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Excited energies in ^{72,74}Ge , ^{72,74}Se and ^{72,74}As nuclei using surface delta interaction

طاقات التهيج في النوى ^{72,74}Ge , ^{72,74}Se , ^{72,74}As باستخدام جهد دلتا السطحي

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Abstract

By using a surface delta interaction, we obtain energy levels of the ^{72,74}Ge , ^{72,74}Se and ^{72,74}As isotopes .Different model spaces are adopted to generate the eigen values and final energies.

A computer code were written by Matlab 2013 to achieve the configuration mixing shell model calculations by employing the surface delta interaction (SDI) as residual interaction. In this study , predicted, the low-lying levels (energies, spins and parities) were quite successful in describing of above nuclei when its comparison with the available experimental data which showing the ability of our effective interaction to provide an acceptable description of nuclear structure properties in the fp-shell region.

Key words : Energy Levels ,Shell Model, Model Spaces, Surface Delta Interaction. Spins,

الخلاصة

باستخدام تفاعل دلتا السطحي حصلنا على مستويات الطاقة للنظائر ^{72,74}Ge, ^{72,74}Se, ^{72,74}As فضاءات أنموذج مختلفـة هي اعتمدت لتوليد القيم الذاتية والطاقات النهائية .تم استخدام برنامج مكتوب بلغة الماتلاب 2013 لانجاز حسابات أنموذج القشـرة للترتيب المختلط باستخدام جهد دلتا السطحي كتفاعل متبقي.في هذه الدراسة توقع مستويات الطاقة المنخفضة (الطاقات ،البروم والتماثلات) كانت ناجحة جدا في وصف النوى أعلاه عند مقارنتها مع البيانات التجريبية المتوفرة التي تبين قدرة تفاعلنا الفعال لتقديم وصف مقبول لخصائص التركيب النووي في منطقة القشرة fp.

1.Introduction

The nuclear shell model(SM) is the basic model in nuclear physics. This model describes nuclei by valence protons and valence neutrons outside a semi- or doubly magic core as ^{38}Sr and ^{90}Zr nuclei as in this study ,also the model includes an attractive potential arising from the short-range interaction between neighbouring nucleons which is directly dependent on the shape of the nuclear distribution .Therefore, the shell model is able to treat each nucleon as an independent particle that acts within a mean field of all the rest, thus allowing nucleons to occupy the various orbitals within the shells. These fundamental ideas form the basis for the description of nuclear structure within the shell model[1].

2.Theory

Nucleon-nucleon interaction(NN) is the main objective in the nuclear structure theory study , as well as to understand the different properties of nuclei. The study of various nuclei in the vicinity of closed shells rather well, containing a few valence nucleons is in the extremely important. Actually, it has provided the best testing for the basic ingredients of a nuclear shell-model calculations, in particular as regards the matrix elements of the effective NN interaction[2,3,4]. Because the nuclear force is strong and quite complex, no one has yet a universal effective interaction; instead of finding appropriate interaction for each model space.

The surface delta interaction (SDI) is one of the simple two-body interactions which can be used to successfully correlate many observed nuclear properties when a truncated shell model(SM)[5,6].

The interaction between two nucleons of zero range is assumed to be localized on the nuclear surface of the close core shell [7]. The SDI interaction can be written as [8,9]:-

$$V_{12}(A,t_z) = -\hat{V}_0(A,t_z) \times \delta(r_1 - r_2) \times \delta(\cos\theta_1 - \cos\theta_2) \times \delta(\phi_1 - \phi_2) \qquad (1)$$

Here $V_0(A,t_z)$ the interaction strength factor for each nucleus($A+2\delta$) is given by :

$$V_0(A,t_z) = \hat{V}_0(A,t_z) \times C_0(\mathrm{n}\ell) \qquad (2)$$

While , θ_1 and θ_1 are the angle between r_1 and r_2 .

In spherical coordinates, the radial integral evaluated as:

$$C_0(n\ell) = \frac{1}{4} R^4_{n\ell}\ (r) \times \frac{1}{r^2}.dr \qquad (3)$$

Is assumed to be equal for all orbits (nl)with main quantum number (n) and orbital angular momentum(l) , ($j = l \pm 1/2$)

For investigate systems ($A+2\delta$) with a doubly magic core of atomic mass number A = N +Z ,(N neutrons, Z protons) and two valence nucleons $\delta = \pm 1$,here the parameters($\delta = +1$, $\delta = -1$) refers to the systems with particles and holes on the respectively.The justification for choosing of this interaction, which is effective only at the nuclear surface lies in two facts which are . First that the principle of the NN interaction will cause scattering predominantly at the nuclear surface where there are states available into which the nucleons may be scattered. Second no local features of the NN potential tend to suppress the wave function of nucleon on nuclear interior[10]. SDI are succeeded in energy levels calculation for nuclei various. For this reason it has been used in several previous studies .In 1970 M. Waroquier and . K. Heyde have been studied for the *N* = 82 odd-proton nuclei using SDI [11] D.s. Chuu et.al analyzed the positive parity states for ^{91}Y, ^{92}Zr and ^{93}Nb Spectra using SDI in 1979[12].SDI has been used to calculate the energy levels of ^{30}P nucleus by A.K. Hasan and F.H.Obeed in 2011 [13].

3.Results and Discussion

The objective of the present study is to calculate the energy level values for ^{72}Ge,^{72}Se,^{72}As ,^{74}Ge,^{74}Se and^{74}As isotopes in the fp-shell region .The calculations have been carried out by performing SM with SDI. Several model spaces have been used in this study .The theoretical values are given by the levels energies with respect to^{70}Ge and^{72}Ge close core of nuclei ^{72}Ge,^{72}Se,^{72}As and ^{74}Ge,^{74}Se,^{74}As on the respectively. We can interpret and discuss each nucleus separately as follows:-

3.1 ^{72}Ge and ^{74}Ge nuclei

The low-lying energies of even-even nucleus ^{72}Ge are shown in figure (1) .In this nucleus, valance neutrons distributed over the single particle-orbits $2p_{1/2,}1g_{9/2}$ respect to^{70}Ge close core. The neutron single-particle energies are -7.409 MeV and -7.210 MeV for the $2p_{1/2,}1g_{9/2}$ orbits, respectively. From the figure (1) indicate that the J^{π};2^+,4^+,0^+ and 6^+ states in our calculations are close to rather to experimental levels [14].Theoretically ,the spin and negative parity J^{π}; 4^- confirmed of experimental energy value 3.565 MeV which is in agreement with calculated value 3.537 MeV .On other hand, experimentally, the values 3.128 MeV and 3.760 MeV at the J^{π}; 5^- and 8^+states were corresponded with the theoretical values 2.982 MeV and 3.612 MeV .While in^{74}Ge nucleus ,the two neutrons were distributed in $1g_{9/2}$ shell respect to^{72}Ge close core . The neutron single-particle energy is -6.782 MeV of $1g_{9/2}$ orbit . A comparison between the calculated theoretical levels and experimental work [15] were displayed in figure (2). In our calculations ,confirmed the J^{π} ;6^+ state for energy level 2.569MeV uncertain experimentally in spin and parity. Specified ,the angular momentum and parity J^{π} ;8^+ for experimental energy 3.211MeV , which was very close to the theoretical value 3.276MeV.

3.2 ^{72}Se and ^{74}Se nuclei

For the ^{72}Se and ^{74}Se isotopes , the model space includes on the two particle (two protons) were located at $1f_{5/2}$,$2p_{1/2}$ and $1g_{9/2}$ orbits outside the ^{70}Ge and ^{72}Ge close cores respectively . The proton single-particle energies for ^{72}Se nucleus are -4.612 MeV and -3.605 MeV and -3.609MeV for the $1f_{5/2}$,$2p_{1/2}$ and $1g_{9/2}$ orbits respectively . The comparison between our calculations and experimental data[14] of the ^{72}Se nucleus are presented in figure (3).The spins and parities 7^-,3^-,5^-,8^+ and 0^+, specified of empirical values 2.965, 3.382, 4.217,4.325 and 4.713 MeV, which were excellent agreement with theoretical levels 3.046 MeV,3.546MeV, 4.376MeV, 4.573MeV and 4.664 MeV. Experimental levels at energies 1.876 and 3.226 MeV, confirmed at spin 4 and 2 respectively as well as determined the positive parity of these states from through our theoretical expected .The empirical level 4.310 MeV with J^π ;6^+state was compatible well with the theoretical level 4.502 MeV with J^π ;6^+ state .Theoretically, a new energy levels predicted in values 3.589MeV,3.657MeV ,4.384MeV,4.412 MeV and 4.661MeV for J^π ; 0^+,3^+ , 2^+ , 4^- and 4^+ states respectively, which were not found in the empirical data .While in the ^{74}Se nucleus, comparison of the experimental [15] and theoretical levels are displayed in figure(4), the agreement is excellent for higher energy levels values in this ^{74}Se nucleus. The proton single-particle energies are -5.655 MeV and -5.570 MeV and -5.227MeV for the $1f_{5/2}$,$2p_{1/2}$ and $1g_{9/2}$ orbits respectively. The experimental levels 2.918, 3.112, 3.250, 3.306 and 3.539 MeV confirmed at spins and parities J^π ;2^+,3^+,3^-,(2^- ,4^- and 6^-) and 2^+ theoretically .Confirmed ,the spins and parities J^π ;0^+ and 6^+ for experimental levels 3.379 MeV and 3.624MeV which seems very close to the theoretical values3.355 and 3.613 MeV .Reasonable agree for the theoretical value 2.827 MeV, J^π ;5^- with experimental value 2.842 MeV, J^π ;5^-. Anew energy levels ,expected in our calculations at the values 2.778 MeV, 3.016MeV, 3.358 MeV, 3.408MeV, 3.550 MeV, and 3.676MeV of J^π ;7^- , 0^+,5^-,4^- , 4^+ and 8^+ states which were not observed in experimental work.

3.3 ^{72}As and ^{74}As nuclei

Figure (5)shows comparison between theoretical and experimental values[14] of ^{72}As nucleus which has one proton in $1f_{5/2}$,$2p_{1/2}$ and $1g_{9/2}$ model space and one neutron in $2p_{1/2}$ and $1g_{9/2}$ model space. We expected confirm of the J^π ;$2^+$and 0^+ states for empirical energies 0.288 and 0.514 MeV respectively by our results .Avery Compatible acceptable for the empirical energies values 0.309,0.414,0.715 and 1.401 MeV with theoretical energies values 0.442, 0.470,0.783 and 1.743 MeV. We found a new energy levels intruded upon between the theoretical levels 0.405MeV, 0.550MeV, 1.061MeV, 1.342MeV,1.512MeV, 1.525MeV , 1.891 MeV to 2.148 MeV of the J^π ; 7^-,5^-, 6^-,1^+,5^-,4^- and 5^- to 8^+ states. Either in the ^{74}As nucleus, two nucleons were distributed as follows : one proton in $1f_{5/2}$,$2p_{1/2}$, $1g_{9/2}$ model space and one neutron in $1g_{9/2}$ shell .A comparison between the theoretical and experimental work [15] displayed in figure (6) ,Which showed remarkably good agreement of this comparison. Confirmed of the angular momentum J^π ;5 and identified with negative parity for empirical value 0.315 ,but the empirical level 0.958 MeV confirmed with positive parity and predicted at the angular momentum J^π ;1 from our calculations which were not specific the spin experimentally. The spins J^π ; 3^-, 3^+,6^+ and 8^+ confirmed of experimental values 0.776, 1.300 ,1.530 and 1.627 MeV respectively compared to theoretical energies 0.783 ,1.343,1.531 and 1.573 MeV. Anew levels can be predicted in our calculations at energies 0.368MeV, 0.405MeV, 0.450MeV and 1.466MeV for J^π ;0^+,7^-,4^- and 4^+ states, which not indicate at the empirical data. Expected ,the determination of the angular momentum and parties J^π ; 6^-,9^+,4^-,5^-,2^+ and 5^+ for empirical levels 1.052,1.174,1.207,1.230,1.265 and 1.400 MeV which correspond well with the predicted levels 1.062 MeV, 1.168 MeV, 1.213 MeV, 1.233 MeV, 1.320MeV and 1.395MeV.

4.Conclusions

In the framework of shell model calculations using surface delta interaction ,we conclude that the nuclei ^{72,74}Ge,^{72,74}Se,^{72,74}As was acceptable agreement of the theoretical energy levels with experimental at values 2.982 MeV ,3.537 and 3.612 MeV in ^{72}Ge nucleus; 3.159 MeV and 3.276 MeV for ^{74}Ge nucleus ; 3.046 MeV,3.224MeV,3.331MeV,3.546MeV, 4.376MeV, 4.573MeV and 4.664MeV for ^{72}Se nucleus ;2.827 MeV ,2.927 MeV,2.980MeV,3.227MeV,3.323MeVand 3.544MeV in ^{74}Se nucleus ;0.470 MeV and ,0.783MeV in ^{72}As nucleus; 0.302MeV, 0.783MeV, 0.976MeV ,1.343MeV ,1.373MeV ,1.395MeV ,1.531MeV and 1.573MeV fo^{74}As nucleus. Determined , the spins and parity for experimental levels in unit MeV at values 3.211:8^+ of ^{74}Ge nucleus ;2.965:7^- ,3.382:3^- ,4.217:5^- ,4.325:8^+ and 4.713:0^+ for ^{72}Se nucleus; 1.052 :6^-, 1.174:9^+,1.207:4^-,1.230: 5^-,1.265:2^+ and 1.400 :5^+ of ^{74}As nucleus .Confirmed , the spins and parity for experimental levels at values 3.565MeV:4^- for ^{72}Ge;2.569MeV:6^+ for^{74}Ge,1.876MeV:4^+ and 3.226MeV:2^+ for^{72}Se nucleus ;2.918MeV:2^+ ,3.112MeV:3^+ ,3.250 MeV :3^- ,3.306 MeV :2^-,4^- and 6^- and 3.539 MeV:2^+ for ^{72}Se nucleus;0.288MeV:$2^+$and 0.514MeV:$0^+$for ^{72}As nucleus ;0.315MeV:5^- ,0.776MeV:3^- ,1.300MeV:3^+ ,1.530MeV:$6^+$and 1.627 MeV:8^+ for ^{74}As.A new energy levels in our calculations identified at values 3.589MeV :0^+,3.657MeV: 3^+,4.384MeV:2^+,4.412MeV:4^- and 4.661MeV:4^+ for ^{72}Se nucleus; 2.778 MeV:7^- ,3.016MeV:0^+,3.358MeV:5^-,3.408 MeV:4^- ,3.550 MeV:4^+ and 3.676 MeV :8^+ for^{74}Se nucleus; 0.405MeV:7^-,0.550MeV: 5^-,1.061MeV :6^-,1.342MeV :1^+,1.512MeV:5^-,1.525MeV:4^-,1.891MeV:5^-,1.942MeV:3^+,1.948MeV:7^+,1.957MeV:2^+,1.963MeV: 1^+,1.971MeV:5^+,2.040MeV:4^-,2.041 MeV:0^+, 2.105MeV:6^+, 2.115MeV:4^+, 2.148MeV:8^+ for ^{72}As nucleus;0.368MeV:0^+,0.405MeV:7^-,0.450 MeV:4^-,1.466MeV:4^+ for^{74}As nucleus. This investigation increases the theoretical knowledge of all isotopes with respect to energy levels. The theoretical calculations by using SDI reasonably agree with the experimental data. This indicates that the shell model is very good to describe the nuclear structure for ^{72,74}Ge, ^{72,74}Se and ^{72,74}As nuclei.

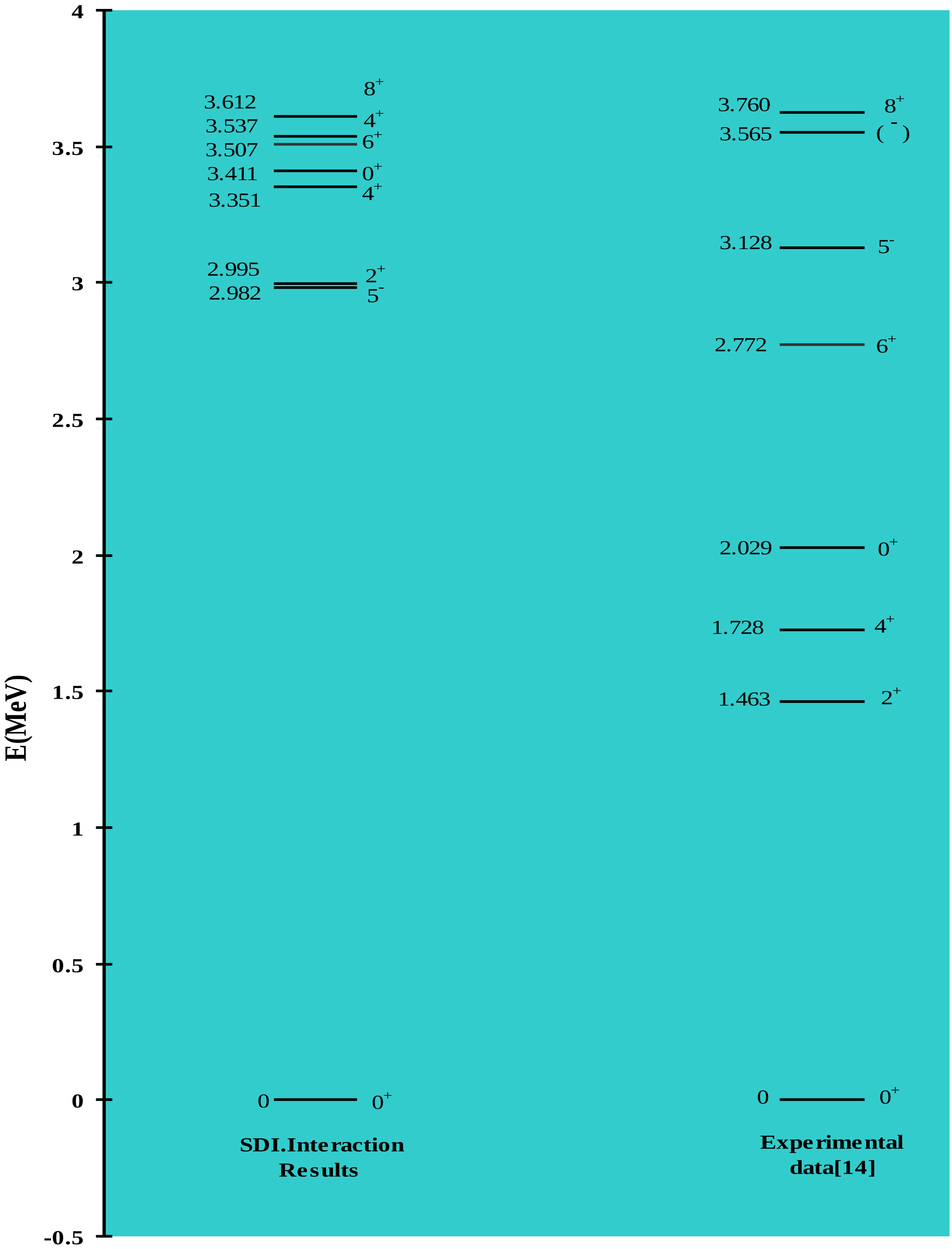

Figure (1):Theoretical and experimental energy levels[14] and spins of ^{72}Ge nucleus using surface delta interaction

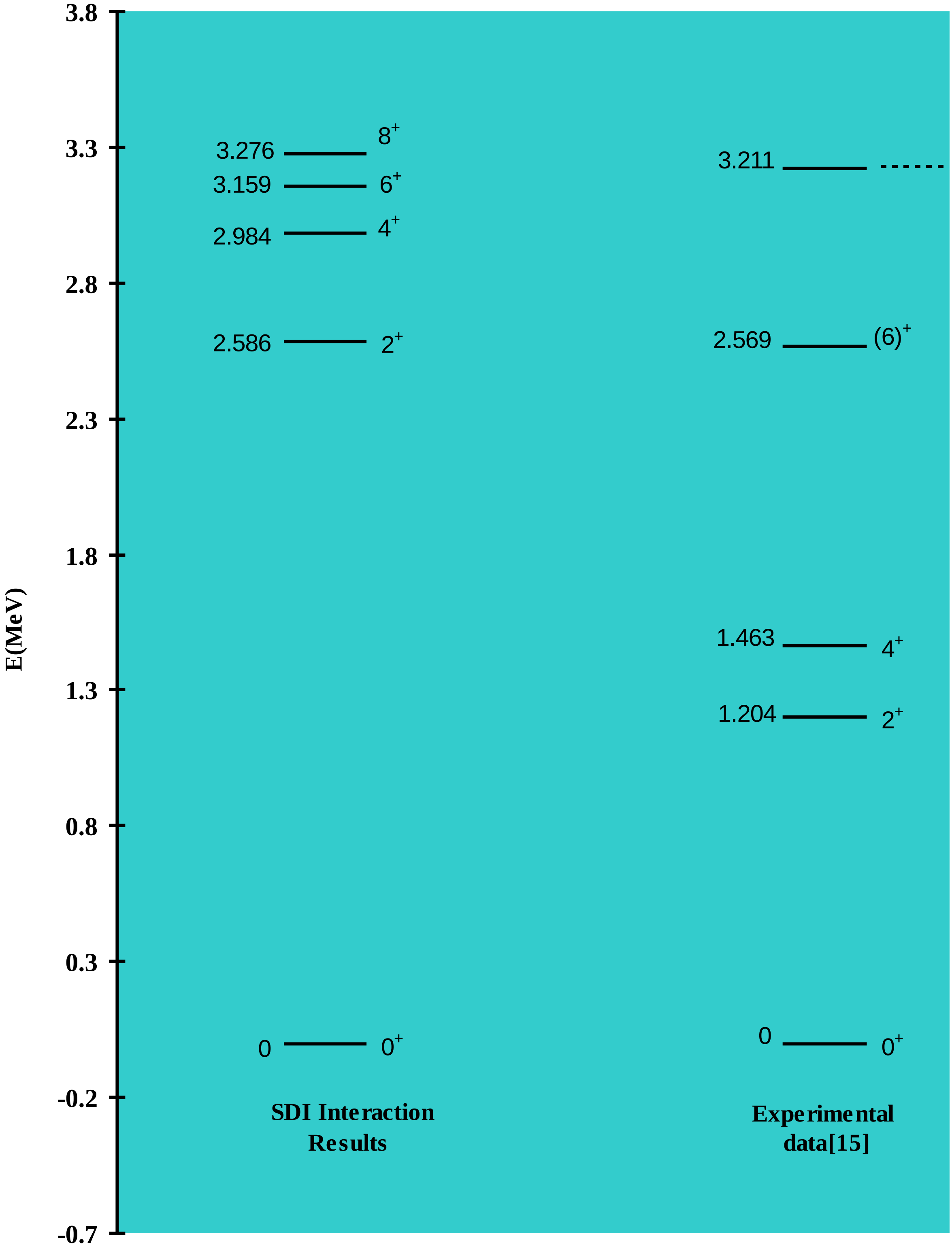

Figure (2): Theoretical and experimental energy levels[15] and spins of ^{74}Ge nucleus using surface delta interaction

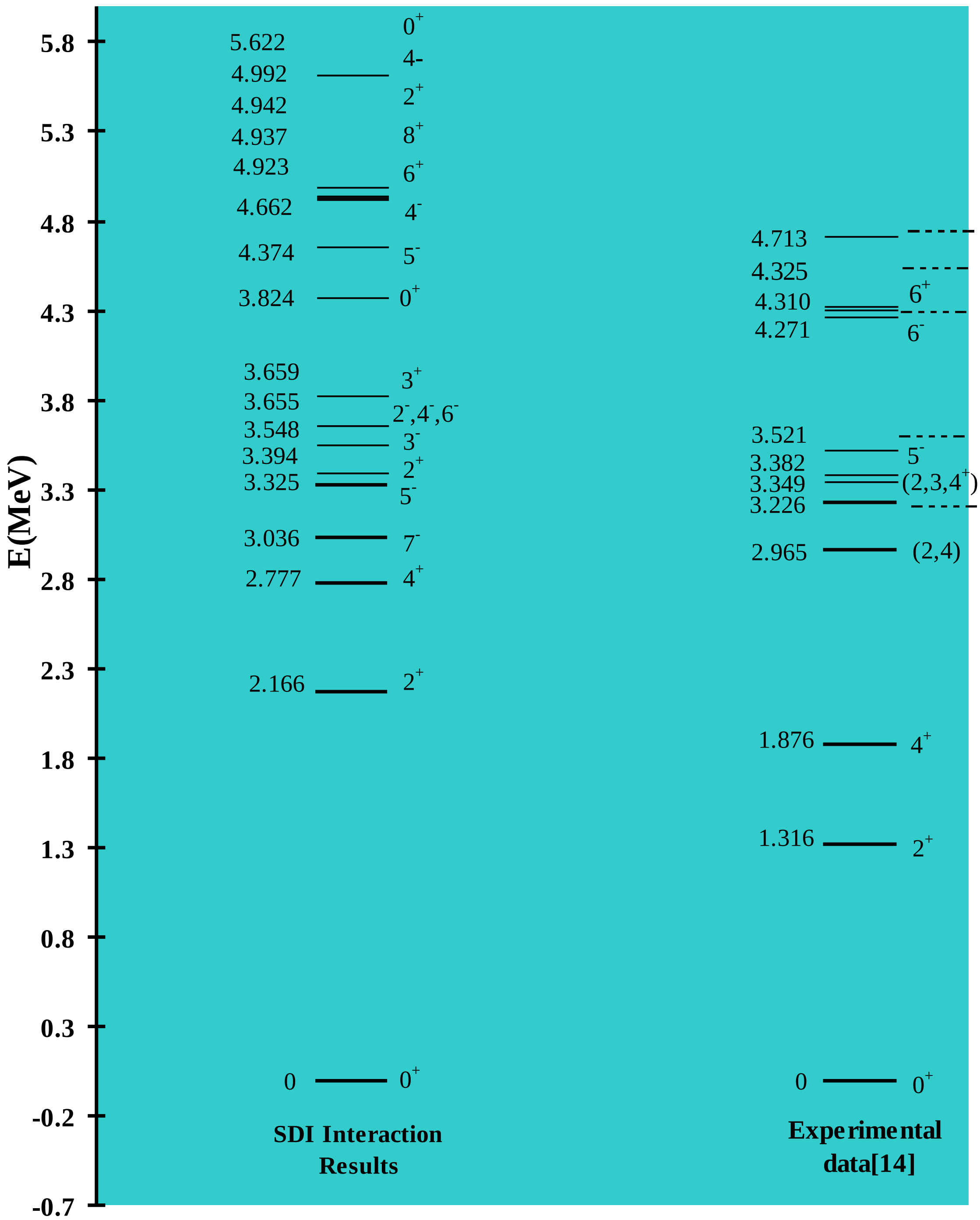

Figure (3):Theoretical and experimental energy levels[14] and spins of ^{72}Se nucleus using surface delta interaction

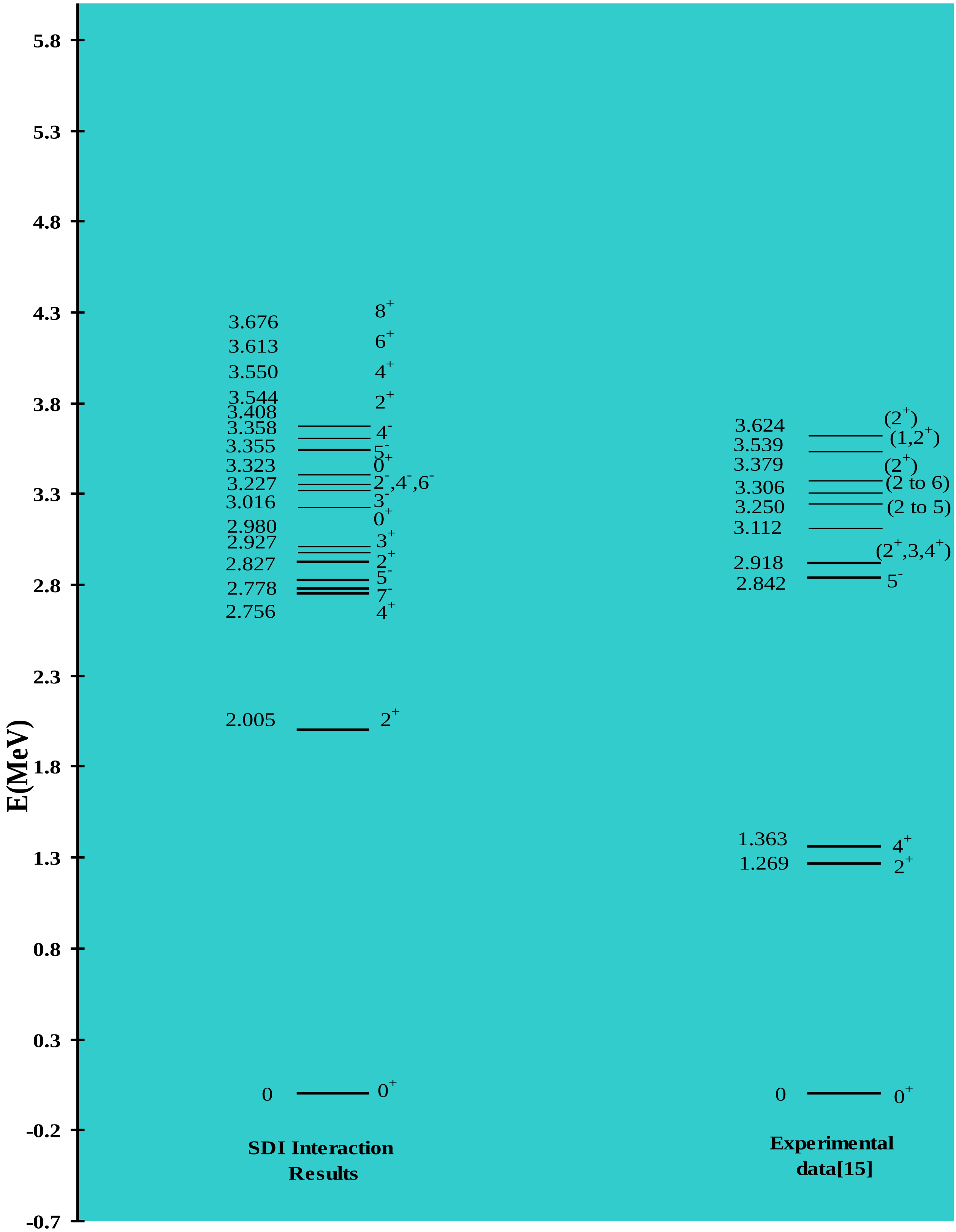

Figure (4):Theoretical and experimental energy levels[15] and spins of ^{74}Se nucleus using surface delta interaction

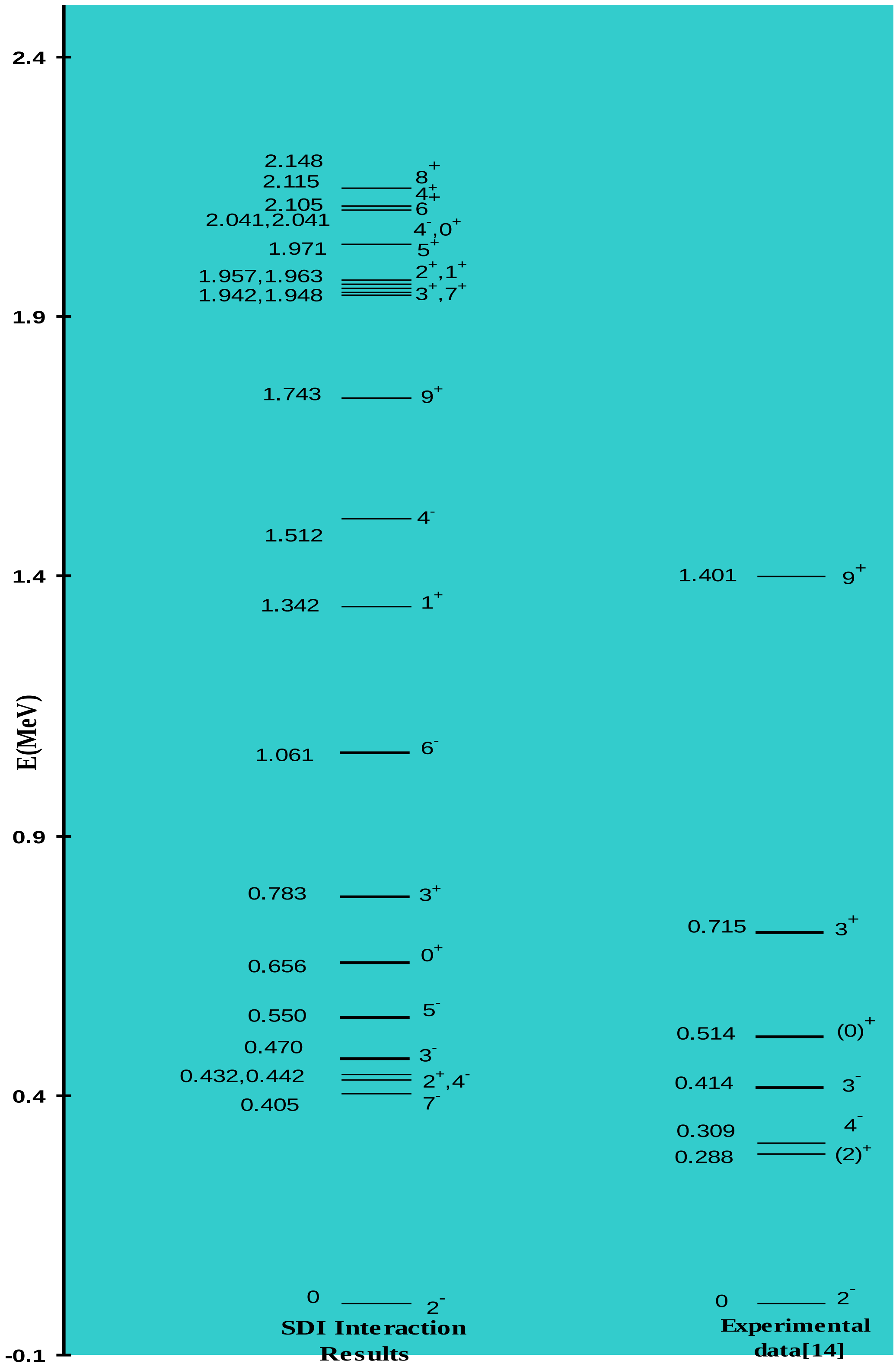

Figure (5):Theoretical and experimental energy levels [14]and spins of ^{72}As nucleus using surface delta interaction

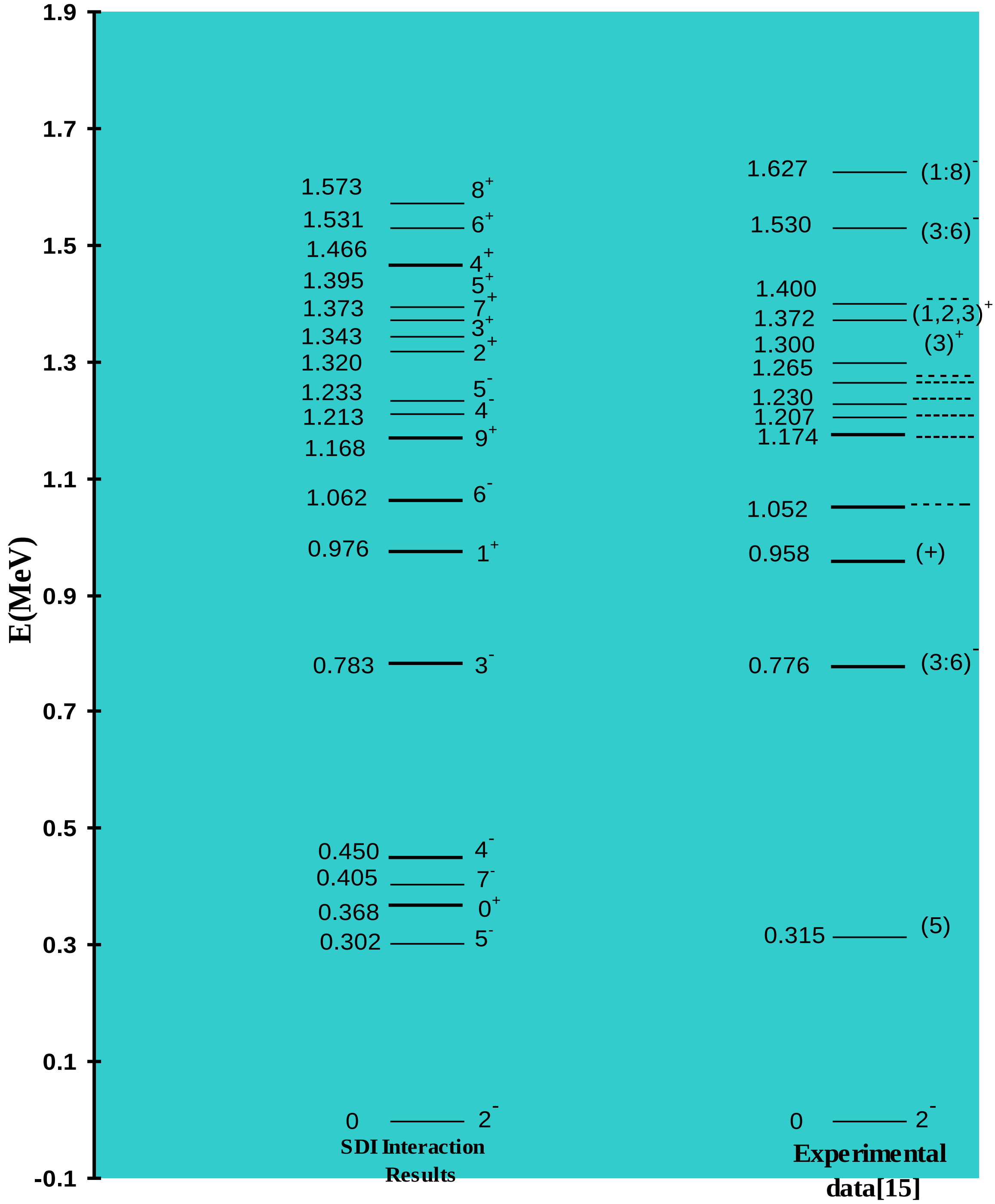

Figure (6):Theoretical and experimental energy levels[15] and spins of ^{74}As nucleus using surface delta interaction

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