

# Lawrence Berkeley National Laboratory

## Recent Work

### Title

ISOSPIN STRUCTURE OF PAIRING VIBRATIONS

### Permalink

<https://escholarship.org/uc/item/7z54881j>

### Author

Sorensen, Bent.

### Publication Date

1969

*by J*

ISOSPIN STRUCTURE OF PAIRING VIBRATIONS

RECEIVED  
LAWRENCE  
RADIATION LABORATORY

FEB 11 1969

LIBRARY AND  
DOCUMENTS SECTION

Bent Sørensen

January 1969

TWO-WEEK LOAN COPY

This is a Library Circulating Copy  
which may be borrowed for two weeks.  
For a personal retention copy, call  
Tech. Info. Division, Ext. 5545

LAWRENCE RADIATION LABORATORY  
UNIVERSITY of CALIFORNIA BERKELEY

*by J*

## **DISCLAIMER**

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Submitted to Second Conference on  
Nuclear Isospin, Asilomar, Pacific  
Grove, California, 13-15 March 1969

UCRL-18715  
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory  
Berkeley, California 94720

AEC Contract No. W-7405-eng-48

ISOSPIN STRUCTURE OF PAIRING VIBRATIONS

Bent Sørensen

January 1969

Isospin Structure of Pairing Vibrations.\* Bent Sørensen.† Lawrence Radiation Laboratory, Berkeley.-- The possible existence of an isospin structure in collective pairing-type excitations is discussed in connection with the confrontation of experimental data and a reliable pairing force calculation<sup>1</sup> which neglects isospin structure. Evidence for the isospin structure suggested by Bohr<sup>2</sup> is found in C, Mg, Si, Ti, and Ni isotopes.

---

\* This work was performed under the auspices of the U. S. Atomic Energy Commission.

† On leave from the Niels Bohr Institute, University of Copenhagen, Denmark.

1. B. Sørensen, Nucl. Phys. A97, 1 (1966).
2. A. Bohr, Proc. of Int. Symp. on Nucl. Structure, Dubna 1968.

CONFERENCE ON NUCLEAR ISOSPIN

ISOSPIN STRUCTURE OF PAIRING VIBRATIONS\*

Bent Sørensen†

Lawrence Radiation Laboratory, University of California  
Berkeley, California

A calculation of pairing-type states in the neighborhood of closed neutron shells all over the periodic table has been performed by applying the boson expansion method (1) to a system of like particles interacting via a pairing force with constant matrix elements. The purpose of this calculation was to exhibit the limitations of such a model and possibly point to the nature of the additional structure which might be required in different regions of nuclei.

This model in general provided a surprisingly good agreement with experiments, not only for excited levels believed to be pairing states, but also for the ground state energies after a correction for Coulomb energy. The parameters of the calculation are i) the single-particle levels, which were adjusted from those extracted from one-particle stripping experiments by sum-rule methods, in order to roughly reproduce the excitation energies of non-collective pairing states in the even nuclei adjacent to the closed neutron shells, and ii) the pairing strength, chosen as  $G = g A^{-1}(1-0.75(N-Z)A^{-1})$ , where  $g \approx 23$  depends somewhat on the number of configurations included. An explanation of the deviations which were found seems in all cases to require consideration of couplings to proton degrees of freedom. Two main sources of such couplings would be a) a quadrupole interaction, which adds to ground state correlations and produces jumps in the ground state energies when permanent deformation occurs, and which

\*This work performed under the auspices of the U. S. Atomic Energy Commission.

†On leave from the Niels Bohr Institute, University of Copenhagen, Denmark.

CONFERENCE ON NUCLEAR ISOSPIN

further produces low lying 0+ states which do couple with the pairing degrees of freedom, although in many cases not very much, and b) proton-neutron interaction which together with the pp and nn pairing interactions may have approximately the structure suggested by A. Bohr (2) of a T = 1 isospin pairing interaction

$$V_P = \frac{G}{4} \sum_{jj'} \left[ (a_{j'}^+ a_j^+)_{J=0}^{t=1} (\bar{a}_j \bar{a}_{j'})_{J=0}^{t=1} \right]^{T=0} \sqrt{3(2j+1)(2j'+1)} \quad (1)$$

plus a non-pairing type interaction, which splits the isospin multiplets. In case of a permanent pairing distortion this additional interaction may contain an iso-Coriolis force causing leading order energy shifts.

$$\Delta E_T = AT(T+1) \quad (2)$$

A phenomenological model for isospin and quadrupole interactions between pairing modes has been considered by Damgaard (3). The experimental evidence to be presented here seems to suggest an isospin structure which can be approximated by Eq. (2), although some of the nuclei involved are non-superfluid ( $^{12}\text{C}$ ,  $^{28}\text{Si}$ ,  $^{50}\text{Ti}$ ,  $^{68}\text{Ni}$ ).

The various statements made above are substantiated by Figs. 1-5, showing 0+ spectra of C, Mg, Si, Ti, and Ni isotopes. Possible evidence of similar structure is present in Ca. We plot the calculated pairing states by subtracting from the energies a term proportional to A, which makes the energies of the two even neighbors to each closed shell nucleus equal. Collective states are drawn with heavy lines. At each level are quoted (tp) cross sections from the ground state of the A-2 nucleus (arrow pointing right) and (pt) cross sections from the ground state of A+2 (arrow pointing left), normalized to the ground state transition. For each isotope the corresponding experimental evidence is placed to the right and in the middle we have added energy shifts following Eq. (2) to some of the theoretical pairing vibrational levels, and inserted the lowest quadrupole type 0+ state at twice the 2+ energy and with indication of the percentage of mixing with the ground state required for explaining the experimental sharing of strengths.

In  $^{22}\text{Mg}$  and  $^{42}\text{Ti}$  there is evidence of a strong increase in deformation. The calculated Ni spectra are combined results of starting the boson calculation either

CONFERENCE ON NUCLEAR ISOSPIN

at the  $N = 28$  or the  $N = 40$  closed shell. The pure neutron pairing calculation starting from  $N = 40$  fits all ground state energies except  $N = 28$ . In Fig. 5 the spectra of  $N = 28$  to 32 uses the  $N = 28$  basis.

References

- (1) B. Sørensen, Nucl. Phys. A97, 1 (1966).
- (2) A. Bohr, Proc. of Int. Symp. on Nucl. Structure, Dubna, 1968.
- (3) J. Damgaard, private communication.

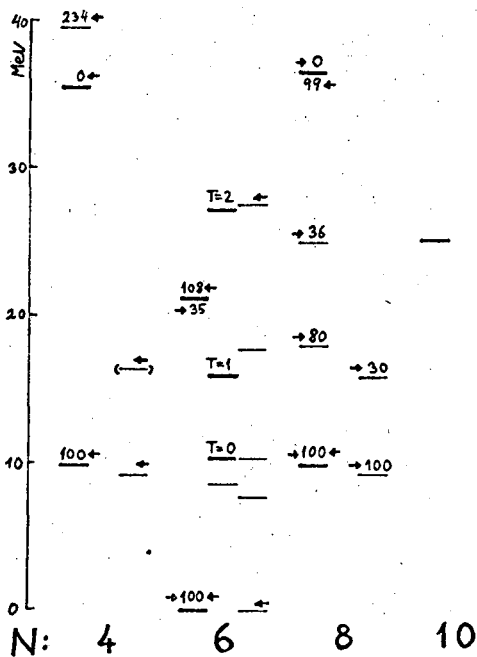


Fig. 1. C isotopes,  $G = 1.8$ .



CONFERENCE ON NUCLEAR ISOSPIN

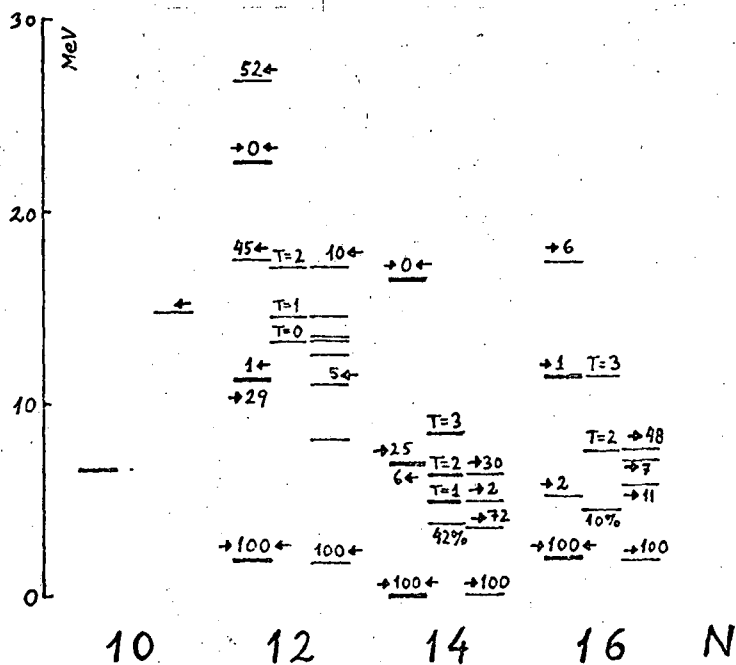


Fig. 2. Mg isotopes, G = 1.0.

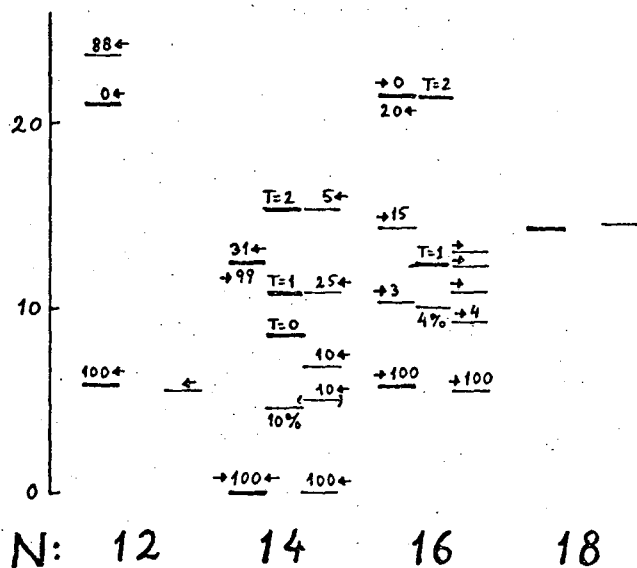


Fig. 3. Si isotopes, G = 0.9.

CONFERENCE ON NUCLEAR ISOSPIN

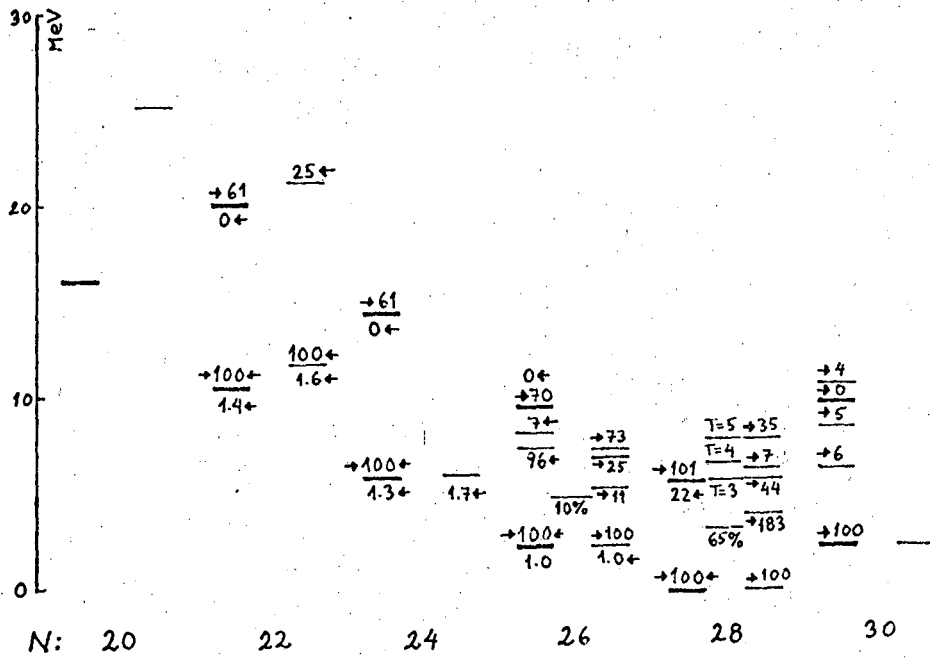


Fig. 4. Ti isotopes, G = 0.419.

CONFERENCE ON NUCLEAR ISOSPIN

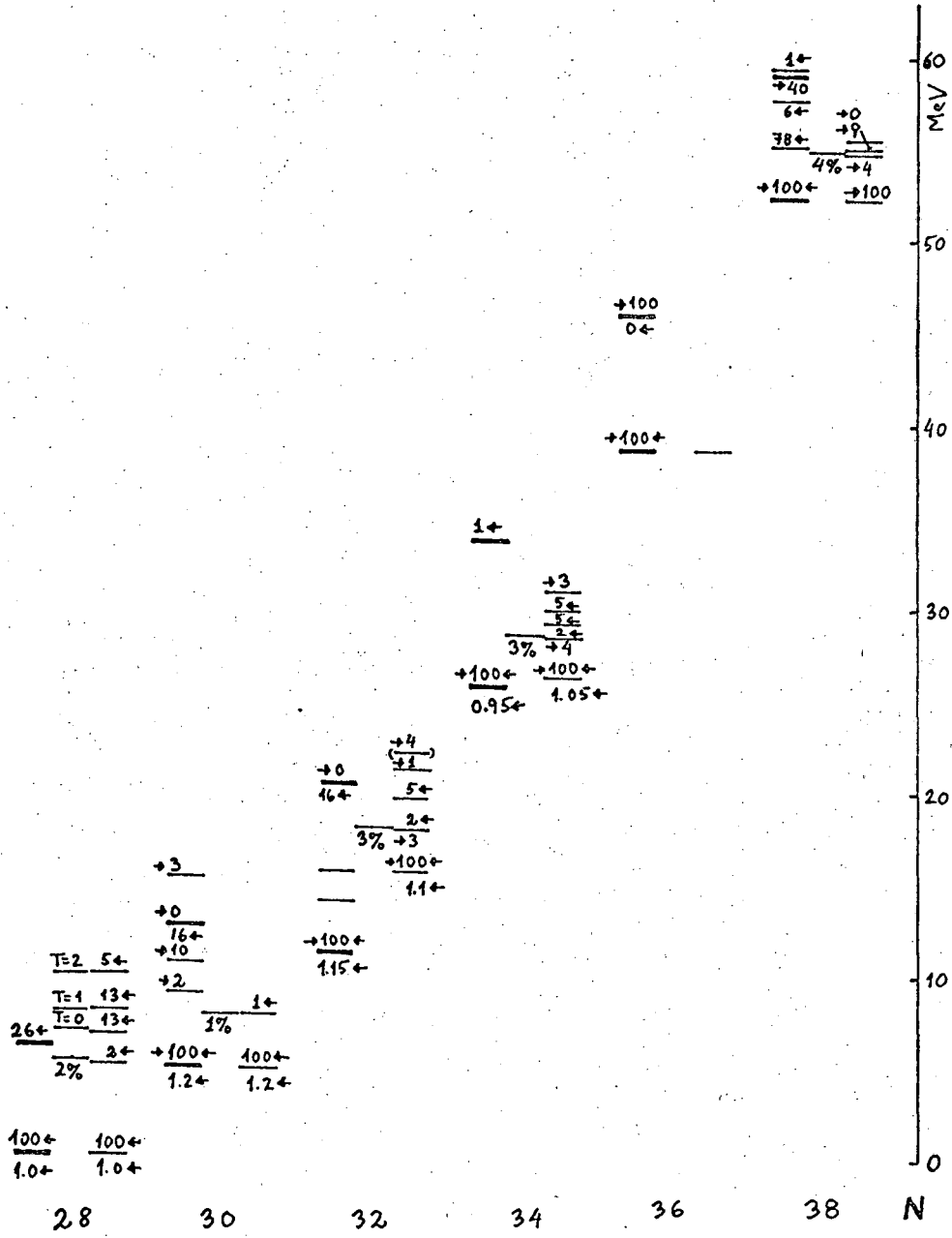


Fig. 5. Ni isotopes,  $G = 0.411$  at  $N = 28$ ,  
 $G = 0.293$  at  $N = 40$ .

LEGAL NOTICE

*This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:*

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or*
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.*

*As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.*

TECHNICAL INFORMATION DIVISION  
LAWRENCE RADIATION LABORATORY  
UNIVERSITY OF CALIFORNIA  
BERKELEY, CALIFORNIA 94720