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EFFECTIVE INTERACTIONS IN p-SHELL NUCLEI AND THE REALISTIC INTERACTIONS - I

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ABSTRACT

The effective interaction of Jain et al. derived from the Yale interaction by including the prominant core polarization diagrams is analyzed in terms of the interaction radial integrals and their spin tensor components. The interaction is also compared with some phenomenological effective interactions. The general features of the effective force in the ^{1}p shell region are discussed.

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The various approaches to determining the effective interactions in the finite nuclei could be divided into two categories. In the phenomenological approach, one parametrizes the interaction to best fit a set of properties of the nuclei under consideration. In the second approach, one starts with the free nucleon-nucleon interaction and evaluates various corrections to it arising out of the admixtures of the necessary configurations. The latter technique would have been most satisfactory but for the uncertainties[1] in the quantitative reliability of various approximations invoked upon to evaluate the various diagrams. More rigorous techniques are desirable. On the other hand, in the phenomenological approach, various renormalizations are implicitly included. However it is difficult to determine some parameters unambiquously. In fact, it is possible that a number of interactions, having widely different features, give equally good fits to the observed nuclear properties. For example, in the p-shell region, a number of effective interactions have so far been given by various authors[2)-4)] Recently Kumar[4)] has derived an effective interaction for the p-shell nuclei. He observes that his interaction has some different features with relation to the interaction by Cohen and Kurath (CK)[2)], particularly in the non-central components. For example, even the sign of the otherwise believed to be well established triplet even (TE) tensor force is in disagreement. In this respect, it would be useful to be guided by the effective interaction derived from a realistic interaction.

Jain et al. (JMW)[5] have taken the effective interaction ($\mathcal{K}$) of Shakin et al.[6] as the starting base for the study of the p-shell nuclei. They have included prominent core polarization contributions, namely the three particle - one hole (K_{3p-1h}) two particle and two hole ($K_{2p} + K_{2h}$) diagrams. The values the single-particle energies and size-parameter taken by them are the experimental ones. The JMW interaction, however, does not reproduce well the observed energy spectra. This should not dissuade us from using this interaction because though it is not the 'true' interaction, it is an improvement over the bare interaction.

In this paper, we discuss the spin-tensor structure of the JMW interaction and the changes resulting from the inclusion of the prominant core-polarization diagram. The phenomenological interactions of Kumar and CK have also been compared with the JMW interaction in terms of the radial integrals (RI) and their spin tensor components.

The RI of the JMW interaction along with those of CK and Kumar have been listed in table III. As expected, the central force components predominate. These are also seen to change considerably due to core-polarization. Among the central T = 1 forces, the most sizeable effect of core-polarization is on the odd state interaction making it more repulsive. The change is mostly due to the K_{3p-1h} term. When $K_{2p} + K_{2h}$ term is also added, the value comes out to be in between those of CK and Kumar. In the singlet even (SE) state[2], the interaction becomes more attractive by about 2 MeV due to core-polarization

effects. Both the K_{3p-1h} and $K_{2p} + K_{2h}$ diagram are substantial.

The central part of the T = 0 interaction in the singlet odd (SO) state becomes less repulsive when renormalization is done. K_{3p-1h} terms are seen to be more important.

Comparison of the JMW interaction with the phenomenological interactions reveals that Kumar's value of the SO central force is consistent with it while this force is attractive in CK. It should be noted here that the width of the T = 2 state of ^8Be at 27.48 MeV and channel spin ratio for it's 17.64 MeV state in $^7Li(p,\gamma)$ reaction depend rather sensitively on this interaction part[4]. Kumar has adjusted it to fit the observed values. For the triplet even (TE) state the renormalization results mostly from $K_{2p} + K_{2h}$ term and brings JMW interaction closer to both the CK and the Kumar values.

Let us now examine the spin-orbit components. In the triplet odd (TO) state, the spin orbit parts of the various interactions agree with one another. The $K_{2p} + K_{2h}$ and K_{3p-1h} contributions are of the same order of magnitude but of opposite sign in the JMW interaction. The triplet even (TE) interaction is much changed with the inclusion of the core-polarization effects. It changes the sign to become repulsive. The attractive values of this force component in the CK and Kumar interactions are inconsistent with the value of this force in the renormalized JMW interaction. The repulsive TE spin-orbit force in the JMW interaction is consistent with our calculations of the spin orbit splittings near 16_O [8] where we have shown that to reproduce observed splittings the TE spin-orbit force is required to be repulsive.

Next we examine the tensor components. The tensor force is changed considerably by core-polarization and results in the considerable enhancement in the coupled channel particularly due to $K_{2p} + K_{2h}$ contributions. The TO component is repulsive in all the three interactions. K_{3p-1h} and $K_{2p} + K_{2h}$ diagrams contribute in the opposite sense, the latter being larger in magnitude. TE tensor component is repulsive in the CK interaction which is contrary to the general belief[7]. In all the realistic interactions this force is attractive. Consistent with the accepted belief, this force component is attractive in both the Kumar and JMW interactions. The disagreement between the values of the TE tensor force in the CK and JMW interactions is just one case which brings out clearly that one should be vigilant about the choice of the interaction parameters. The study suggests that among the various fits obtainable, one should prefer the one which agrees with the realistic interaction, at least in general features.

Some general features of the effective interaction in the p-shell nuclei have also emerged from this study:

1. Central forces are seen to be most predominant. The central force in the even states is found to be strong and attractive whereas in the odd states, it is weaker and repulsive.[9]

2. The spin-orbit component in the odd state is attractive. It must be repulsive in the even state.

3. The tensor forces in the even state are in general stronger than the tensor forces in the odd state, odd state tensor force is in general repulsive. It is suggested that even state tensor force must be attractive.

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References

1) M.W. Kirson, Annals of Phys. (N.Y.) 66 (1971) 624, ibid 82 (1974) 345.

2) S. Cohen and D. Kurath, Nucl.Phys.73 (1965)1; 89 (1966) 707; A101 (1967)1; A141 (1970) 145.

3) Goldhammer, P., J.R.Hill and J.Nachamkin, Nucl.Phys.A106 (1968) 62.

4) N.Kumar, Nucl. Phys. A225 (1974) 221.

5) M.C.Jain, G.K. Mehta and Y.R. Waghmare, Phys.Rev.C3 1466(1971) M.C.Jain, Ph.D. thesis (I.I.T.) Kanpur, 1970),unpublished.

6) C.M.Shakin, Y.R. Waghmare, and M.H.Hull, Jr.Phys.Rev.161, 1006 (1967); C.M.Shakin, Y.R. Waghmare, M.Tomaselli and M.H. Hull, Jr., Phys.Rev.161, 1015 (1967).

7) K.P.Joshi, G.K. Mehta and Y.R. Waghmare, Phys.Rev.176 1154 (1968); K.P.Joshi and Y.R. Waghmare, Phys.Rev.C7,874 (1973)

8) G.K. Upadhyaya and K.P.Joshi, Nucl.Phys.(India)15B 225 (1973).

9) Schmittros, Ph.D. Thesis (Oregon State University).

TABLE - I

Break-Up of the L-S Coupled TBME of JMW Interaction in the Spin-tensor Components

TBME	Labelling	G Total value	G K=0 part	G K=1 part	G K=2 part
T = 1					
2021 V 2021	P_1	-3.245	-3.245	0	0
1121 V 1121	P_2	0.0282	0.169	-0.3211	0.181
1111 V 1111	P_3	-0.4161	0.169	0.3211	-0.905
1101 V 1101	P_4	2.6210	0.169	0.6422	1.81
0001 V 0001	P_5	-4.9325	-4.9325	0	0
T = 0					
2130 V 2130	P_6	-3.969	-4.18	-0.03	0.24
2120 V 2120	P_7	-5.0015	-4.18	-0.015	-0.84
2110 V 2110	P_8	3.2936	-4.18	-0.045	0.84
0110 V 0110	P_9	-7.2352	-7.2352	0	0
1010 V 1010	P_{10}	3.8266	3.8266	0	0
0110 V 2110	P_{11}	-2.0606	0	0	-2.0606

TABLE - II

Break-Up of the L-S Coupled TBME of JMW Interaction in the Spin-tensor Components

Labelling	$G + G_{3p-1h}$ Total Value	$G + G_{3p-1h}$ K=0 part	$G + G_{3p-1h}$ K=1 part	$G + G_{3p-1h}$ K=2 part	$G+G_{3p-1h} + G_{4p-2h} + G_{2s}$ Total Value	K=0 part	K=1 part	K=2 part
P_1	-3.018	-3.018	0	0	-4.1214	0	0	0
P_2	0.7638	0.8812	-0.3034	0.186	0.4477	0.7965	-0.3244	0.175
P_3	0.2545	0.8812	0.3034	-0.930	0.2429	0.7965	0.3244	-0.8780
P_4	3.3480	0.8812	0.6068	1.8600	3.2012	0.7965	0.6488	1.7560
P_5	-5.7454	-5.7454	0	0	-6.5306	-6.5306	0	0
P_6	-4.1286	-4.2159	-0.0435	0.1308	-4.3764	-4.6872	0.1766	0.1342
P_7	-4.652	-4.2159	0.02175	-0.4578	-5.2456	-4.6872	-0.0883	-0.4697
P_8	-3.693	-4.2159	0.06525	0.4578	-4.4822	-4.6872	-0.2649	0.4697
P_9	-7.1053	-7.1053	0	0	-9.5076	9.5076	0	0
P_{10}	2.9830	2.9830	0	0	2.8263	2.8263	0	0
P_{11}	-2.5246	0	0	-2.5246	-3.6357	0	0	-3.6357

TABLE III

COMPARISON OF RADIAL INTEGRALS

I_{nl}	CK[a]	Kumar[b]	JMW[c] K	JMW[c] K+K_{3p1h}	JMW[c] $K_{2p}+K_{2h}+K_{3p1h}$
Central Force Component (K=0)					
T = 1					
$I_{os}+I_{od}$	- 4.76	- 7.20	-6.490	-6.030	- 8.243
I_{op}	-13.80	0.38	0.1690	0.881	0.797
$I_{os}+I_{1s}$	-13.80	-11.68	-4.933	-5.745	- 6.531
T = 0					
I_{op}	- 0.29	2.35	3.827	2.983	2.826
$I_{os}+I_{1s}$	-16.76	-19.54	-14.470	-14.210	-18.015
$I_{os}+I_{od}$	-11.74	-11.16	- 8.360	- 8.432	- 9.374
Spin-orbit Force Component (K=1)					
I_{op}	- 0.54	- 0.64	- 0.642	- 0.607	- 0.649
I_{od}	- 1.027	- 0.28	- 0.030	- 0.043	0.177
Tensor Force Components (K=2)					
I_{op}	0.94	1.055	0.905	0.930	0.878
I_{od}	1.295	-1.615	- 0.666	- 0.458	-0.470
I_{1sod}	- 0.523	0.530	- 1.463	- 1.785	- 2.570

a. Ref. 2
b. Ref. 4
c. Ref. 5