B(E2) and lifetime values in ^{118}Sn

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Introduction

In the experimentally observed nuclear level spectra, it is very rare to encounter pure configurations. More often, the actual nuclear states are complex mixtures of multiple components. However, in many, if not most of the cases, it is possible to retrieve of the underlying physics and make at least semi-quantitative calculations by employing a simple mixing technique. The present work demonstrates this fact for the case of the singly magic nucleus, ^{118}Sn.

Formalisms, Calculations, and Results

The Two-State Mixing Model[1] is applied in order to investigate the features of the low-lying 0^+ and 2^+ states belonging the nucleus, ^{118}Sn. These states are formed through a linear superposition of basis states as described in the following:
$|0_1^+\rangle = a|0_g\rangle + b|0_e\rangle$,
$|0_2^+\rangle = -b|0_g\rangle + a|0_e\rangle$,
$|2_1^+\rangle = A|2_g\rangle + B|2_e\rangle$,
$|2_2^+\rangle = -B|2_g\rangle + A|2_e\rangle$.

Where the suffixes '*g*' and '*e*' represent the states associated with the ground and excited bands, respectively. The labels, '*a*', '*b*', '*A*', and '*B*' represent the corresponding mixing amplitudes. Following the nomenclature as used in Ref.[1], the matrix elements are defined as: $\langle 0_g||M(E2)||2_g\rangle = M_g$
and, $\langle 0_e||M(E2)||2_e\rangle = M_e$.
Further, it is also assumed that there exists no interlinking transitions between the "*g*" and "*e*" bands. Under this assumption, the matrix elements for the electric quadrupole transition can be constructed as the linear combination of the basis states, and represented, for example, as:
$\langle 0_1^+||M(E2)||2_1^+\rangle = AaM_g + BbM_e = M_0$,
Similarly M_1, M_2, M_3, can be constructed. The extracted matrix elements are enlisted in Table I.

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TABLE I: Transition matrix elements for the different 0^+, $2^+ \rightarrow 2^+$, 0^+ transitions in ^{118}Sn.

	B(E2) (W.u.)†	M(E2) (W.u.)$^{\frac{1}{2}\ddagger}$
$2_1^+ \rightarrow 0_1^+$	12.100	7.778 (M_0)
$0_2^+ \rightarrow 2_1^+$	19.000	4.359 (M_1)
$2_1^+ \rightarrow 0_1^+$	0.075	0.612 (M_2)
$2_2^+ \rightarrow 0_2^+$	39.000	13.964 (M_3)

†*the experimental B(E2) values have been taken from the very recent work of Ref.[2]* . ‡*Calculated using:* $M(E2) = \sqrt{(2J_i+1)B(E2)}$

It is worthwhile mentioning that the calculated matrix elements of Table I provide a perplexing sign ambiguity. In our phase convention, we have meticulously accounted for all the positive matrix elements (referred as original fit in the follow up discussion). As depicted in Table II, it is quite interesting to note that the 2^+ states exhibit a higher degree of mixing as compared to that of the 0^+ states. To delve deeper into this phenomenon, an alternative fit has been performed by considering M_2 as negative. The outcomes of this fit provide compelling evidence that for the pure configuration of the 0^+ states.

TABLE II: Mixing amplitudes and mixing matrix elements of the $0^+ \leftrightarrow 2^+$ mixing in ^{118}Sn.

	Original fit	Alternative fit
b	0.436	0.936
B	0.611	0.588
M_g	6.437	7.099
M_e	11.973	11.596

In addition, the mixing potential strengths have been extracted for the 0^+ and 2^+ states using the formalisms[1]:$\Delta V_0 = ab\Delta E_0$ and

ΔV_2=ABΔE_2, where ΔV_is and ΔE_is are the energy difference of the unperturbed and perturbed levels between the yarst and non yrast states for the spin value of i. The values extracted thereby are presented in Table III. Similar to the 0^+, 2^+ states, the 4^+ states are considered to be comprised of the linear combination of the following basis states. The corresponding matrix elements are represented as: $|4_1^+\rangle = C|4_g\rangle + D|4_e\rangle$, $|4_2^+\rangle = -D|4_g\rangle + C|4_e\rangle$.

$\langle 2_g||M(E2)||4_g\rangle = M_g'$
and $\langle 2_e||M(E2)||4_e\rangle = M_e'$.

As some of the B(E2) values are not known experimentally, the following assumptions have been made:(i) $\frac{M_g}{M_e}=\frac{M_g'}{M_e'}$.(ii)The values of the amplitudes previously calculated for the 2^+ states are to be used. Table IV presents the calculated mixing amplitudes and matrix elements for the $4^+ \to 2^+$ mixings obtained by invoking the aforesaid assumptions.

TABLE III: The mixing potential strengths associated with the 0^+ and 2^+ states in ^{118}Sn.

	Original fit (keV)	Alternate fit (keV)
ΔV_0	690	589
ΔV_2	398	386

TABLE IV: list transition matrix element for the different $4^+ \to 2^+$ transitions in ^{118}Sn.

	B(E2) (W.u.)*	M(E2) (W.u)$^{\frac{1}{2}}$
$4_1^+ \to 2_1^+$	14.000	11.225
$4_2^+ \to 2_1^+$	N.A.	N.A.
$4_1^+ \to 2_2^+$	17	12.369
$4_2^+ \to 2_2^+$	N.A.	N.A.

the experimental B(E2) values have been taken from Ref.[2].

TABLE V: Mixing amplitudes and mixing matrix elements for the $4^+ \to 2^+$ mixing in ^{118}Sn.

	Original fit
C	0.992
D	0.128
M_g'	12.060
M_e'	22.431

It is observed that the mixing potential strengths of the 4^+ states is very small, $v$iz.ΔV_4=26(or 7)keV based on the two different fits, as mentioned above, obtained considering the mixing amplitudes of the 2^+ states. The unknown transition probabilities are calculated and subsequently compared with the predicted values from IBM-2 calculations[3](see Table VI).

TABLE VI: Comparison of the B(E2) values(in W.u.) for the $4^+ \to 2^+$ transitions in ^{118}Sn.

	NNDC	TSM	IBM-2
$4_1^+ \to 2_1^+$	14.000	14.000	22.950
$4_2^+ \to 2_1^+$	N.A.	5.072	1.272
$4_1^+ \to 2_2^+$	17.000	17.000	17.452
$4_2^+ \to 2_2^+$	N.A.	38.286	51.107

The calculated lifetime values of the 4_2^+ state from the present work has been provided in Table VII and compared with the adopted value of NNDC data base[4].

TABLE VII: Comparison of the lifetime values (in ps) for the 4_2^+ state in ^{118}Sn.

	original fit (ps)	alternate fit (ps)	NNDC[4] (ps)
4_2^+	35.14	1.48	>0.55

Conclusion

The findings reveal that the 0^+ and 2^+ states are comparatively well mixed and while the 4^+ states remain predominantly pure in nature. Furthermore, the excited state band is found to exhibit and enhanced collectivity(having the enhancement factor of 3.5[as per the $(\frac{M_e}{M_g})^2$ value presented in the Table II]) in comparison to that of the ground state band. The calculated lifetime value of the second 4^+ excited state is found to be closely align with the experimental observations, suggesting thereby the validity of the Two State Mixing model.

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References

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