j_i \\ l_v & 1/2 & j_v \\ \lambda & S & J \end{bmatrix} \\ & \times \langle nlNL;\lambda|n_il_in_vl_v;\lambda\rangle^2_{MB} \langle nl||v_c||nl\rangle\,, \end{aligned} \tag{21}$$

where $v_c = e^2(1+2\tau_{z_i})/4r$ is the Couloumb interaction between the valence proton and the core protons. The loss in Coulomb energy ΔV_c when the two protons overlap for $r < r_0$ can be obtained from an expression similar to (20) with the radial matrix element equal to $\langle nl||\theta(r_0-r)v_c||nl\rangle$. The difference of six quark clusters for two neutrons m_{nn} and two protons m_{pp} has been estimated by Köch and Miller [10] both in the nonrelativistic quark model (NRQM) and in MIT bag model. In the case of NRQM, these authors have used three different sets for oscillator length parameter and strong interaction parameter α_s , and have obtained slightly different values for $m_{nn} - m_{pp}$. The mass difference of six quark cluster of neutron hyperon $m_{n\Lambda}$ and proton hyperon $m_{p\Lambda}$ has been calculated by us in the following manner. The mass of $3n$ quark bag can be expressed as [9]

$$E = 1.44 \sum_{i<j}^{3n} \frac{Q_iQ_j}{R_{3n}} + 0.42 \sum_{i=1}^{3n} \frac{C_i}{R_{3n}} \tag{22}$$

if the terms which do not contribute to the mass difference are omitted and $m_i = C_i/R$. Q_i and m_i are the charge and the mass of the i^{th} quark respectively and R_{3n} is the radius of $3n$ quark bag. With $C_d - C_u = 4$ MeV and $R_6 = 1.2$fm equation (22) leads to a difference of $m_{p\Lambda} - m_{n\Lambda} = 0.599$ MeV. The six quark probabilities $P^{6q}_{NN}(r_0)$ and $P^{6q}_{\Lambda N}(r_0)$ depend on the cutoff radius r_0. If nucleons have radii of about 1 fm, r_0 is expected to be of the same order. If r_0 is much smaller than 1 fm, P^{6q} becomes very small. If $r_0 >$ 1fm the conventional meson exchange picture of nuclear forces is

TABLE I

Probabilities $P^{6q}_{NN}(r_0)$ for the valence nucleon to form a six quark bag with the core nucleons as a function of cut off radius r_0.

r_0(fm)	Direct term	Exchange term	$P^{6q}_{NN}(r_0)$
0.85	0.0316	0.0135	0.0124
0.89	0.0418	0.0179	0.0164
0.93	0.0546	0.0234	0.0215
0.95	0.0549	0.0235	0.0216
1.0	0.0706	0.0303	0.0278
1.1	0.1382	0.0592	0.0543

difficult to understand. In most of the earlier studies [10, 13, 17] a value of $r_0 = 1$fm has been preferred. In Table I and Table II we present the results for $P^{6q}_{NN}(r_0)$ and $P^{6q}_{\Lambda N}(r_0)$ for r_0 ranging between 0.85 fm to 1.1 fm. It is worth noting that the Pauli exchange term in $P^{6q}_{NN}(r_0)$ is about 40% of the direct term and leads to a sizable reduction in the six quark probability. Using the value calculated by us of $P^{6q}_{NN}(r_0)$ and $P^{6q}_{\Lambda N}(r_0)$, $m_{n\Lambda} - m_{p\Lambda}$, ΔV_c and NRQM and MIT valuse of $m_{nn} - m_{pp}$ we have estimated the six

TABLE II

Probabilities $P^{6q}_{\Lambda N}(r_0)$ for the valence nucleon to form a six quark bag with the hyperon as a function of r_0.

r_0(fm)	$P^{6q}_{\Lambda N}(r_0)$
0.85	0.0035
0.89	0.0047
0.93	0.0061
0.95	0.0062
1.0	0.0080
1.1	0.0159

quark cluster contribution to the binding energy difference between ${}^{6}_{\Lambda}$Li and ${}^{6}_{\Lambda}$He for different cases. In Table III we present the result for $r_0 = 1.0$fm for various terms. We can compare our value of $P^{6q}_{NN}(r_0) = 0.028$ with the value of $P^{6q}_{NN}(r_0) = 0.0342$ obtained by Nag and Sural for $A = 4$ hypernuclei for same r_0. As expected our value is slightly smaller because the valence nucleon in $A = 6$ hypernuclei is in the relative p-state and is expected to have smaller overlap with core nucleons compared to the overlap between s-state

TABLE III

Six quark cluster effect on the Λ-binding energy difference between mirrer hypernuclei ${}^{6}_{\Lambda}$He and ${}^{6}_{\Lambda}$Li for the cutoff radius $r_0 = 1$fm. The values of ΔB_{6q} obtained by us are shown in the last column of the Table. Values of other quantities mentioned in the text are shown in other columns.

Model	$m_{nn}-m_{pp}$ (MeV)	$P^{6q}_{NN}(r_0)$	$P^{6q}_{\Lambda N}(r_0)$	ΔV_c (MeV)	$m_{p\Lambda}-m_{n\Lambda}$ (MeV)	$(\Delta B)_{6q}$ (keV)
NRQM 1	-1.86					42
NRQM 2	-1.45	0.028	0.008	0.035	0.599	36
NRQM 3	-0.58					24
MIT Bag	0.432					10

nucleons as in $A = 4$ hypernuclei. The largest contribution to the binding energy difference is obtained as 42 keV for NRQM Model 1 out of which 15 keV is obtained from the hyperon nucleon cluster formation probability.

Charge symmetry of the ΛN interaction leads to the expectation that Λ-hyperon should have equal binding energy in mirror pair ${}^{6}_{\Lambda}\mathrm{He} - {}^{6}_{\Lambda}\mathrm{Li}$. The experimental Λ-binding energy in ${}^{6}_{\Lambda}$He and ${}^{6}_{\Lambda}$Li are 4.25 MeV [14, 15], and 4.50 MeV [15, 16], respectively showing a difference of 250 keV. The experimental value of Coulomb displacement energy for the mirror pair ${}^{6}_{\Lambda}\mathrm{He} - {}^{6}_{\Lambda}\mathrm{Li}$ is not available. If we add our calculated value of 468 keV for $r_0 = 1$fm the discrepancy increases to a substantial value of 718 keV indicating a large violation of charge symmetry breaking effect. The results of our calculations show that six quark cluster formation effect increases the binding of Λ-hyperon in ${}^{6}_{\Lambda}$He than in ${}^{6}_{\Lambda}$Li. This is in accordance with the observation made in [9] and [10] that quark effects increase the binding of a neutron rich nucleus in comparison to that of its proton rich partner because the colour magnetic hyperfine interaction between quarks make $m_{nn} - m_{pp}$ less than the corresponding term $2m_n - 2m_p$ for free nucleons. This however does not give the right sign to the NS anomaly for ${}^{6}_{\Lambda}\mathrm{Li} - {}^{6}_{\Lambda}\mathrm{He}$ pair. It is worth mentioning that the right sign obtained in [13] for ${}^{4}_{\Lambda}\mathrm{He} - {}^{4}_{\Lambda}\mathrm{H}$ is probably due to the particular values of P_{6q} and $\tilde{P}_{6q}$ (defined in [13]) used in the calculation.Only P_{6q} is related to experimental data but $\tilde{P}_{6q}$ is strongly dependent on the wave functions and the other parameters used in the calculation.

4. Conclusion

We have made a simple calculation of the six quark effect contribution to the binding energy difference of the mirror pair hypernuclei ${}^{6}_{\Lambda}\mathrm{He} - {}^{6}_{\Lambda}\mathrm{Li}$. The calculated values are small (42 keV to 24 keV for NRQM and 10 keV for bag model) and depend very much on the model used. The overlap probability of the valence nucleon with the hyperon also make a small contribution to the binding energy difference and should be included in any reliable estimate. However, quark effects make Λ-hyperon more bound in ${}^{6}_{\Lambda}$He than in ${}^{6}_{\Lambda}$Li and do not give correct sign to the NS anomaly. Unfortunatly the nuclear wave functions needed as input to determine the matrix element in the calculation of P^{6q} are not directly related to experiments as in the case for $A = 3$ nuclei. We probably need a detailed description of the conventional wave function and a better study of various other contributions to the binding energy difference to understand the large charge symmetry violation in the experimental results.

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