ON THE INFLUENCE OF GROUND STATE CORRELATIONS ON THE PARTICLE-CORE STRUCTURE OF ^{39}K

M. Micklinghoff* and B. Castel
Physics Department, Quenn´s University, Canada

The low-lying spectrum of ^{39}K has been the subject of a large number of experimental and theoretical investigations. The early shell model calculations of Erné |1| and Maripuu |2| as well as the R.P.A. calculations of Goode and Zamick |3| dealt primarily with energy level predictions and only with moderate success. The present calculation for ^{39}K differs from the previous particle-core model |4| by taking explicitly into account the perturbation diagrams resulting from the particle-hole structure of the phonon and the ground state correlations in the ^{40}Ca core. These diagrams are shown to be important for the correct description of the low-lying energy levels of ^{39}K as well as for reproducing the observed spectroscopic strength of the negative parity states populated by pick-up reactions on ^{40}Ca |5|.

In the particle-vibration coupling Hamiltonian used |6|

$$H = H_c + H_p + H_{int} + H_{pairing}$$

the properties of the core Hamiltonian H_c were derived from the experimental spectrum of ^{40}Ca |7|. The interaction Hamiltonian H_{int} involved a quadrupole-quadrupole and octupole-octupole interaction with strength $\langle k \rangle =$ $= 20$ MeV |8|. Finally, the single hole states $d_{3/2}$, $s_{1/2}$ and $d_{5/2}$ were included together with the 1p-2h states $|(d_{3/2})^{-2}_{J=0}\; j\rangle$ with $j = f_{7/2}$, $f_{5/2}$ and $p_{3/2}$ using a pairing strength $G = 1.2$ MeV.

In order to antisymmetrize the particle-phonon wave

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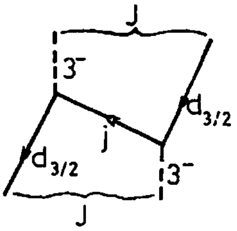
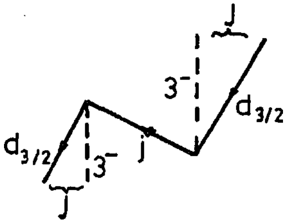
[*] Present address: I. Institut für Theoretische Physik, Universität Hamburg.

functions the following diagrams were included |9,10|





These second-order diagrams correspond to an energy shift of $\Delta E = -0.19$, 0.29, 0.42 and 0.04 for $J = 3/2^-$, $5/2^-$, $7/2^-$ and $9/2^-$ and are important for a correct correspondence between the states of the $|d^{-1}_{3/2} \times 3^-\rangle$ multiplet and the collective states strongly excited in deuteron inelastic scattering experiment |11|.

In Table 1 we compare the calculated energy levels

TABLE 1

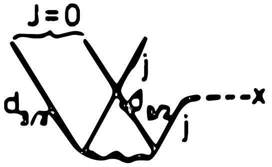
Energy levels, spectroscopic factors and E3 transition rates in ^{39}K

Energy (MeV)		J	C^2S		$B(E3;\ J\rightarrow g.s.)(e^3 fm^6)$	
Exp.	Calc.		Calc.	Exp.	Calc.	Exp.
0	0	$3/2^+$	3.87	4.23		
2.52	2.36	$1/2^+$	1.90	1.62		
2.81	2.73	$7/2^-$	0.37	0.46	500	550
3.02	3.05	$3/2^-$	0.08	0.04	3197	3411
3.60	3.85	$9/2^-$			2756	<2200
(3.88)	4.02	$5/2^-$	0.06			
	4.16	$5/2^+$	0.12			
	4.20	$3/2^+$				
4.10	4.27	$1/2^+$	0.09	0.17		
	4.57	$7/2^-$	0	0		

with the states observed below 5 MeV |7|. Good agreement is achieved for the six states for which there exists definite spin assignment. In our model, the $J = 7/2^-$ member of the multiplet is the highest because of the inclusion of the 1p-2h states in our model space which modifies the perturbation energy diagram for that state.

The calculated spectroscopic factors are given in Table 1 together with the results of a pick-up reaction on ^{40}Ca |5|. The spectroscopic factors of the negative parity states deserve special attention since they would be non-existent if no core ground state correlations were included. After diagonalisation the negative parity states can be expressed as $|\Psi_j\rangle = \alpha|(d_{3/2})^{-2}_{0} \times j\rangle +$ $+ \beta|(3^- \times d^{-1}_{3/2})j\rangle + \ldots$. The spectroscopic factors are then given by $C^2S = (2j + 1)\ [\alpha A + \beta B]^2$ with

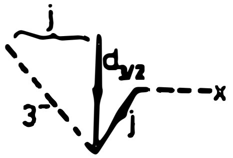
A =



$$= \frac{G}{(\varepsilon_{d_{3/2}} - \varepsilon_j)}\ \frac{\sqrt{3}}{2}$$

and

B =



$$= \frac{\langle(\lambda \times d_{3/2})_j|H_{int}|j\rangle}{\varepsilon_{d_{3/2}} - \varepsilon_j - \hbar\omega}$$

The first diagram is due to the short range core correlations and the second one results from the octupole-octupole part of the interaction |12|. It is interesting to notice that the relatively large spectroscopic factor of the first excited $J = 7/2^-$ state is due to a constructive interference of the two contributions whereas the vanishingly small value of $C^2S((7/2^-)_2) = 1.8 \times 10^{-5}$, due to a destructive interference, is consistent with the fact that no pick-up strength has been observed for that state.

The only well established transition rates are those observed in the decay of the first four excited states. Our calculated value for $B(E2: 1/2^+ \rightarrow 3/2^+) = 47\ e^2fm^4$ agrees well with a recent experiment ($44\ e^2fm^4$) |13|. As for the E3 rates they are given in Table 1 and show a good correspondence with the measured values |14|.

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