(3) Coupling of pairing and quadrupole vibrations. — Trial wave function can be expressed by means of a generator wave function depending on two parameters, β and Δ. It is proposed that the overlap integrals $O(\beta\Delta; \beta'\Delta')$ and $H(\beta\Delta; \beta'\Delta')$ be approximated with the Gaussian functions of $(\beta-\beta')$ and the method described above be used to treat the pairing vibrations.

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C2 The Pairing Vibrations

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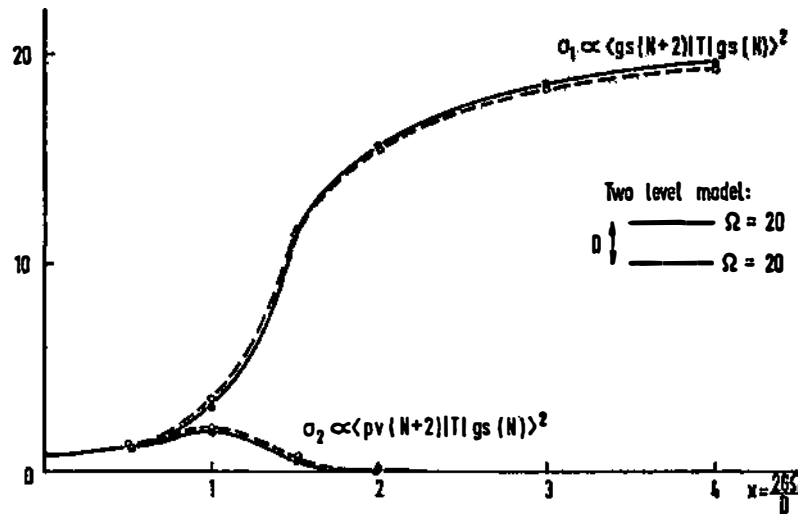
A new approach in calculating pairing vibrational states proposed earlier[1] is tested on a two-level model. The approximate eigenfunctions were constructed with the generator coordinate method

$$\Psi(x) = \int \Phi_N^{BCS}(x, \Delta) f(\Delta) d\Delta.$$



The N-projected BCS wave functions $\Phi_N(x, \Delta)$ were taken as basic functions and the quantity Δ as the generator coordinate. The matrix elements for the two body transfer reactions were calculated and compared with the exact

calculations of Broglia et al[2]. The transition rates from the ground state of the 38 nucleon system to the ground state (σ_1) and pairing vibrational state (σ_2) of the 40 nucleon system are presented in Fig. 1. The integral is replaced by a sum over 10 basic functions $\Phi_N^{BCS}(\Delta_i)$. 10 different values of Δ proved sufficient, although the exact dimension of the model is 21. After orthogonalization the basis is further truncated to the dimension 5.

Both nonsuperconducting and superconducting cases were treated in the same way. There were no irregularities in the transition region where the RPA calculations break down[2]. It is an important feature of the proposed method that it describes the transition region well, because the nuclei in this region may be expected to have pronounced pairing vibrational states.

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C3 An Approximate Method for the Projection of the Number of Particles

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For a system with one kind of interacting nucleons the N-projected BCS function can be written in the following form:

$$\psi_N(\Delta) = C \int_0^{2\pi} \frac{d\varphi}{2\pi} \langle e^{-in\varphi} \left(u_m(\Delta) + e^{i\varphi} v_m(\Delta) \cdot a_m^+ a_{-m}^+\right) | 0 \rangle .$$

Here $2n$ is the number of particles and Δ is the gap parameter. The last single-particle state before the Fermi surface is denoted by N_f. The ratios $\xi_m = \left(\frac{u_m(\Delta)}{v_m(\Delta)}\right)^2$ for $i < N_f$ and $\eta_m = \left(\frac{v_m(\Delta)}{u_m(\Delta)}\right)^2$ for $i > N_f$ as function of single-particle energies can be fitted by exponential curves.

The approximation is proposed where the ratios ξ and η are replaced by exponential functions. The new u and v deviate to some extent from the standard BCS values, but the projection is exact. Using this approximation the expectation value of the Hamiltonian can be expressed in a rather simple form.

The proposed approximation will be used as a basis for a given generator-coordinate function[1,2].

The approximate method is tested on a schematic model of 22 doubly degenerate equidistant levels as well as on Ni isotopes. For the schematic model

an additional approximation is used which drastically reduces the size of calculations. In the calculation of matrix elements the sums over the finite numbers of single particle states are replaced by infinite ones.

TABLE 1

The ground-state energy E relative to the energy of the lowest configuration. $\langle N\rangle$ and $\langle \Delta N\rangle^2=\langle N^2\rangle-\langle N\rangle^2$ is calculated with the N-projected BCS(PBCS), BCS and the proposed approximation (AP) for 22 particles in doubly degenerate single-particle levels.

$$H=\sum_k \varepsilon_k a_k^+ a_k - G\sum_{\substack{k>0\\ l>0}} a_k^+ a_{-k}^+ a_{-l} a_l;\quad G=0.415\,D,\ \varepsilon_k=kD.$$

method	E/D	N	ΔN
PBCS	−7.5718	22	0
BCS	−5.9011	22	5.56
AP	−6.4151	22	7.1×10^{-2}

TABLE 2

Ground state energy (MeV) relative to the energy of the lowest configuration for Ni isotopes; $G=0.331$ MeV and $\varepsilon(p_{3/2})=0$, $\varepsilon(f_{5/2})=0.78$ MeV, $\varepsilon(p_{1/2})=1.56$ MeV, $\varepsilon(g_{9/2})=4.52$ MeV.

A	$2n$	E_{PBCS}	E_{BCS}	E_{AP}
58	2	−1.4808	−1.1279	−1.4808
60	4	−2.0815	−1.5135	−1.8837
62	6	−3.2837	−2.6459	−2.9878
64	8	−3.5656	−2.9029	−3.1545
66	10	−2.9291	−2.2020	−2.6571

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C4 The Characterization of Collective States with Density Matrices

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1. Pairing vibrations

States with a high degree of pairing are characterized by having a large eigenvalue of the two-body density matrix $\varrho_{abcd}=\langle\Psi|a_b^+ a_a^+ a_c a_d|\Psi\rangle$. For exa-