第26卷 第9期
2002年9月

高能物理与核物理

HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS

Vol.26, No.9
Sep., 2002

Ground State Characteristics of the Light Nuclei with $A \leqslant 6$ on the Basis of the Translation Invariant Shell Model by Using Nucleon-Nucleon Interactions

S. B. Doma[1]

(Mathematics Department, Alexandria University, Alexandria, Egypt)

Abstract Phenomenological nucleon-nucleon interactions consisting of central, tensor, spin-orbit and quadratic spin-orbit terms, with Gaussian radial dependence, are constructed by varying their parameters in order to obtain the best fit between the calculated and the experimental values of the binding energy, the root mean-square radius, the D-state probability, the magnetic dipole moment and the electric quadrupole moment of deuteron. The ground-state nuclear wave function of deuteron is expanded in terms of the translation-invariant shell model basis functions corresponding to the number of quanta of excitation $0 \leqslant N \leqslant 10$. Moreover, the binding energy, the root mean-square radius and the magnetic dipole moment of the nuclei ^3H, ^4He, ^5He and ^6Li are also calculated by using the new interactions. The wave functions of these nuclei are expanded in terms of the basis functions of the translation-invariant shell model with $N = 10$ for the first two nuclei, $N = 7$ for ^5He and $N = 6$ for ^6Li. Furthermore, the role of the three-body force is investigated for the triton nucleus. The obtained results are in good agreement with the corresponding experimental values.

Key words nucleon-nucleon interactions, finite nuclei, nuclear structure

1 Introduction

One of the most interesting concepts of nuclear physics is to understand the nature of the nucleon-nucleon interactions and to explain the properties of complex nuclei in terms of these nuclear forces. The description of nuclear systems can be attempted by developing relevant macroscopic or many-body concepts, models, and parameters in terms of which a satisfactory treatment of complex nuclei could be sought. In one approach of the study of effective interactions for light nuclei the many-body theorists try to deduce from the bare nucleon-nucleon force the effective interaction appropriate to a particular model space in a particular nucleus. In the other approach work continues with simple empirical effective interactions designed to fit many-body data in specified model space. One hopes eventually that these two approaches will agree in their effective interactions.

Received 19 December 2001

1) E-mail: sbdoma@hotmail.com

The bare nucleon-nucleon force contains a dominant central force, a tensor force, which is undoubtedly present in any interaction, a strong two-body spin-orbit force and a quadratic spin-orbit force. In the general case of many-particle systems, after the deuteron, it is necessary to calculate matrix elements of two-particle operators by using many-particle wave functions. This can be simplified considerably by introducing the fractional parentage coefficients which enable us to represent the wave function of a system of A particles in the form of products of two wave functions: the first representing the system of A-2 particles and the second representing the system of pair of nucleons, in the all possible configurations of this decomposition.

The aim of this work is to construct a simple phenomenological nucleon-nucleon interaction giving an acceptable fit to the ground-state characteristics of deuteron and reasonable properties for finite nuclei. So, we started with the solution of Schrodinger's wave equation for the ground-state of deuteron by using nucleon-nucleon interactions consisting of central, tensor, spin-orbit and quadratic spinorbit terms with depth and range parameters so chosen in such a way to reproduce good fits to the ground-state chracteristics of deuteron, namely the binding energy, the root mean-square radius, the D-state probability, the magnetic dipole moment and the electric quadrupole moment. For the radial dependence of these terms we take sums of Gaussian functions which are useful for calculations in nuclear physics because they simplify the calculations in both the harmonic oscillator shell model[1] and the refined cluster model[2] in which all wave functions are approximated essentially by Gaussian functions. The potentials which gave results in good agreement with the corresponding experimental values of deuteron are used to calculate the binding energy, the root mean-square radius and the magnetic dipole moment of the ^3H, ^4He, ^5He and ^6Li nuclei. Basis functions of the translation invariant shell model[3—5] with the number of quanta of excitation $N = 10$ for ^3CH and ^4He, $N = 7$ for ^5He and $N = 6$ for ^6Li are used to construct the ground state wave functions of these nuclei.

2 The Potential Model

For each two-nucleon state with orbital-angular momentum $\boldsymbol{l}$, spin momentum $\boldsymbol{s}$ and isospin momentum $\boldsymbol{t}$, our potential is taken to be different, but charge independent:

$$V(r) = {}^{u}X\, V_C(r) + S_{12}V_T(r) + (\boldsymbol{l}\cdot\boldsymbol{s})V_S(r) + L_{12}V_L(r), \quad (2.1)$$

where

$$^{u}X = C_W + (-1)^{s+t+1}C_M + (-1)^{s+1}C_B + (-1)^{t+1}C_H,$$

$$S_{12} = 3(\sigma_1\cdot\boldsymbol{n})(\sigma_2\cdot\boldsymbol{n}) - (\sigma_1\cdot\sigma_2), \quad \boldsymbol{n} = \frac{\boldsymbol{r}}{r}, \quad (2.2)$$

$$L_{12} = (\sigma_1,\sigma_2)\boldsymbol{l}^2 - \frac{1}{2}\{(\sigma_1,\boldsymbol{l})(\sigma_2,\boldsymbol{l}) + (\sigma_2,\boldsymbol{l})(\sigma_1,\boldsymbol{l})\}.$$

The indices C, T, S, L denote central, tensor, spin-orbit and quadratic spin-orbit terms. The four functions $V_C(r)$ to $V_L(r)$ depending on the internucleon distance r only are given by sums of Gaussian functions

$$V_\alpha(r) = \sum_{i=1}^{3} V_{\alpha i}\exp\left(-\frac{r^2}{r_{\alpha i}^2}\right),$$
$$\alpha = C, T, S, L. \quad (2.3)$$

In Eq. (2.2) C_W, C_M, C_B and C_H are the Wigner, the Majorana, the Bartlett and the Heisenberg constants, respectively, which satisfy the well known normalization condition[5]

$$C_W + C_M + C_B - C_H = -1 \quad (2.4)$$

and the additional conditons

$$C_M = 2C_B \quad \text{and} \quad C_H = -2C_W \tag{2.5}$$

for the symmetric forces and

$$C_M = C_W \quad \text{and} \quad C_H = -C_B \tag{2.6}$$

for the Serber forces.

3 The Ground State of Nuclei with $2 \leqslant A \leqslant 6$

If we add and subtract an oscillator potential referred to the center of mass of the deuteron the Hamiltonian of the internal motion of the two nucleons can be written in the form[6]

$$H = H_0 + V', \tag{3.1}$$

where

$$H_0 = \frac{1}{2}\left[\frac{(\boldsymbol{p}_1 - \boldsymbol{p}_2)^2}{2m} + \frac{1}{2}m\omega^2(\boldsymbol{r}_1 - \boldsymbol{r}_2)^2\right] \tag{3.2}$$

is the translation invariant shell-model Hamiltonian for the two nucleon system and

$$V' = V(|\boldsymbol{r}_1 - \boldsymbol{r}_2|) - \frac{m\omega^2}{4}(\boldsymbol{r}_1 - \boldsymbol{r}_2)^2 = V(r) - \frac{m\omega^2}{4}r^2 \tag{3.3}$$

is the residual interaction.

The energy eigenvalues and eigenfunctions of the Hamiltonian H_0 are given, with the usual notations[6], by

$$E_N^{(0)} = \left(N + \frac{3}{2}\right)\hbar\omega, \tag{3.4}$$

$$\Psi(r,\theta,\phi,s,m_s,t,m_t) \equiv |Nlm_lsm_stm_t\rangle = R_{Nl}(r)Y_{lm_l}(\theta,\phi)\chi_{sm_s}\tau_{tm_t}. \tag{3.5}$$

The last three functions on the right-hand side of Eq.(3.5) are the spherical harmonic, the spin and the isospin functions of the two-nucleon system, respectively. The radial wave function $R_{Nl}(r)$ is given by

$$R_{Nl}(r) = a_0^{-\frac{3}{2}}\sqrt{\frac{2\Gamma\left(\frac{N-l+2}{2}\right)}{\Gamma\left(\frac{N+l+3}{2}\right)}}\,e^{-\rho^2/2}\rho^l L_{\frac{N-l}{2}}^{l+\frac{1}{2}}(\rho^2), \tag{3.6}$$

where $\rho = \frac{r}{a_0}$, $a_0 = \sqrt{\frac{\hbar}{m\omega}}$ and $L_{\frac{N-l}{2}}^{l+\frac{1}{2}}(\rho^2)$ is the associated Laguerre polynomial. The functions (3.5) are known as the translation invariant shell model basis functions for the two nucleon system. The ground-state of deuteron has total angular momentum $j = 1$, total isospin $t = 0$, and even parity, with values of the z-components of the total angular momentum and the isospin equal $m_j = j = 1$ and $m_t = t = 0$. The ground-state wave function of deuteron is expanded in terms of the basis functions (3.5), in the usual manner, as follows

$$|j = m_j = 1, t = m_t = 0\rangle = \sum_{Nls} C_{Nls}^{1,0} \sum_{m_l + m_s = 1}(lm_l, sm_s|11)|Nlm_l, sm_s00\rangle, \tag{3.7}$$

where $C_{Nls}^{1,0}$ are the state-expansion coefficients and $(lm_l, sm_s|11)$ are Clebsch-Gordan coefficients of the rotational group R_3 for $j = m_j = 1$. In the first summation on Eq.(3.7) N takes only even integers, since the ground-state of deuteron has even parity. Accordingly, $s = 1$ and $l = 0,2$.

The matrix elements of the oscillator term in Eq.(3.3) with respect to the basis functions (3.5) do not depend on the spin-isospin coordinates and are given by

$$\langle Nlm_l, 1m_s00|\frac{m\omega^2r^2}{4}|N'l'm'_l, 1m_s00\rangle = \frac{\hbar\omega}{4}[(2N+3)\delta_{N',N} -$$

$$\sqrt{N-l+2}\sqrt{N+l+3}\,\delta_{N',N+2}-\sqrt{N-l}\sqrt{N+l+1}\,\delta_{N',N-2}]\,\delta_{l',l}\delta_{m_l',m_l}. \quad (3.8)$$

The matrix elements of the central term $V_C(r)$ in Eq.(2.1) with respect to the basis functions (3.5) are given by

$$\langle Nlm_l,1m_s00|V_C(r)|N'l'm_l',1m_s'00\rangle = \sum_{i=1}^{3}V_{Ci}\langle Nl\left|\exp\left(-\frac{r^2}{r_{Ci}^2}\right)\right|N'l\rangle\times\delta_{l',l}\delta_{m_l',m_l}\delta_{m_s',m_s}. \quad (3.9)$$

The matrix elements of the tensor term $S_{12}V_T(r)$ with respect to the basis functions (3.5) can be calculated by writing the tensor operator S_{12} in the form of a scalar product of two second-degree tensors and then applying the Wigner-Eckart theorm[1] to obtain

$$\langle Nlm_l,1m_s00|S_{12}V_T(r)|N'l'm_l',1m_s'00\rangle = (-1)^{l'}\sqrt{120(2l+1)}(l0,20|l'0)\times \sum_{i=1}^{3}V_{Ti}\begin{Bmatrix}l & 1 & 1\\ 1 & l' & 2\end{Bmatrix}\times\langle Nl|\exp\left(-\frac{r^2}{r_{Ti}^2}\right)|N'l\rangle\,\delta_{l',l}\delta_{m_l',m_l}\delta_{m_s',m_s}, \quad (3.10)$$

where $(l0,20|l'0)$ is a Clebsch-Gordan coefficient of the rotational group R_3 and $\begin{Bmatrix}l & 1 & 1\\ 1 & l' & 2\end{Bmatrix}$ is a 6j-symbol.

The matrix elements of the spin-orbit term for $j=s=1$ are simply given by

$$\langle Nlm_l,1m_s00|(\boldsymbol{l}\cdot\boldsymbol{s})V_S(r)|N'l'm_l',1m_s'00\rangle = -\frac{1}{2}l(l+1)\sum_{i=1}^{3}V_{Si}\times \langle Nl\left|\exp\left(-\frac{r^2}{r_{Si}^2}\right)\right|N'l\rangle\times\delta_{l',l}\delta_{m_l',m_l}\delta_{m_s',m_s}. \quad (3.11)$$

The matrix elements of the quadratic spin-orbit term with respect to the basis functions (3.5) can be calculated by rewriting the operator L_{12} in the form

$$L_{12} = 2\boldsymbol{s}^2\boldsymbol{l}^2 - 2\boldsymbol{l}^2 - 2(\boldsymbol{l}\cdot\boldsymbol{s})^2 - \boldsymbol{s}\cdot\boldsymbol{l} \quad (3.12)$$

so that

$$\langle Nlm_l,1m_s00|L_{12}V_L(r)|N'l'm_l',1m_s'00\rangle = \frac{1}{2}l(l+1)[5-l(l+1)]\sum_{i=1}^{3}V_{Li}\times \langle Nl|\exp\left(-\frac{r^2}{r_{Li}^2}\right)|N'l\rangle\times\delta_{l',l}\delta_{m_l',m_l}\delta_{m_s',m_s}. \quad (3.13)$$

The radial integrals in Eqs.(3.9),(3.10),(3.11) and (3.13) can be easily calculated and the result can be found in Ref.[7].

Accordingly, the Hamiltonian matrix of the ground-state of deuteron is constructed as function of the depth and the range parameters of the interaction and the parameter a_0 which is related to the oscillator parameter $\hbar\omega$ by the relation $a_0^{-2}=0.0241\,\hbar\omega$.

The calculations of the root mean-square radius, the D-state probability, the magnetic dipole moment and the electric quadrupole moment of deuteron can be found in Ref.[6].

The Hamiltonian operator of a nucleus with mass number A corresponding to the internal motions of its nucleons can be written in the form[8]

$$H = H_0 + V', \quad (3.14)$$

where

$$H_0 = \frac{1}{A}\sum_{1=i<j}^{A}\left[\frac{1}{2m}(\boldsymbol{p}_i-\boldsymbol{p}_j)^2+\frac{1}{2}m\omega^2(\boldsymbol{r}_i-\boldsymbol{r}_j)^2\right] \quad (3.15)$$

is the translation invariant shell-model Hamiltonian for the A-nucleon system and

$$V' = \sum_{1=i<j}^{A}\left[V(|\boldsymbol{r}_i - \boldsymbol{r}_j|) - \frac{m\omega^2}{2A}(\boldsymbol{r}_i - \boldsymbol{r}_j)^2\right] \tag{3.16}$$

is the residual interaction.

The energy eigenvalues and eigenfunctions (basis functions) of the Hamiltonian H_0 are given, with the usual notations, by Ref.[8]

$$E_N^{(0)} = \left[N + \frac{3}{2}(A-1)\right]\hbar\omega, \tag{3.17}$$

$$|A\Gamma M_L;\Gamma_S M_S M_T\rangle \equiv |AN\{\rho\}(\nu)[f]LM_L;[\tilde{f}]SM_S TM_T\rangle. \tag{3.18}$$

The nuclear wave function with total angular momentum quantum number J, isotopic spin T and parity π can be expanded in series in terms of the basis functions (3.18) as follows

$$|J^{\pi}TM_JM_T\rangle = \sum_{\Gamma,S} C_{\Gamma S}^{J^{\pi}T} \sum_{M_L+M_S=M_J} (LM_L,SM_S|JM_J)|A\Gamma M_L;\Gamma_S M_S M_T\rangle, \tag{3.19}$$

where $C_{\Gamma,S}^{J^{\pi}T}$ are the state-expansion coefficients and $(LM_L, SM_S | JM_J)$ are Clebsch-Gordan coefficients of the rotational group R_3. In the first sum of Eq.(3.19) N is permitted to be either even or odd integer depending on the parity of the state π. The calculations of the different ground state characteristics of nuclei with $A\leqslant6$ with respect to the basis functions (3.18) can be found in Refs. [8,9].

4 Results and Conclusions

In previous papers[6,7,10] we have intoduced two different types of nucleon-nucleon interactions, which fit the same ground-state characteristics of deuteron and have the same shape as given by Eqs. (2.1) and (2.2), by assigning the following well-known sets of values for the Wigner, the Majorana, the Bartlett and the Heisenberg exchange constants: $C_W = 0.1333$, $C_M = -0.9333$, $C_B = -0.4667$ and $C_H = -0.2667$ (for the symmetric forces), which are known as the Rosenfeld constants[5]; $C_W = -0.41$, $C_M = -0.41$, $C_B = -0.09$ and $C_H = 0.09$ (for the Serber forces), which are taken in accordance with the Lederer potential[11].

The radial dependence of these interactions are a single Gaussian term in Refs.[6,7] and a sum of two Gaussian terms in Ref.[10].

In the present paper we have started with the conditions (2.4), (2.5) and (2.6) and gave values for each of the Wigner, the Majorana, the Bartlett and the Heisenberg exchange constants in the range between -1.0 and 1.0 with a step 0.0001 and considering the resulting potentials. The radial dependence are taken in the form of sums of three Gaussian terms. The depth and the range parameters of the potentials are allowed to vary in the following ranges. $-100.0\leqslant V_\alpha\leqslant100.0$ with a step of 0.0001 and $0.4\leqslant r_\alpha\leqslant3.0$ with a step of 0.0001.

Accordingly, we calculated the mimimum energy eigenvalue of the ground-state of deuteron. The potential which gave result in good agreement with the experimental value of the binding energy of deuteron is used to calculate the other ground-state characteristics of deuteron. The following two sets of values of the exchange constants are able to reproduce potentials, with radial dependence in the form of a sum of three Gaussian terms, giving rise to good agreement between the calculated and the corresponding experimental values of the ground-state characteristics of deuteron:

case (1) symmetric forces

$C_W = 0.1667$, $C_M = -1.0000$, $C_B = -0.5000$, $C_H = -0.3333$;

case (2) Serber forces

$C_W = -0.3333, C_M = -0.3333, C_B = -0.1667, C_H = 0.1667.$

In Table 1 we present the values of the depth and the range parameters of the two potentials D1 and D2 which belong to case (1) and case (2), respectively, and fit the ground-state characteristics of deuteron.

In Table 2 we present the results of calculating the binding energy, the root mean-square radius, the D-state probability, the magnetic dipole moment and the electric quadrupole moment of deuteron by using the two potentials D1 and D2 together with the corresponding experimental values[12] and preveious results by using the OPEP plus core[13].

Moreover, in Table 3 we present the results of calculating the binding energy, the root mean-square radius and the magnetic dipole moment of the nuclei ^3H, ^4He, ^5He and ^6Li by using the two potentials D1 and D2, and basis functions of the translation-invariant shell model corresponding to number of quanta of excitation $N = 10$ for ^3H and ^4He, $N = 7$ for ^5He and $N = 6$ for ^6Li. The experimental values of the binding energy, the root mean-square radius and the magnetic dipole moment of these nuclei are also given in Table 3.

Table 1. Range and depth parameters of the potentials.

Parameter		Central	Tensor	Spin-orbit	Qu. spin-orbit
Case (1)	V_1/MeV	55.6949	18.2212	20.4052	16.3376
D1	r_1/fm	1.6214	2.2331	0.8721	0.6555
	V_2/MeV	-43.3347	-40.3772	-15.7750	-12.6626
	r_2/fm	0.8142	0.9322	0.6663	0.7214
	V_3/MeV	-18.7112	-12.7731	-16.5520	-19.7733
	r_3/fm	0.6532	0.6429	1.2035	1.1042
Case (2)	V_1/MeV	38.1211	-14.5654	-16.3244	-28.6623
D2	r_1/fm	0.8387	2.9120	0.6511	1.2201
	V_2/MeV	-44.7741	-25.4442	-19.3589	-32.1476
	r_2/fm	0.6854	1.5541	0.9201	0.8825
	V_3/MeV	-24.9521	35.7789	63.5471	34.0214
	r_3/fm	1.3564	1.5647	0.5347	1.2154

Table 2. Ground-state characteristics of deuteron.

Case Characters	B.E./MeV	R/fm	P_D	μ_d/N.M.	Q_d/efm^2
Exper.[12]	2.22457	1.963	0.04—0.07	0.8574	0.2859
D1, $\hbar\omega$ = 18MeV	2.2245	1.961	0.0622	0.8555	0.2944
D2, $\hbar\omega$ = 19MeV	2.2249	1.958	0.0428	0.8558	0.2992
OPEP + Core[13]	2.224575	1.9484	0.0750	—	0.28652

Table 3. Ground-state characteristics of nuclei with $3 \leqslant A \leqslant 6$.

Case	Characteris	B.E./MeV	R/fm	μ/N.M.	$\hbar\omega$/MeV
^3H	D1	8.229	1.755	3.144	11
	D2	8.135	1.782	3.235	13
	Exper.[14]	8.4819	1.41—1.62	2.98[5]	—
^4He	D1	27.444	1.478	—	24
	D2	27.211	1.551	—	25
	Exper.[14]	28.296	1.46	—	—
^5He	D1	26.854	1.958	-1.767	27
	D2	26.938	2.032	-1.752	29
	Exper.[14]	27.410	—	-1.802[5]	—
^6Li	D1	24.572	2.147	0.787	20
	D2	23.996	1.986	0.769	22
	Exper.[14]	31.996	2.38	0.822[5]	—

It is seen from Table 2 that the calculated ground state characteristics of deuteron by using the two new potentials D1 and D2 are in good agreement with the corresponding experimental values and the preveious results by using the OPEP. More-over, it is seen from Table 3 that the two potentials D1 and D2 also gave reults in good agreement with the corresponding experimental binding energy, root mean-square radius and magnetic dipole moment of the nuclei ^{3}H, ^{4}He, and ^{5}He. Concerning the nucleus ^{6}Li the calculated values of the binding energy and the root mean-square radius are not in so good agreement with the corresponding experimental values as for the other nuclei since we have used a truncated space with basis functions corresponding to number of quanta of excitation $N = 6$ which is not sufficient to describe the ground state wave function of ^{6}Li[9].

In is well known that three-body forces are important to describe the properties of finite nuclei. The parameters in the nucleon-nucleon potential may not be unique or there may be some redundant parameters in order to reproduce the deuteron properties. In order to investigate these points of view, we have considered the triton nucleus and used the following Hamiltonian operator, which takes into consideration the three-body forces:

$$H = H_0 + V' + V'', \tag{4.1}$$

where the first two terms in Eq.(4.1) are given by Eqs.(3.15) and (3.16) and

$$V'' = \sum_{1 = i < j < k} V(\boldsymbol{r}_i, \boldsymbol{r}_j, \boldsymbol{r}_k) \tag{4.2}$$

is the three-body force. For the three-body potential we have used the Skyrme Ⅲ potential[15]

$$V'' = t_3 \delta(\boldsymbol{r}_1 - \boldsymbol{r}_2) \delta(\boldsymbol{r}_2 - \boldsymbol{r}_3), \tag{4.3}$$

where $t_3 = 14000.0 \text{MeV} \cdot \text{fm}^6$.

In Table 4 we present the calculated values of the binding energy, the root mean-square radius and the magnetic dipole moment of triton by using the two-and the three-body potentials. The corresponding experimental values are also given in Table 4.

Table 4. Ground-state characteristics of ^{3}H by using two-and three-body potentials.

Characteristics	B.E./MeV	R/fm	μ/N.M.	$\hbar\omega$/MeV
D1 + Skyrme Ⅲ	8.377	1.712	3.121	11
D2 + Skyrme Ⅲ	8.242	1.745	3.202	13
Experimental	8.4819	1.41—1.62	2.98	—

It is seen from Table 4 that the inclusion of the three-body force in the Hamil-tonian operator has improved the calculated values of the binding energy, the root mean-square radius and the magnetic dipole moment of the triton nucleus. Similar calculations are necessary to investigate the role of the three-body forces in the ground-state characteristics of the other nuclei.

The author would like to thank the referee for his valuable comments and directions.

References

1 Talmi I. Simple Models of Complex Nuclei. The Shell Model and Interacting Boson Model. USA: Harwood Academic Publisher, 1993

2 Hackenbroich H H, Heiss P. Z. Phys., 1970, **231**: 225

3 Bargman V, Moshinsky M. Nucl. Phys., 1960, **18**: 697; 1961, **23**: 177

4 Kretzchmar M. Z. Phys., 1960, **158**: 284

5 Vanagas V V. Algebraic Methods In Nuclear Theory. Mintis, Vilnius, 1971

6 Doma S B, El-Nohy N A, Gharib K K. Helvetica Phys. Acta, 1996, **69**: 90

7 Doma S B, Gharib K K, El-Nohy N A. Egypt. J. Phys., 1996, **27**: 55

8 Doma S B. Helvetica Phys. Acta, 1985, **58**: 1072

9 Doma S B. Ukrainian Journal of Phys., 1997, **42**(3): 279

10 Doma S B, Gharib K K, El-Nohy N A. Egypt. J. Phys., 1998, **29**: 323

11 Lederer L K. Diplomarbeit, Munchen, 1957

12 Wong Samuel S M. Introductory Nuclear Physics. Englewood Cliffs, New Jersy: Prentics Hall, 1990

13 Sprung D W L, Van Dijk W et al. Phys. Rev., 1994, **C4**: 2942

14 ZHENG D C, Vary J P, Barrett B R. Phys. Rev., 1994, **C50**: 2841

15 Beiner M, Flocard H, Van Giai N et al. Nucl. Phys., 1975, **A238**

基于平移不变壳模型的轻核($A \leqslant 6$)基态特性

S. B. Doma[1]

(Mathematics Department, Alexandria University, Alexandria, Egypt)

摘要 包含中心力、张量力、自旋-轨道力和四级自旋-轨道力且具有高斯型径向关系的唯象核子-核子相互作用被构造并通过调节有关参数来得到氘核结合能、均方根半径、D态几率、磁偶极矩和电四极矩的理论值和实验值之间的最好拟合. 氘核基态波函数用对应主量子数 $0 \leqslant N \leqslant 10$ 的平移不变壳模型基函数来展开. 另外,用新的相互作用还计算了 ^{3}H, ^{4}He, ^{5}He 和 ^{6}Li 核的结合能、均方根半径和磁偶极矩. 这些核的波函数也是用平移不变壳模型基函数来展开,只是对前两个核, $N=10$; 对 ^{5}He, $N=7$; 对 ^{6}Li, $N=6$. 对氘核,进一步研究了三体力的作用. 所得结果与相应的实验数据符合甚好.

关键词 核子-核子相互作用 有限核 核结构

2001-12-19 收稿

1) E-mail: sbdoma@hotmail.com