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A CONTRIBUTION TO THE QUASI-PARTICLE DESCRIPTION OF SPHERICAL NUCLEI

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ABSTRACT

A central force with only the singlet component is used to solve the BCS-Baranger equations for some single-closed 82-neutron nuclei and the resulting wave functions are in turn used to calculate some excited levels of even-even nuclei. The roles of the quasiparticle residual terms are studied and within Tamm-Dancoff approximation (TDA) certain conditions are found to be necessary for the theory to agree with the experimental trends of the energy spectra, the enhanced 2+ → 0+ ground state and retarded 4+ → 2+ transitions. For the quasiparticle interactions in TDA, a triplet force as strong as the singlet seems to be needed. A rough estimate of the lowest order ground state correlation is made for the enhanced 2+ → 0+ transition, and the contribution appears to be negligible.

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Description of the Problem.

In a spirit similar to that of Arvieu *et al* [1], the BCS plus Tamm-Dancoff Approximation (TDA) are applied to some single-closed 82-neutron nuclei, with special attention on Ce^{140}. Of interest are the level spectra of $J > 0$ states, the largely enhanced first $2+ \rightarrow 0+$ (ground state) transition, the large retardation of 4+ to 2+ transition and the gyromagnetic ratio of the 4+ state in Ce^{140}. Except for 0+ states which require an entended method [1], TDA seems to be sufficient.

(a) The single particle (shell model) levels are taken, in MeV, as $1g_{7/2}(0.)$, $2d_{5/2}(1.00)$, $2d_{3/2}(2.88)$, $1h_{11/2}(2.18)$, and $3s_{1/2}(3.20)$.

(b) The BCS-Baranger equations [3] are solved with the pairing matrix elements computed with $V_{SE} = -37.8$ MeV, r_o(= range) = 1.73F, and $V_{TO} = 0$. The strength is adjusted to fit the odd-even mass differences.

(c) The TDA equation is solved for $J > 0$ states with the unperturbed wave functions as given by the results of (b). A strong attractive V_{TO} ($\approx V_{SE}$) is found to be needed to fit the ground-to-2+ and 2+-to-4+ relative spacings.

(d) The B(E2) values for the $2+ \rightarrow 0+$ and $4+ \rightarrow 2+$ transitions are computed in TDA. The relevant transition matrix elements are

$$|\langle 0+|M(E2)|2+\rangle| = \sqrt{5}\,\Big|\sum_{a\geq b}\langle a\|er^2Y_2\|b\rangle(u_a v_b + v_a u_b)C_{ab2}\delta_{\kappa 2}\delta_{\mu-m}\Big| \quad (1)$$

and

$$|\langle 2+|M(E2)|4+\rangle| = \Big|\sum_{a\geq b}\sum_{a'\geq b'}(-)^{j_a+j_{b'}}C_{ab2}C_{a'b'4}\underline{P}(ab;a'b') \quad (2)$$

$$\{\langle a'\|er^2Y_2\|a\rangle\, W(42aa';2b')\,(u_a u_{a'} - v_a v_{a'})\delta_{bb'}\}\Big|\delta_{\mu,-(m+m')}$$

where C_{ab2} and $C_{a'b'4}$ are 2+ and 4+ wave function amplitudes respectively, W is the Racah coefficient, and $\underline{P}(ab;a'b')$ arranges the quantity in curly bracket so that all possible combination of aba'b' obtains <u>without changing the positions for the primed and unprimed labels</u>.

The large enhancement of B(E2;2+ → 0+) implies that the individual term in the sum of Eq. (1) contributes coherently. If one chooses the configuration (ab) such that $\langle a\|er^2Y_2\|b\rangle = \eta|\langle a\|er^2Y_2\|b\rangle|$, then C_{ab2} should be of the same sign in order to make the entire terms coherent. This condition favors a large V_{TO}/V_{SE} value. On the other hand, the interference in the contributions in Eq. (2) due to the configuration mixing, combined with retardation factor [Racah coefficient and (uu-vv) factor], is expected to reduce the matrix element [Eq. (2)] considerably. The effect of the ground state correlation on the B(E2;2+ → 0+) was also examined by introducing four-quasi-particle states into the ground state, and the result seems to indicate that the contribution is negligible.

(e) The TDA wave functions are used to compute the magnetic g factors of 4+ states. Around Ce^{140} (which is the only nucleus whose moment has been measured), the g factors for $g_{7/2}$ and $d_{5/2}$ are taken from neighboring odd-A nuclei, whereas the rest are just Schmidt values. The results do not depend on u and v factors, and hence may give a sensitive test for the configuration mixing computed in (c).

Comparison with Experiments.

The spectra of 2+, 3+, and 4+ states are given in Fig. 1 for some of the nuclei around Ce^{140} for which experimental results are more or less known. The radial wave function is the usual harmonic oscillator type with oscillator parameter $\nu^{-1/2} = 2,288F$. We varied the V_{TO}/V_{SE} around unity to fit the data.

The B(E2) values for $2+ \rightarrow 0+$ transition are experimentally known for Ba^{138}, Ce^{140}, and Nd^{142}. In the single particle unit $[B(E2)_{sp}]$, the theoretical results (for $V_{TO}/V_{SE} = 1.0$) are 11, 13, and 16 respectively, compared with experiments 14, 17, and 15. The present experimental knowledge of $4+ \rightarrow 2+$ E2 transition is scarce; compare the theoretical value of 1/28 to the experimental value of 1/17 for Ce^{140}. The later results are very sensitive to the components of the wave function, but at least the qualitative retardation is understood here.

The most recent magnetic g factor measurement for 4+ in Ce^{140} reports [4] $g_{4+}(Ce^{140}) = 0.95 \pm 0.10$ and our result $g = 0.92$ compares well with the experiment. In the quasi-particle configuration, such an agreement implies a dominant $(g^2_{7/2})$ configuration with other components mixed in. A variation of V_{TO}/V_{SE} shows again the V_{TO} should be sufficiently attractive.

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FIGURE CAPTION

1. Level spectra for $J\pi = 2+, 3+, 4+$. The far right entry in parenthesis corresponds to the dominant component of the wave function.

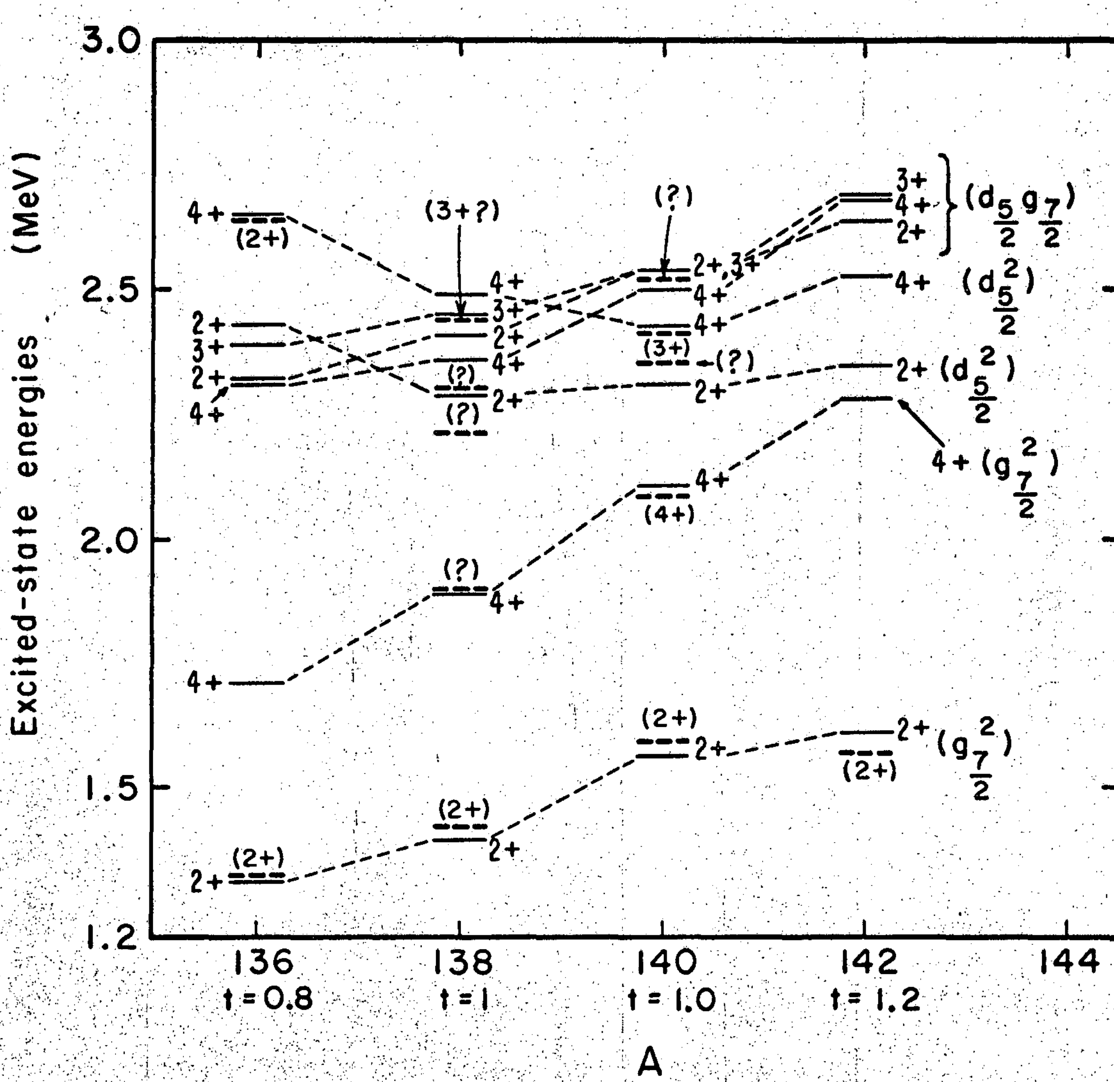

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Fig. 1

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