E2 AND M1 STRENGTHS AND STRONG SUB-SHELL CLOSURE EFFECTS IN NEUTRON-RICH A~100 NUCLEI*

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ABSTRACT

E2 strengths of several $A \sim 100$ nuclei were deduced from ps level-lifetime measurements at the fission-product separator TRISTAN. The exceptionally low B(E2) values for ^{90,92,94,96}Sr reveal a close similariity between spherical Sr and Zr nuclei. For Sr and Y nuclei with $N \geq 60$, B(M1) and B(E2) values indicate that the deformation saturates just at its onset. A dramatic change in the Sr collectivity occurs at $N = 60$, where the B(E2) strength abruptly increases by a factor of ~ 15, suggesting a "phase change" in the collectivity.

INTRODUCTION

For more than a decade neutron-rich $A \sim 100$ nuclei have attracted considerable interest due to their unusual features: an extremely abrupt change from spherical to highly deformed shapes, coexistence of very low-lying spherical and highly deformed shapes, very large rotational moments of inertia, and weaker than normal pairing correlations. Rotational bands in deformed $A \sim 100$ nuclei have implied axially symmetric deformations β of ~ 0.4. Discussions of these aspects of the $A \sim 100$ region are given in Ref. 1 and in references therein.

A new β-γ-γ fast-timing method[2] has made it possible to measure level lifetimes down to ~ 10 ps. Large deformations ($\beta \sim 0.4$) for Sr, Y and Zr with $N > 58$ have been directly determined[3,4,5,6] with this method. In contrast, for $N \leq 58$, sub-shell closures at $Z = 38, 40$ and $N = 56, 58$ should retard the development of collectivity for $50 < N < 60$. Level lifetime measurements for Sr nuclei with $50 < N < 60$ are needed to study the extent of this retardation effect.[7]

SATURATION OF DEFORMATION

For Sr and Y with $N \geq 60$, the B(M1) and B(E2) values indicate that the deformation saturates just at its onset.[3,4] Briefly, for ^{99}Sr and ^{99,100}Y the g-factors definitively establish the Nilsson assignments of the low-lying rotational bands built upon $\pi 5/2[422]$ and $\nu 3/2[411]$. The g-factors and the intrinsic quadrupole moment Q_o are well described by a simple picture for the structure of these nuclei, namely that the deformation of the even-even ^{98}Sr core is constant, unaffected by the presence of one or two valence nucleons.[3,4] In particular, the

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core Q_o of 3.78(6) b deduced[8] for the deformed band in ^{98}Sr is the same as the Q_o values of 3.8(5) b for ^{99}Sr and 3.9(4) b for ^{99}Y. The saturation of deformation inferred from this analysis[3,4] is confirmed by a new ^{100}Sr measurement[9] that gives a Q_o of 3.80(8) b. The "early" (i.e., before neutron midshell) saturation of deformation can be explained in terms of the valence Nilsson orbitals.[3,4,9]

SUB-SHELL CLOSURE EFFECTS

The B(E2) values[7] in Table I for ^{90,92,94,96}Sr, which fill the N=52–58 gap in the known B(E2) rates for $^{78-100}$Sr, are remarkably low. These low values establish a close similarity between spherical Sr and Zr isotopes, which along with spherical Pb nuclei exhibit the lowest B(E2) for all known nuclei past A=56.

Table I. Experimental data for 2^+ levels of Sr (Z=38) nuclei

A	E(2^+) (keV)	meanlife (ps)	B(E2,$0^+ \to 2^+$) (e^2b^2)	B(E2,$0^+ \to 2^+$) (W.u.)	β_2(1st order)	Q_o (b)
78	278	224(27)	1.07(13)	108(13)	0.434(27)	3.28(21)
80	385	57(5)	0.84(7)	82(7)	0.377(16)	2.90(13)
82	573	12.8(5)	0.513(20)	48(2)	0.290(6)	2.27(4)
84	793	4.6(7)	0.28(4)	26(4)	0.211(5)	1.68(12)
86	1077	2.7(4)	0.106(16)	9.4(14)	0.128(10)	1.03(8)
88	1836	0.213(12)	0.092(5)	7.9(4)	0.117(3)	0.96(3)
90	832	10(3)^a	0.10(3)	8.3(27)	0.120(19)	1.00(16)
92	815	12(5)^a	0.09(4)	8(3)	0.116(24)	0.98(20)
94	837	10(4)^a	0.10(4)	8(3)	0.115(25)	0.98(21)
96	816	7(4)^a	0.17(9)	13(7)	0.15(4)	1.3(4)
98	144	4010(100)^b	1.29(3)	96.4(24)	0.409(5)	3.61(4)^d
100	129	5640(230)^c	1.44(6)	104(4)	0.426(9)	3.80(8)

^{a}present results of Mach et al.[7]
^{b}mean of 4.04(12) ns (Ref. 8) and 3.95(17) ns (Ref. 10).
^{c}new result by Lhersonneau et al.[9]
^{d}Q_o=3.78(6) b for the unmixed deformed band [Mach et al.[8]].

A strong similarity in the B(E2) values of Sr and Zr nuclei is observed from shell closure at N=50 to deformation at N=60.[7] These nuclei are more similar in their collectivity than is suggested by their 2_1^+ energies, which are nearly constant for $^{90-96}$Sr but vary significantly for $^{92-98}$Zr. These nuclei are similar due to subshell closures at Z=38($\pi 2p_{3/2}$), 40($\pi 2p_{1/2}$) and at N=56 ($\nu 2d_{5/2}$), 58($\nu 3s_{1/2}$). These sub-shells (for low-j orbits) stabilize spherical configurations,[11] thereby permitting Sr and Zr with N=50–58 to very effectively resist the normal smooth progress towards deformation as N increases above 50.

Q_o SYSTEMATICS OF SR NUCLEI

The Sr and Zr nuclei are unique in their B(E2) systematics. No other nuclei (see the compilation of Ref. 12) exhibit such an abrupt and large change in B(E2) values from "spherical" values of ~8 W.u. to deformed values of ~100 W.u. This change in collectivity is most dramatically seen in Fig. 1 which gives the intrinsic quadrupole moment Q_o for Sr nuclei. The Q_o given above for ^{99}Sr is included, as is the ^{97}Sr value[6] of 3.5(4)b. For ^{98}Sr, Fig. 1 includes both the "mixed" value of 3.61(4) b and the "unmixed" value of 3.78(6)b, obtained[8] by correcting for the mixing of the 0_1^+ and 215-keV 0_2^+ states in ^{98}Sr.

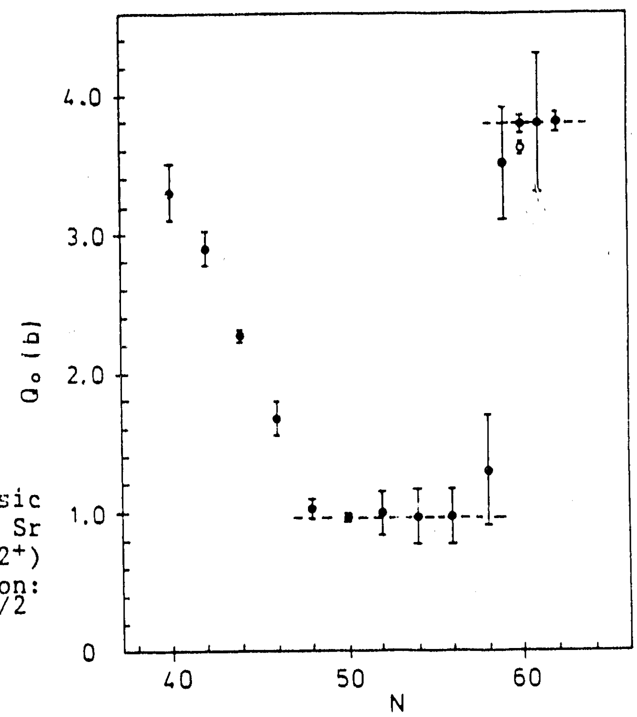

Fig.1: Systematics of intrinsic quadrupole moments Q_0 for the Sr nuclei obtained from $B(E2,0^+\to2^+)$ using the rotational expression: $Q_0 = [(16\pi/5)B(E2,0^+\to2^+)/e^2]^{1/2}$

Figure 1 reveals two plateaus: one for N=50–58, with mean Q_o of 0.96(3) b, and one for N=59–62, with mean Q_o of 3.79(4) b. This change in the Sr collectivity, which corresponds to a factor of $\sim$15 increase in B(E2), is so remarkably large and abrupt that it suggests a "phase transition" in the Sr collectivity. The term "phase transition" .. used to emphasize that the abruptness contrasts sharply with the rather smooth "evolution" (such as is observed in Fig. 1 for neutron-deficient Sr nuclei) of nuclear collectivity that occurs for all other known shape-transition regions.

REFERENCES

1. Nuclear Structure of the Zirconium Region, edited by J. Eberth, R. A. Meyer, and K. Sistemich (Springer-Verlag, Berlin, 1988).
2. H. Mach, et al., Nucl. Instr. Methods A280, 49 (1989); see also invited paper by R.L. Gill, this symposium.
3. F. K. Wohn, et al., Nucl. Phys. A507, 141c (1990).
4. H. Mach et al., Phys. Rev. C 41, 1141 (1990).
5. G. Lhersonneau et al., Z. Phys. A 332, 243 (1989).
6. M. Buescher et al., Phys. Rev. C 41, 1115 (1990).
7. H. Mach et al., Nucl. Phys. A (in press).
8. H. Mach et al., Phys. Lett. B 230, 21 (1989).
9. G. Lhersonneau et al., Z. Phys. A (in press).
10. H. Ohm et al., Z. Phys. A 327, (1987).
11. G. Molnár et al., Nucl. Phys. A500, 43 (1989).
12. S. Raman et al., At. Data Nucl. Data Tables 42, 1 (1989).

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