

Importance of T=0 and T=1 pairing in light mass nuclei (N=Z)

Annanya Mahajan and H. M. Mittal

Department of Physics, Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, Punjab
(144008) India

1. Introduction

Pairing interactions are a fundamental aspect of nuclear structure, analogous to Cooper pairing in superconductors [1]. Traditionally, isovector (T = 1) pairing, corresponding to neutron-neutron (nn) and proton-proton (pp) correlations, has been extensively studied. However, in $N \approx Z$ light nuclei, the isoscalar (T = 0) neutron-proton (np) pairing can have a comparable or dominant role due to the proximity of proton and neutron Fermi surfaces [2]. Understanding T = 0 and T = 1 pairing is crucial for: explaining experimental binding energies and odd-even mass differences. Interpreting rotational properties such as back bending and alignment phenomena. Predicting band-head spins in superdeformed (SD) and normal-deformed (ND) bands. Pairing correlations play a pivotal role in the structure of atomic nuclei, affecting energy spectra, rotational properties, and band-crossing phenomena. In light mass nuclei, both isoscalar (T = 0) and isovector (T=1) pairing contribute significantly due to comparable numbers of protons and neutrons. This paper discusses the interplay of T = 0 and T = 1 pairing in light nuclei, emphasizing their influence on binding energies, rotational alignment, and back bending phenomena. The analysis is supported by theoretical calculations within the Woods-Saxon Cranked Shell Model (WSCSM) and schematic pairing models [3].

2. Theoretical Framework

The nuclear Hamiltonian including pairing can be expressed as:

$$H = H_{sp} + H_{pair}^{(T=1)} + H_{pair}^{(T=0)} \quad (1)$$

where H_{sp} is the single-particle Hamiltonian, $H_{pair}^{(T=1)}$ represents isovector pairing, and $H_{pair}^{(T=0)}$ represents isoscalar pairing. T = 1 pairing: Dominates between identical nucleons, important in nuclei far from $N = Z$. T = 0 pairing: Acts between neutron-proton pairs in time-reversed orbitals, influencing high-spin states and delayed alignment. In light nuclei, competition between these pairing modes modifies total Routhian surfaces (TRS) and band-crossing frequencies.

3. Role in Light Mass Nuclei (N=Z)

3.1 Binding Energy and Odd-Even Staggering

T = 1 pairing produces the traditional odd-even mass differences [4]:

$$\Delta^3(N) = \frac{(-1)^N}{2} [B(N+1,Z) - 2B(N,Z) + B(N-1,Z)] \quad (2)$$

where $B(N,Z)$ is the binding energy. Inclusion of T = 0 pairing slightly modifies the pairing gap, especially in $N \approx Z$ nuclei such as ^{20}Ne , ^{24}Mg , ^{36}Ar , and ^{40}Ca .

3.2 Rotational Alignments and Back bending

In the Cranked Shell Model, $T = 0$ pairing delays the alignment of neutron-proton pairs, resulting in back bending at higher rotational frequencies compared to $T = 1$ pairing.

4. Discussion

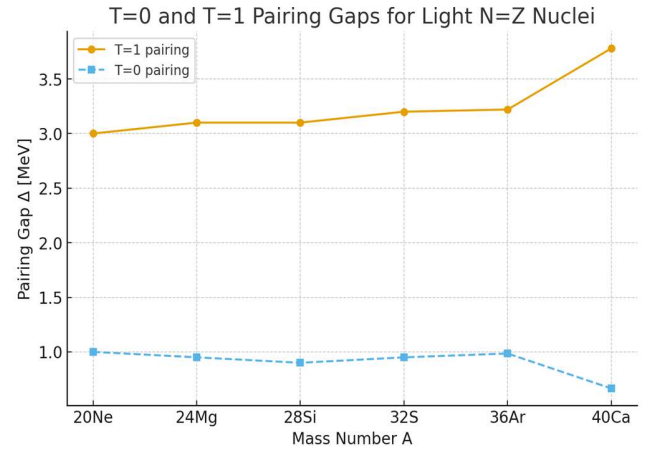
$T = 0$ pairing becomes significant in light $N \approx Z$ nuclei, influencing band head spins and high-spin behavior. Coexistence of $T = 0$ and $T = 1$ pairing explains observed delayed alignments and enhanced binding energies. Neglecting $T = 0$ pairing can lead to underestimation of rotational frequencies and misassignment of band head spins.

5. Conclusion

The interplay between $T = 0$ and $T = 1$ pairing is essential for a comprehensive understanding of light mass nuclei. $T = 1$ pairing governs the traditional pairing correlations, while $T = 0$ pairing introduces significant modifications in rotational spectra, high-spin behavior, and binding energies. Incorporating both pairing modes is crucial for accurate nuclear structure predictions in $N \approx Z$ nuclei such as ^{20}Ne , ^{24}Mg , ^{36}Ar , and ^{40}Ca .

Table 1: Representative pairing gaps for ^{20}Ne , ^{24}Mg , ^{36}Ar and ^{40}Ca .

Nucleus	$\Delta_{T=1}$ [MeV]	$\Delta_{T=0}$ [MeV]
^{20}Ne	3.00	1.000
^{24}Mg	3.10	0.950
^{36}Ar	3.22	0.985
^{40}Ca	3.78	0.665



Interpretation

The solid circles show $T=1$ (isovector) pairing, which is stronger and fairly stable around 3–4 MeV. The dashed squares show $T=0$ (isoscalar) pairing, which is weaker (≈ 0.6 –1 MeV) and slowly decreases with increasing mass number. This clearly illustrates that in light even-even $N=Z$ nuclei, $T=1$ dominates over $T=0$, while $T=0$ is still present due to pn correlations.

References

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