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DIFFERENT CORE INTERACTING BOSON-FERMION MODEL AND SPECTROSCOPIC FACTOR ANALYSIS

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ABSTRACT

The level structure of 125Te by considering 124Te as a core for positive parity low-lying states has been investigated. Spectroscopic factor for both pick-up and stripping reactions were deduced according to the Interacting Boson-Fermion Model(IBFM) and compared with experimental results. Considering 126Te as a core gives best description to the 125Te nucleus.

Introduction:

Low-lying level scheme of the near magic nuclide 125Te73 has been investigated using different experimental techniques[1-4]. The 125Te nucleus, with 73 neutrons fill the orbit below the major shell closure at N = 82. The positive-parity states mainly governed by coupling a single fermion (neutron hole) from the 1g7/2, 2d5/2, 2d3/2 and 3s1/2 to the even-even core.

The 125Te can be produced through two different reactions, one pick-up reaction on 126Te and another is the stripping reaction on 124Te nucleus. For the pick-up reaction, the core nucleus will be the 126Te which has five bosons only. Investigating the low-lying positive-parity states of 125Te nucleus with 126Te even-even core in the framework of the Interacting Boson-Fermion Model (IBFM), were reported in refs.[4,5] using multilevel calculations.

For stripping reaction, the core nucleus is 124Te, which has six bosons, so it should loss one hole in order to construct the 125Te nucleus.

Theory: IBFM

In the IBFM, odd-A nuclei are described by the coupling of the odd fermionic quasiparticle to a collective boson core. The total Hamiltonian can be written as the sum of three part

$$H = H_B + H_F + H_{BF} \quad ....(1)$$

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where HB is the usual IBM-2 Hamiltonian[6] for the even-even core, HF is the fermion Hamiltonian containing only one-body terms.

$$H_F = \sum \varepsilon_j \overset{+}{a}_{jm} a_{jm} \quad ......(2)$$

Where εj are the quasiparticle energies and a+jm ajm is the creation (annihilation) operator for the quasiparticle in the eigen state 1jm>.

The boson-fermion interaction, VBF that describes the interacting between the odd quasi-nucleon and the even-even core nucleus contains, in general, many different terms and is rather complicated, but has been shown to be dominated by the following three terms:

$$V_{BF} = \sum_j A_j [(\overset{+}{d} \, x \, \tilde{d})^0 \, x (\overset{+}{a}_j \, x \tilde{a}_j)]^0 +$$

$$\sum_{jj'} \Gamma_{jj'} [Q^2 \, x (\overset{+}{a}_j \, x \tilde{a}_j)^2]^0_0 +$$

$$\sum_{jj'j''} \Lambda^{j''}_{jj'} :[(\overset{+}{d} \, x \tilde{a}_j)^{j''} \, x (\overset{+}{a}_j \, x \tilde{d})^{j''}]^0_0 : \quad .....(3)$$

where the core boson quadrupole operator,

$$Q^2 = (\overset{+}{s} \, x \tilde{d} + \overset{+}{d} \, x \tilde{d})^2 + \chi (\overset{+}{d} \, x \tilde{d})^2 \quad ....(4)$$

and χ is a parameter shown by microscopic theory to lie between $\pm \frac{\sqrt{7}}{2}$, s, d , s+ ,d+ are boson operators with $\tilde{a}_{jm}$ = (-1)j-m aj-m and ::

denotes normal ordering where by contributions that arise from commuting the operators are neglected. The first term in VBF is a monopole interaction which plays in a minor role in actual calculations. The dominant terms are the second and third, which arise from the quadrupole interaction. The third term represents the exchange of the quasiparticle with one of the two fermion forming a boson and has shown that this exchange force is a consequence of the Pauli principle on the quadrupole interaction between protons and neutrons. The remaining parameters in equation (3) can be related to the BCS occupation probabilities, uj , vj of the single particle orbits. The Hamiltonian of equation(1) was diagonals by means of the computer program ODDA [7] in which the IBFM parameters are identified as: A0 = BFM, Γ0 = BFQ and Λ0 = BFE .The electromagnetic transition operators can be written as the sum of the two terms, the first of which acts only on the boson part of the wave function, and the second acts only on the fermions part in equation (1) .In the IBFM the E2 operator is

$$T^{(E2)} = e_B Q^{(2)} + e_F \sum Q_{j'} (a_j \, x \, \tilde{a}_j)^2 \quad ....(5)$$

Where eB and eF are the boson and fermion effective charges

The M1 operator is

$$T^{(M1)} = \sqrt{\frac{30}{4\pi}} g_d (\overset{+}{d} \, x \, \tilde{d})^{(1)} - \sum g_{jj'} [j(j+1)(2j+1)4\pi]^{1/2} (a_j \, x \, \tilde{a}_j)^{(1)} \quad ..(6)$$

Where gB is the boson g-factor determined by the even-even core, and gjj' is the single particle contribution which depends on gland gs (orbital and spin g-factor) of the odd nucleon.

Transfer Reaction Amplitudes:

One-nucleon transfer reactions are an important tool to test the structure of the wave functions. Analysis of spectroscopic factors within the framework of IBFM, presents a two-fold interest. Firstly, it represents a stringent test of validity for the model and secondly, its operators are fermionic character only.

Two different IBFM one-particle transfer transition operators can be considered. One deal with reactions where a fermion is added to an even-even core and thus the number of bosons is conserved (pick-up reaction) and can be written as:

$$\overset{+}{A}_{jp} = [\zeta_j \, a_j] + \sum [\zeta_{jj'} (\overset{+}{s} \, x \, \tilde{d} \, x \, \overset{+}{a}_j)^{(j)}]_p \quad ..(7)$$

The second operator deals with the reaction where a boson is broken up and one fermion is taken away, leaving the final nucleus with one boson less and one fermion more (stripping reaction)

$$\overset{+}{B}_{jp} = [\theta_j \, a_j] + \sum [\theta_{jj'} (\overset{+}{d} \, x \, \overset{+}{a}_{j'})^{(j)}]_p \quad ....(8)$$

The ζ and θ coefficients can be expressed in terms of BCS occupation probabilities of single particle levels with total angular momentum j. The transfer strengths are then given by

$$S_{\ell j}(J_i \to J_f) = \frac{1}{(2j+1)} \left| \left\langle J_f \right| \overset{+}{A}_j + \overset{+}{B}_j \left| J_i \right\rangle \right|^2 ..(9)$$

Results and Discussions:

- **Energy levels and Electromagnetic calculations:**

In the description of the low-lying positive parity states of 125Te nucleus using 124Te as a core in the framework of the IBFM, a multilevel calculation is used. The core parameters used are taken from ref.[6]. The levels included in this calculation are 3s1/2, 2d3/2 and 2d5/2.

In Fig.(1) a comparison between experimental and calculated energy levels are shown. Firstly, the same values for the single particle, quasi-particle energies and occupation probabilities of ref.[5] are used. The IBFM parameters to fit the energy levels are: BFQ= -0.229, BFE= 1.466 and BFM= -0.375 MeV. The energy levels predicted are shown in Fig.(1,a). The energy level 5/2 appears lower than the level 7/2 in the first band. However, the same case also appears with the super symmetry calculation of ref.[8]. Compared with experimental the spacing between levels are acceptable. The average percentage deviation between experimental and IBFM (124Te as a core) prediction is 34%, while in the case of 126Te as a core, was 15% (second column in Fig.(1)).

An attempt has been made in order to make the agreement, between the experimental and IBFM prediction in both sequence and energy levels, better by changing the occupation probability of the levels included in the calculations. The occupation probabilities used for the levels are 0.55, 0.108 and 0.846 respectively. The IBFM parameters used are BFQ= 0.61, BFE= -0.769 and BFM= -0.885 MeV. The IBFM energy levels predications are shown in Fig. (1,b). Although, the sequence of the two levels in the first band (5/2 and 7/2) are modified and become as in the experimental levels, but the case is reversed in the last band between the levels 3/2 and 5/2. Moreover, the average percentage deviation between experimental and IBFM prediction is very high and cannot be accepted.

The parameters used in both cases, shows a major effect for quadrupole and exchange interactions in constructing the level sequence and spacing.

The three new levels at 402, 538 and 653 keV from (n, γ) reaction suggested experimentally by ref.[3] with assignments 3/2+, 1/2+ and (3/2, 5/2)+ respectively, can not be confirmed with present IBFM analysis. Moreover, nuclear structure studies of 125Te with (n,γ), (d,p) and (3He,α) reactions by Honzatko et al.[4] had no suggestion about any states with these energies and assignments.

The wave function obtained by diagonalization of the IBFM Hamiltonian by the computer code ODDA have been used by the code PBEM to calculate the reduced transition probabilities for E2 and M1. In these calculations the values of the parameter used are E2SD= 0.27 e.b., E2DD= -0.18 e.b. Table (1) shows a comparison between the present calculations with the experimental and theoretical works. Experimental and present calculations for most transitions for both B(E2) and B(M1) calculations show poor agreement, while in the case of 126Te core the agreement is quite good.

- **b) Spectroscopic Factor:**

The nucleus 125Te has been studied experimentally by both pick-up and stripping reactions.

In Fig.(2) experimental spectroscopic factor for both pick-up and stripping reactions for the levels 1/2, 3/2, 5/2 and 7/2, are compared with the IBFM predictions.

The pick-up IBFM spectroscopic factors are in good agreement with the experimental results. This can be attributed to the good agreement reached between experimental and the IBFM prediction for energy levels and electromagnetic transitions when 126Te nucleus used as a core[5].

In the stripping spectroscopic factor, and also as its results are connected with the energy level distribution, the agreement between experiment and IBFM prediction is not quite well. However, this is only for the levels 5/2 and 7/2. Moreover, there is a discrepancy in the stripping reaction strength between experimental results as well. The same situation have been noticed especially for the level 7/2 in the super symmetry studies of ref.[8]. Although, it had been mentioned that for the stripping reactions, the absolute value of the spectroscopic factors need to be normalized to the experimental value[8], the spectroscopic factor value in this work are not normalized to the experimental value. Comparison between experimental and the IBFM prediction for stripping reaction are also shown in Fig.(2).

Conclusion

The spectra for the odd-neutron nuclei are very complex, resulted from the deformation of the even-even core in this region. Describing 125Te nucleus with 126Te core gives very good results for energy levels, electromagnetic transitions, quadrupole and magnetic moments and the spectroscopic factors. No evidence for new positive-parity levels in low-lying states.

The stripping reactions, especially for odd-neutron nuclei, seem to give inaccurate results when analyzed with IBFM.

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Table(1)
B(E2)(e^2b^2) and B(M1)(μ^2_N) values in comparison for both experiment and IBFM calculations.

Transition $2J_i$ $2J_f$	B(M1) (μ^2_N) Exp.[4]	B(M1) Theo.[4]	B(M1) present ^{124}Te core	B(M1) present ^{126}Te core	B(E2) (e^2b^2) Exp.[4]	B(E2) Theo.[4]	B(E2) present ^{124}Te core	B(E2) present ^{126}Te core
3_1 1_1	$0.398x10^{-1}$	$0.532x10^{-3}$	0.0083	0.037	$0.378x10^{-1}$	$0.721x10^{-2}$	0.0411	0.0186
3_2 1_1	$0.232x10^{-2}$	$0.625x10^{-3}$	0.010	0.0022	$0.89x10^{-1}$	$0.352x10^{-1}$	0.4769	0.0414
3_2 3_1	$0.351x10^{-2}$	$0.584x10^{-3}$	0.0094	0.0012	$0.679x10^{-1}$	$0.369x10^{-2}$	0.0633	0.0536
5_1 3_1	$0.215x10^{-1}$	$0.912x10^{-4}$	0.004	0.0096	$0.486x10^{-1}$	$0.238x10^{-1}$	0.8602	0.0378
7_1 3_1					$0.178x10^{-1}$	$0.394x10^{-1}$	0.3164	0.0269
7_1 5_1	$0.216x10^{-2}$	$0.194x10^{-5}$	0.0041	0.001	$0.15x10^{-5}$	$0.635x10^{-2}$	0.2709	0.0006
7_2 3_1					$0.1x10^{-2}$	$0.279x10^{-2}$	0.2884	0.0053
3_3 1_2	$0.326x10^{-2}$	$0.183x10^{-2}$	0.0093	0.0265				
3_3 3_2	$0.312x10^{-2}$	$0.786x10^{-2}$	0.0015	0.0041				
3_3 3_1	$0.238x10^{-2}$	$0.159x10^{-2}$	0.0004	0.0003				
3_3 1_1					$0.150x10^{-2}$	$0.150x10^{-2}$	0.1813	0.0022
5_2 5_1	$0.673x10^{-1}$	$0.358x10^{-1}$	0.0249	0.0044	$0.22x10^{-1}$	$0.110x10^{-3}$	0.0006	0.0007
5_2 3_2	$0.278x10^{-1}$	$0.648x10^{-1}$	0.0497	0.0115				
5_2 3_1	$0.922x10^{-1}$	$0.618x10^{-2}$	0.0045	0.0157	$0.36x10^{-1}$	$0.184x10^{-1}$	0.0516	0.0313
5_2 1_1					$0.438x10^{-1}$	$0.269x10^{-1}$	0.5914	0.0496
7_2 3_2					$0.37x10^{-3}$	$0.429x10^{-3}$	0.4277	0.0012

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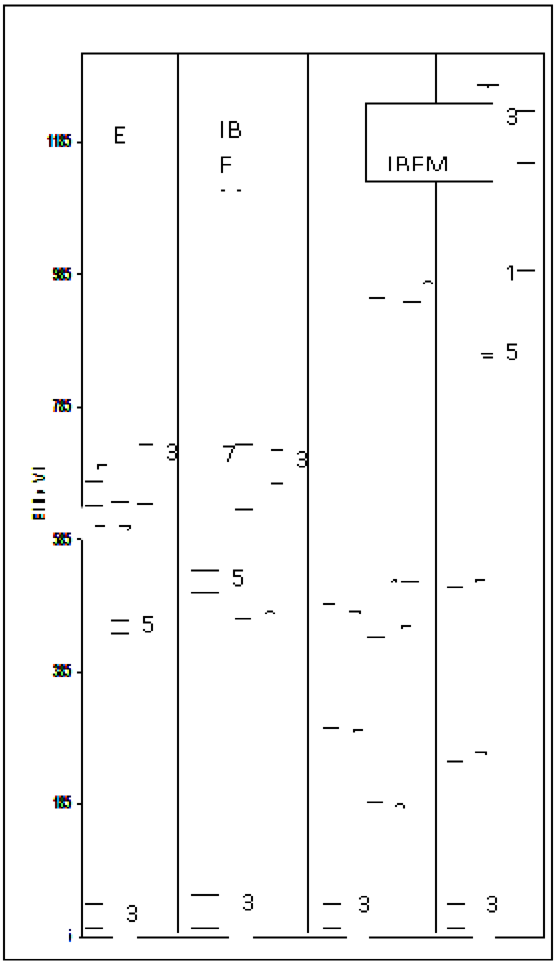

Fig. (1): Experimental and calculated positive –parity levels of Te-125 .Spin values are shown multiplied by two.

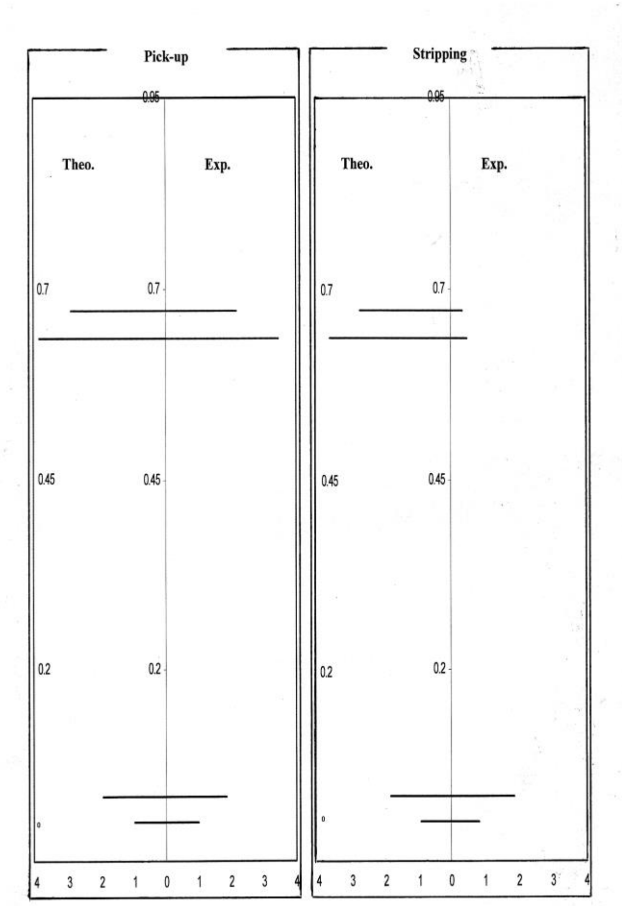

Fig.(2): The experimental and theoretical Spectroscopic Factor for low lying positive –parity levels for ^{125}Te. The x-axis is the Spectroscopic Factors and the y-axis represents the energy levels in MeV .

التحليل باستخدام قلب مختلف بواسطة نظام تفاعل البوزون–فرميون وحساب العامل الطيفي

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الخلاصة

تم دراسة تركيب المستويات في الـ125Te باعتبار 124Te كقلب بالنسبة للمستويات ذات البرم الموجب. العامل الطيفي لكلا التفاعلين الالتقاط والفظي تم حسابه من خلال نظام تفاعل البوزون–فرميون، وقورنت النتائج مع النتائج العملية. اعتبار 126Te كقلب يعطي وصف أفضل من اعتبار 124Te كقلب.