COLLECTIVE PROPERTIES OF ODD-MASS Sb, I, Cs, AND La NUCLEI

D. B. Fossan

Physics Department

State University of New York, Stony Brook, NY

and

Lawrence Berkeley Laboratory

University of California, Berkeley, CA

Invited paper presented at

"International Conference on the Structure of Medium-Heavy Nuclei,"

Rhodos, Greece, 1-4 May 1979

COLLECTIVE PROPERTIES OF ODD-MASS Sb, I, Cs, AND La NUCLEI

D. B. Fossan*

Physics Department

State University of New York, Stony Brook, NY

and

Lawrence Berkeley Laboratory

University of California, Berkeley, CA

ABSTRACT

The collective properties for the $Z \geq 50$ transition region have been studied via heavy-ion induced γ-ray experiments using $^{6,7}Li$, ^{10}B, $^{12,13}C$, ^{14}N, and ^{16}O beams. The high-spin systematics for odd-mass $^{113-125}Sb$ (Z=51), $^{115-127}I$ (Z=53), $^{119-133}Cs$ (Z=55), and $^{125-127}La$ (Z=57) nuclei have been obtained. Two collective features were observed, the first being systematic ΔJ=1 bands built on low-lying $1g_{9/2}$ proton-hole states, and the second systematic ΔJ=2 bands built on $2d_{5/2}$, $1g_{7/2}$, and $1h_{11/2}$ quasi-proton states. Unexpected properties were observed.

*On sabbatical leave at Lawrence Berkeley Laboratory, University of California.

INTRODUCTION

A systematic experimental investigation of collective properties in the $Z \gtrsim 50$ transition region, which has been carried out with the Stony Brook FN tandem accelerator via γ-ray measurements following heavy-ion induced reactions, will be presented. High-spin level spectra were studied in the odd-mass $^{113-125}$Sb (Z=51),[1] $^{115-127}$I (Z=53),[2] $^{119-133}$Cs (Z=55),[3] and $^{125-127}$La (Z=57)[4] nuclei. This investigation was motivated by the fact that the rich high-spin level spectra in odd-mass nuclei have a considerable sensitivity to collective properties. The onset of collective structure resulting from neutron-proton interactions near closed shells is of current theoretical interest. The nature of the collectivity for transitional nuclei (vibrations and rotations) is discussed in the invited papers of this conference by Iachello in terms of the interacting boson model and by Kumar with the dynamic deformation model. The present experimental studies cover the transition region between the Z=50 closed proton shell and the odd-mass La (Z=57) nuclei for which Stephens, *et al.*[5] had previously observed $\Delta J=2$ bands (rotational alignment) built on $11/2^-$ states.

Two collective features were observed in this $Z \gtrsim 50$ transition region,[1-4] the first being systematic $\Delta J=1$ bands built on low-lying $9/2^+$ states. These $9/2^+$ intruder states, which involve a $1g_{9/2}$ proton excited through the Z=50 major shell, have energies that follow for each Z a parabola-like curve as a function of N with minima that drop to 950 keV in ^{121}Sb, 307 keV in ^{119}I and the ground state in ^{119}Cs. The $\Delta J=1$ band spacings achieve minima near the middle of the neutron shell and decrease with Z. An initial α-particle experiment by Fromm et al.[6] had observed members of the $\Delta J=1$ band in ^{117}Sb. Comparisons with low-lying 0^+ bands from even Sn work by Bron et al.[7] suggest a collective structure relationship between the excitation of a $1g_{9/2}$ proton and that of a pair of $1g_{9/2}$ protons. Secondly, systematic $\Delta J=2$ bands were observed on $2d_{5/2}$, $1g_{7/2}$, and $1h_{11/2}$ quasi-proton states in the odd-mass I, Cs, and La nuclei. The $\Delta J=2$ energy spacings are nearly consistent, as in earlier La studies,[5] with the spacings for the related core nuclei except for those of the $1h_{11/2}$ band in the I nuclei, which decrease by over a factor of 2 relative to those for the Te cores as A decreases. The systematic high-spin level spectra obtained for the $Z \gtrsim 50$ transition region represent a detailed challenge to the theoretical basis for these collective features.

EXPERIMENTAL PROCEDURE

To study the collective excitations in the odd-mass Sb, I, Cs, and La isotopes several (HI,xnγ) fusion-evaporation reactions were employed with ^{6}Li, ^{10}Be, and ^{14}N odd-proton heavy-ion beams and isotopically enriched, self-supporting even-mass targets. Extensive experimental systematics can be achieved with these reactions in this region because of the abundance of stable even-mass targets near the Z=50 closed shell. The following reactions were used for the specific residual nuclei: $^{110-116}Cd(^{6}Li,3n)^{113-119}Sb$,
$^{114-124}Sn(^{6}Li,3n)^{117-127}I$; $^{116-124}Sn(^{10}B,3n)^{123-131}Cs$,
$^{126-130}Te(^{6}Li,3n)^{129-133}Cs$, $^{110,112}Cd(^{14}N,3n)^{121,123}Cs$,

and $^{116}Sn(^{14}N,3n)^{127}La$. For three neutron deficient nuclei, reactions with proton evaporation had to be used: $^{106}Cd(^{12}C,p2n)^{115}I$, $^{106}Cd(^{16}O,p2n)^{119}Cs$, and $^{112}Sn(^{16}O,p2n)^{125}La$. Some limited information was obtained for the higher mass Sb nuclei via the reactions $^{120-124}Sn(^{7}Li,\alpha 2n)^{121-125}Sb$. In-beam measurements with Ge(Li) detectors of γ-ray excitations, γ-γ coincidences, γ-ray angular distributions, and pulsed beam-γ timing were made to establish decay schemes, level energies, J^{π} assignments, γ-ray multipolarities, isomeric lifetimes, and g-factors. The results include eight lifetimes and three g-factors for high-spin isomers. The details of the experimental techniques have been described earlier.[8] Independent (α,2n) experiments have been performed on several of the nuclei where appropriate odd-mass targets are stable: ^{115}Sb,[9] ^{117}Sb,[6] $^{123-125}I$,[20] and ^{129}Cs.[11] Experiments with heavier ions have also recently been made on several of the Cs isotopes.[12] The available results from these independent experiments show agreement with this systematic investigation, where overlap occurs.

RESULTS

The high-spin level spectra deduced for the odd-mass Sb, I, Cs, and La nuclei from the γ-ray measurements following the heavy-ion fusion evaporation reactions have a high degree of similarity. The systematics of the two collective features observed in these measurements are the focus of this report. The ΔJ=1 bands built on low-lying $9/2^{+}$ states, which is the first feature, were observed in $^{113-123}Sb$, $^{115-127}I$, $^{119-125}Cs$, and ^{125}La. They are collected in Figs. 1-3. In general, the $\Delta J=1$ band spacings increase with J except that the Sb nuclei show some squeezing of the $11/2^+$ and $13/2^+$ members. A comparison of the $\Delta J=1$ bands as a function of Z is shown for the N=68 isotones in Fig. 4, which includes ^{125}La. The band spacings can be compared by extracting values of $2\mathcal{J}/\hbar^2 = 2J/(E_J - E_{J-1})$: 34.0, 37.3, 42.0, and 54.3 MeV^{-1}, respectively, for ^{119}Sb, ^{121}I, ^{123}Cs, and ^{125}La. A plot of the quantity $\sqrt{2\mathcal{J}/\hbar^2}$ for all of the $\Delta J=1$ bands is given in Fig. 5. This quantity is roughly related to a rotor deformation.

The γ-ray cascades consist of $J \rightarrow J-1$ M1-E2 transitions (positive mixing ratios), which are corroborated in most cases by enhanced $J \rightarrow J-2$ E2 crossover transitions. The mean lifetimes and g-factor obtained for the $9/2^+$ bandheads are collected in Table I. The $9/2^+$ lifetimes in the I nuclei imply hindrances of $\sim 10^4$ relative to M1 Weisskopf estimates for the transitions to the $7/2^+$ quasi-proton states as expected for proton-hole states. The ^{119}I $9/2^+$ g-factor is consistent with the $1g_{9/2}$ proton-hole character, but has little sensitivity to any collectivity of the core.

The excitation energies for the $9/2^+$ bandheads are shown in Fig. 6 as a function of N. These states, which involve the excitation of a $1g_{9/2}$ proton across the Z=50 major shell, would be 2p-1h, 4p-1h, 6p-1h, and 8p-1h states in the Sb, I, Cs, and La nuclei, respectively. A comparison of the shapes of the $\sqrt{2\mathcal{J}/\hbar^2}$ curves of Fig. 5 with those of the excitation energies of Fig. 6 shows a similarity only for the Cs isotopes. This would suggest that the collectivity responsible for the Cs $\Delta J=1$ band spacings is a dominant influence in the $9/2^+$ bandhead energies. The dashed curve in Fig. 6 represents the 0^+ bandheads observed[7] in the even Sn nuclei, which are expected to be 2p-2h states resulting from the excitation of a pair of $1g_{9/2}$ protons. Corresponding 4p-2h and 6p-2h bands have been searched for in even Te and Xe nuclei with a variety of reactions.[13] Although the lower band members are mixed, the 8^+ (and higher) members are possibly yrast and thus less admixed.

The second collective feature observed in the $Z \gtrsim 50$ transition nuclei involves $\Delta J=2$ bands of levels built on low-lying $5/2^+$, $7/2^+$, and $11/2^-$ levels, which are interpreted as $2d_{5/2}$, $1g_{7/2}$, and $1h_{11/2}$ quasi-proton states. The g-factor obtained[14] for the $11/2^-$ bandhead in ^{129}Cs (see Table I) is consistent with this interpretation. Unfortunately, the g-factor is not sensitive to the collective properties. The γ-ray cascades connecting these bands are consistent with stretched $J \rightarrow J - 2$ E2 transitions. The $\Delta J=2$ bands built on the $11/2^-$ and $5/2^+$ states that were observed in the $^{115-127}$I nuclei are shown in Figs. 7 and 8; the filled circles give the 0^+, 2^+, 4^+,...level energies of the related A-1 even Te core nuclei. The $\Delta J=2$ bands built on the $2d_{5/2}$ quasi-proton states in Fig. 8 have energy spacings similar to the corresponding even Te cores. In contrast, the observed $\Delta J=2$ bands built on the $1h_{11/2}$ quasi-protons as shown in Fig. 7 surprisingly revealed spacings which decrease significantly relative to those for the Te cores in going from the high- to low-A I nuclei. In the Cs nuclei, $\Delta J=2$ bands were observed for the $11/2^-$ states in $^{119-133}$Cs as shown in Fig. 9; the filled circles give the level energies of the related A-1 even Xe core nuclei. The level spacings in the $\Delta J=2$ bands for these $11/2^-$ states as well as those built on the $7/2^+$ $1g_{7/2}$ quasi-proton states in the Cs nuclei, as shown in Fig. 10, are more similar to the spacings in the related Xe core nuclei and do not show the large deviations observed for the $11/2^-$ $\Delta J=2$ bands in the I nuclei.

In Fig. 11, a comparison is made of the ratio R of the lowest $\Delta J=2$ energy spacings of the $11/2^-$ bands in the I, Cs, and La[5] nuclei to the related A-1 even core spacings (E_{2+}). The lines simply connect the experimental points. As shown R falls to below 1/2 for only the $11/2^-$ $\Delta J=2$ bands of the I nuclei, although the $11/2^-$ bands for the Cs nuclei show a similar but reduced effect. This effect was not observed for the $5/2^+$ $\Delta J=2$ bands in the I nuclei (see Fig. 8), nor was it observed (see Fig. 12) for the $\Delta J=2$ bands built on the $1h_{11/2}$ quasi-neutron states obtained simultaneously in the odd-mass Te nuclei, which have the same even-mass Te cores. Thus the effect is most strongly related to the interaction between the $1h_{11/2}$ quasi-proton and the neutrons.

DISCUSSION

The systematic collective properties observed for the $Z \gtrsim 50$ transition region as summarized in the previous section provide a sensitive test as a function of Z and N for the different theoretical approaches to this collectivity. It is important for reasons of consistency and completeness that this entire transition region be examined for a specific theory. This includes the results as a function of N for the odd-mass Sb (Z=51), I (Z=53), Cs (Z=55), and

La (Z=57) nuclei as well as the significant information that exists for the even-mass Sn (Z=50), Te (Z=52), Xe (Z=54), and Ba (Z=56) nuclei. A complete theoretical understanding will presumably contain a transition from the more vibration-like properties near Z=50 to the more rotation-like properties near Z=57 in a consistent way.

Theoretical calculations within limited nuclear models have been made for portions of the observed collective properties of these odd--mass nuclei. Although these calculations can fit many of the experimental results, it does not appear that either the pure rotation or vibration approaches provide a unique theoretical basis for the collectivity of the entire transition region. A strongly coupled deformed (prolate) rotor interpretation can explain the following properties of the $\Delta J=1$ $9/2^+$ bands: 1) band spacings, 2) positive mixing ratios $\delta(E2/M1)$ for the $J \rightarrow J-1$ transitions, 3) enhanced relative $J \rightarrow J-2$ E2 crossover transitions, and 4) the $9/2^+$ band-head energies (see Fig. 6). Band mixing calculations[15,16,2] involving a [404] $9/2^+$ Nilsson proton-hole orbital and appropriate potential energy surfaces for the core nuclei have yielded good fits to the above properties for the Sb and I nuclei that imply prolate rotors with deformations as large as $\beta \approx 0.2$. The $\Delta J=2$ bands built on the quasi-particle states are consistent with decoupled (rotational alignment) bands in the particle plus rotor (prolate) models, although the spacings (see Fig. 11) are not naturally understood. Triaxial rotor calculations[1,3] with the model of Meyer-ter-Vehn[17] have been made. The $11/2^+$ - $13/2^+$ level squeezing (see Fig. 1) in the Sb nuclei require an asymmetry of $\gamma \approx 20^{\circ}$ in this model while $\gamma = 0^{\circ}$

gives reasonable fits to the $\Delta J=1$ bands in the I, Cs, and La nuclei. Calculations with the particle plus anharmonic vibrator models[9,16] have also achieved reasonable fits to many of the above collective properties of the odd-mass nuclei. Arima et al.[18] have offered an explanation to the surprising variations in the spacings for the $11/2^-$ $\Delta J=2$ bands, including those of the I nuclei as shown in Fig. 11, with a semi-microscope model of the particle-core interaction. With the partial but still somewhat unsatisfactory success achieved with the various model calculations, it is now important to develop a more comprehensive theory for the entire $Z \gtrsim 50$ transition region, and hopefully as well, for other transition regions.

ACKNOWLEDGMENTS

The experiments discussed were carried out in conjunction with the following colleagues: R. E. Shroy, U. Garg, T. P. Sjoreen, M. Gai, P. Chowdhury, A. K. Gaigalas, G. Schatz, D. M. Gordon, A. Neskakis, and W. F. Piel. The experimental work was supported in part by the U. S. National Science Foundation. This work was also supported in part by the Nuclear Physics Division of the U. S. Department of Energy under contract No. W-7405-ENG-48.

REFERENCES

1. Gaigalas, A. K., Shroy, R.E., Schatz, G., and Fossan, D. B., 1975, Phys. Rev. Lett. 35, 555; Shroy, R. E., Gaigalas, A. K., Schatz, G., and Fossan, D. B., 1979, Phys. Rev. C 19, 1324.

2. Gordon, D. M., Gai, M., Gaigalas, A. K., Shroy, R. E., and Fossan, D. B., 1977, Phys. Lett. 67B, 161; Fossan, D. B., Gai, M., Gaigalas, A. K., Gordon, D. M., Shroy, R. E., Heyde, K., Waroquier, M., Vincx, H., and Van Isacker, P., 1977, Phys. Rev. C 15, 1732; Chowdhury, P., Stwertka, P. M., Neskakis, A., Garg, U., Sjoreen, T. P., and Fossan, D. B., 1978, Bull. Am. Phys. Soc. 23, 555; Gai, M., Shroy, R. E., and Fossan, D. B., 1978, Bull. Am. Phys. Soc. 23, 556.

3. Garg, U., Sjoreen, T. P., and Fossan, D. B., 1978, Phys. Rev. Lett. 40, 831; Garg, U., Sjoreen, T. P., and Fossan, D. B., 1979, Phys. Rev. C 19, 207 and 217.

4. Garg, U., Chowdhury, P., Sjoreen, T. P., and Fossan, D. B., 1978, Bull. Am. Phys. Soc. 23, 90.

5. Stephens, F. S., Diamond, R. M., Leigh, J. R., Kammuri, T., and Nakai, K., 1972, Phys. Rev. Lett. 29, 438.

6. Fromm, W. D., Brickmann, H. F., Donau, F., Heiser, C., May, F. R., Pashkevitch, V. V., and Rotter, H., 1975, Nucl. Phys. A243, 9.

7. Bron, J., Hesselink, W. H. A., Peker, L. K., Van Poelgeest, A., Uitzinger, J., Verheul, H., and Zalmstra, J., 1978, J. Phys. Soc. Japan 44, Suppl. 513.

8. Brown, B. A., Lesser, P. M. S., and Fossan, D. B., 1976, Phys. Rev. C 13, 1900.

9. Bron, J., Hesselink, W. H. A., Bedt, H., Verheul, H., and VandenBerghe, G., 1977, Nucl. Phys. A279, 365.

10. Hagemann, U., Keller, H. J., and Brinckman, H. F., 1977, Nucl. Phys. A289, 292.

11. Chiba, J., Hayano, R. S., Sekimoto, M., Nakayama, H., and Nakai, K., 1977, J. Phys. Soc. Japan 43, 1109.

12. Venezia, F., Fleissner, J., Rakel, D., Rozak, S., Funk, E., and Mihelich, J. W., 1976, Bull. Am. Phys. Soc. 21, 1003 (1976); Tickle, R. S., Gray, W. S., and Griffin, H. C., 1978, Z. Physik A284, 385; Yoshikawa, N., Gizon, J., and Gizon, A., 1978, J. de Physique Lettres 39 L-102.

13. Chowdhury, P., Garg, U., Piel, Jr., W. F., Sjoreen, T. P., and Fossan, D. B., 1978, Bull. Am. Phys. Soc. 23, 962; 1979, 24, 649.

14. Dewey, M. S., Mahnke, H.-E., Chowdhury, P., Garg, U., Sjoreen, T. P., and Fossan, D. B., 1978, Phys. Rev. C 18, 2061.

15. Heyde, K., Waroquier, M., Vincx, H., and Van Isacker, P., 1976, Phys. Lett. 64B, 135.

16. Van Isacker, P., Waroquier, M., Vincx, H., and Heyde, K., 1977, Nucl. Phys. A292, 125.

17. Meyer-ter-Vehn, J., 1975, Nucl. Phys. A249, 111.

18. Arima, A., Gai, M., and Strottman, D., (to be published).

FIGURE CAPTIONS

Fig. 1. Systematic $\Delta J=1$ bands built on the $9/2^+$ proton-hole states in odd-mass Sb nuclei.

Fig. 2. Systematic $\Delta J=1$ bands built on the $9/2^+$ proton-hole states in odd-mass I nuclei.

Fig. 3. Systematic $\Delta J=1$ bands built on the $9/2^+$ proton-hole states in odd-mass Cs nuclei.

Fig. 4. Systematics of observed $\Delta J=1$ bands built on the $9/2^+$ states for the N=68 isotones.

Fig. 5. The quantity $\sqrt{2\mathcal{J}/\hbar^2}$ extracted from the $9/2^+$ $\Delta J=1$ band spacings of the odd-mass Sb, I, and Cs nuclei. The ^{125}La (N=68) value is 7.37 $MeV^{-1/2}$. This quantity is roughly related to a deformation.

Fig. 6. The $9/2^+$ bandhead energies for the odd-mass Sb, I, and Cs nuclei. The dashed line connects 0_2^+ bandhead energies for the even Sn nuclei (see Ref. 7).

Fig. 7. Systematic $\Delta J=2$ bands built on the $11/2^-$ states in the odd-mass I nuclei. The filled circles give the 0^+, 2^+, 4^+, ... level energies of the related A-1 even Te core nuclei.

Fig. 8. Systematic $\Delta J=2$ bands built on the $5/2^+$ states in the odd-mass I nuclei. The filled circles give the 0^+, 2^+, 4^+, ... level energies of the related A-1 even Te core nuclei.

Fig. 9. Systematic $\Delta J=2$ bands built on the $11/2^-$ states in the odd-mass Cs nuclei. The filled circles give the 0^+, 2^+, 4^+, ... level energies of the related A-1 even Xe core nuclei.

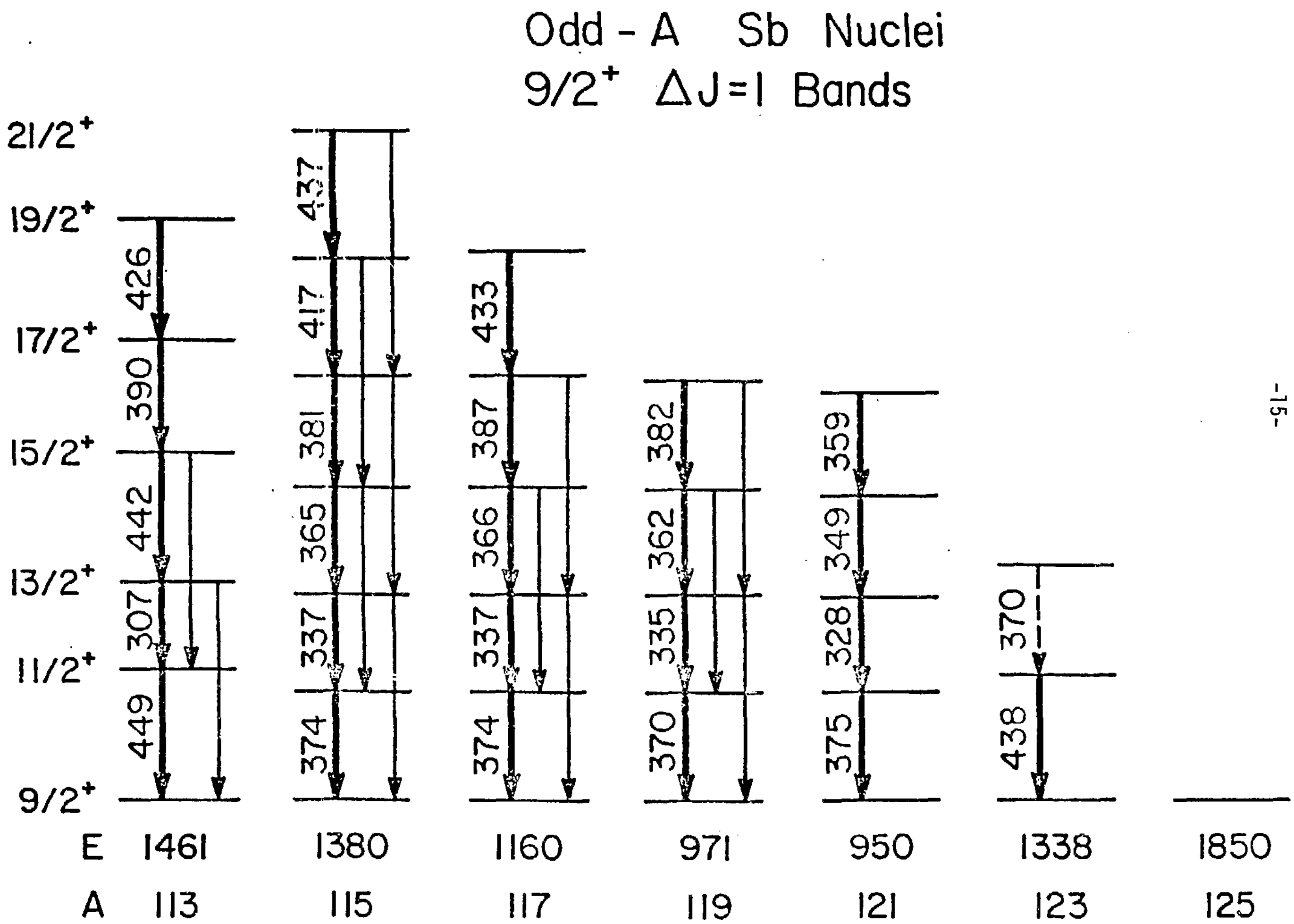
Fig. 10. Systematic $\Delta J=2$ bands built on the $7/2^+$ states in the odd-mass Cs nuclei. The filled circles give the 0^+, 2^+, 4^+, ... level energies of the related A-1 even Xe core nuclei.

Fig. 11. Experimental ratios R of the first $11/2^-$ $\Delta J=2$ band spacing to the E(2+) of the A-1 core nuclei for the I, Cs, and La (Ref. 5) nuclei. The lines simply connect the experimental ratios.

Fig. 12. Systematic $\Delta J=2$ bands built on the $1h_{11/2}$ quasi-neutron states in the odd-mass Te nuclei. The filled circles give the 0^+, 2^+, 4^+, ... level energies of the related A-1 even Te core nuclei.

Table I.

Isomer (keV) J^{π}	τ (ns)	g-Factor
^{115}I (364) $9/2^{+}$ [2]	12.5±0.5	
^{117}I (352) $9/2^{+}$ [2]	17.5±1.0	
^{119}I (307) $9/2^{+}$ [2]	41.5±1.5	+1.20±0.05
^{121}I (434) $9/2^{+}$ [2]	13.5±0.5	
^{129}Cs (575) $11/2^{-}$ [14]	1059±33	+1.191±0.018



Odd - A Sb Nuclei
9/2+ ΔJ=1 Bands
21/2+
19/2+
17/2+
15/2+
13/2+
11/2+
9/2+
426
390
442
307
449
437
417
381
365
337
374
433
387
366
337
374
382
362
335
370
359
349
328
375
370
438
E 1461 1380 1160 971 950 1338 1850
A 113 115 117 119 121 123 125

Fig. 1

Odd-A I Nuclei
$9/2^+$ $\Delta J=1$ Bands

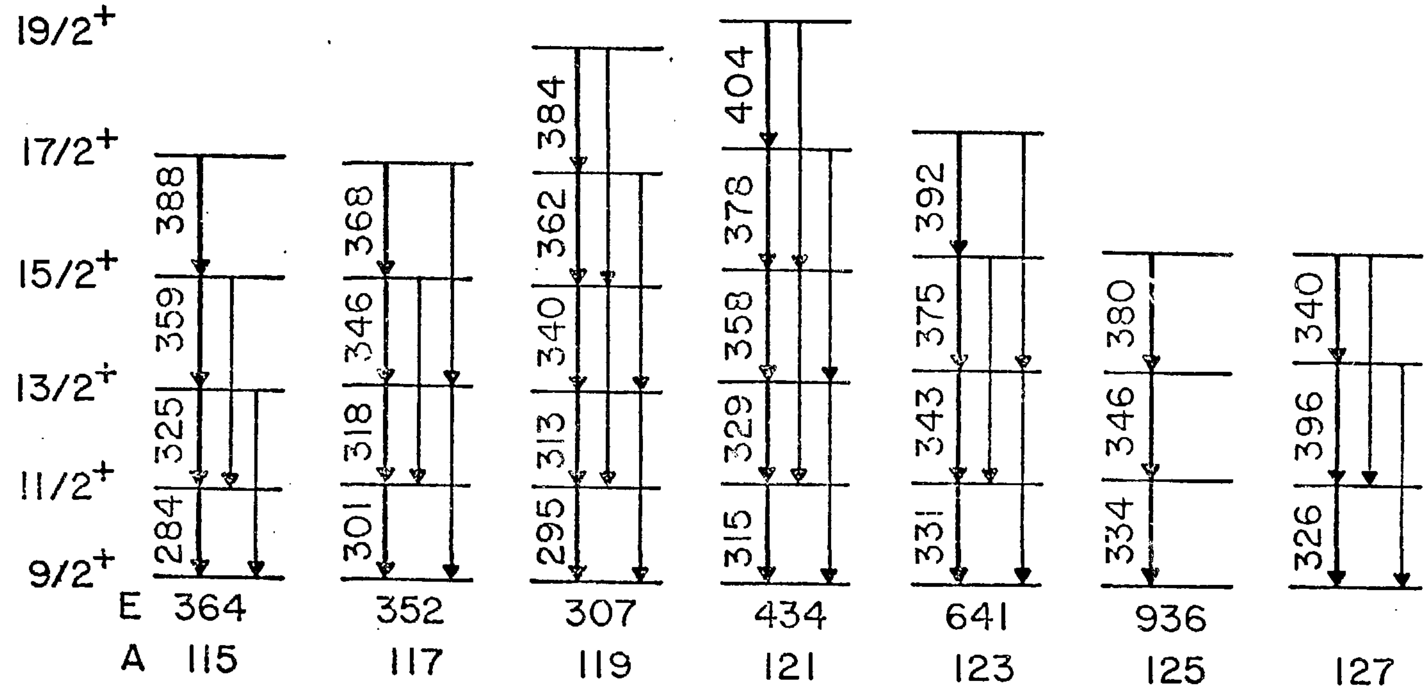


Fig. 2

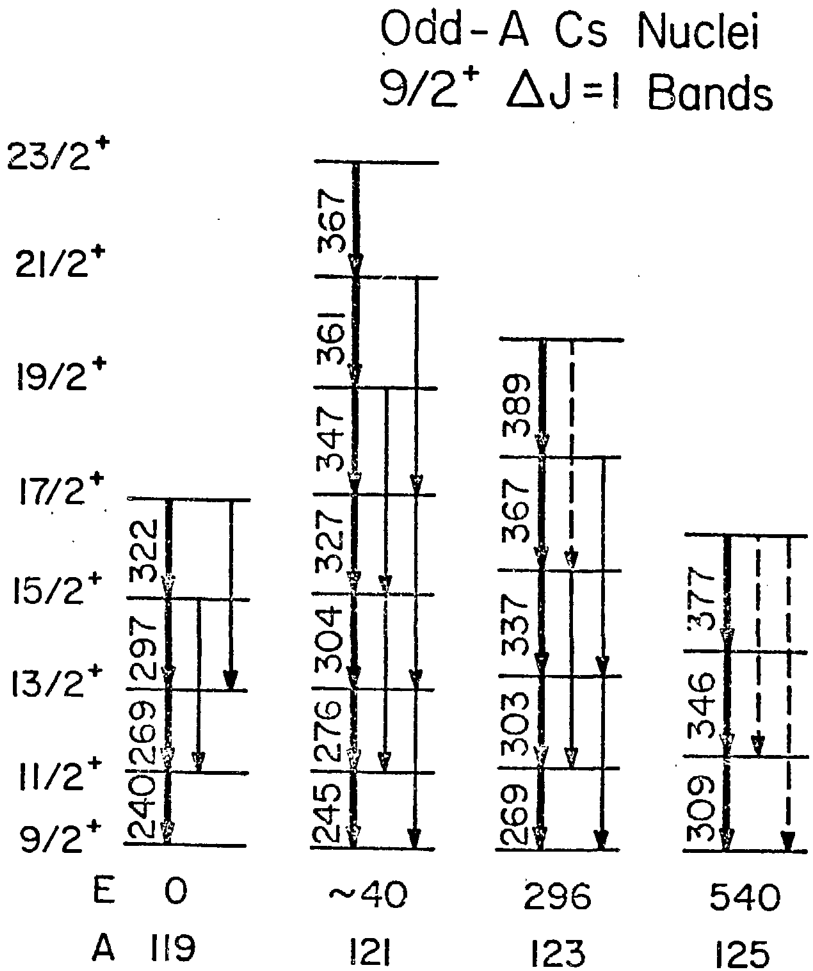

Odd-A Cs Nuclei
9/2+ ΔJ=1 Bands
23/2+
21/2+
19/2+
17/2+
15/2+
13/2+
11/2+
9/2+
322
297
269
240
367
361
347
327
304
276
245
389
367
337
303
269
377
346
309
E 0
~40
296
540
A 119
121
123
125

Fig. 3

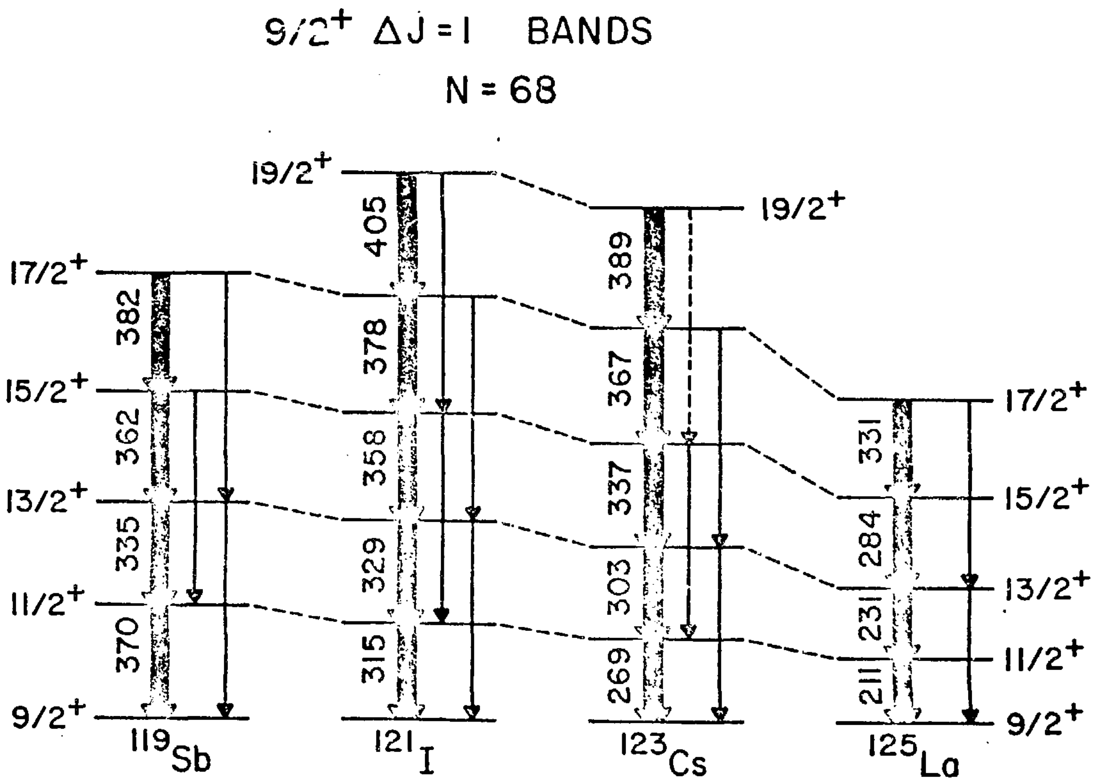

9/2+ ΔJ = 1 BANDS
N = 68
17/2+
15/2+
13/2+
11/2+
9/2+
382
362
335
370
119Sb
19/2+
405
378
358
329
315
121I
19/2+
389
367
337
303
269
123Cs
331
284
231
211
125La
17/2+
15/2+
13/2+
11/2+
9/2+

Fig. 4

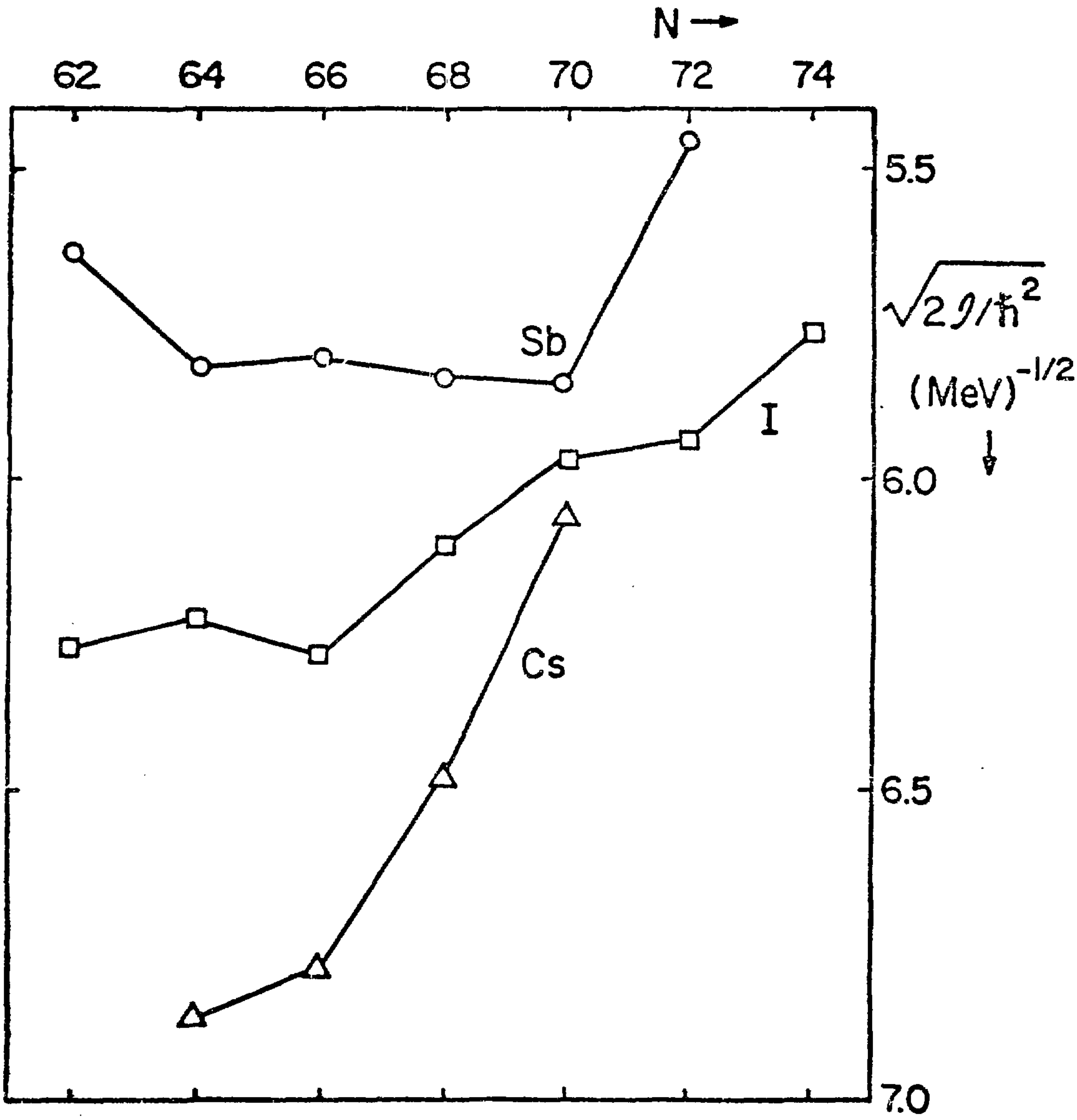

N →
62
64
66
68
70
72
74
5.5
6.0
6.5
7.0
$\sqrt{2\mathcal{J}/\hbar^2}$
$(MeV)^{-1/2}$
Sb
I
Cs

Fig. 5

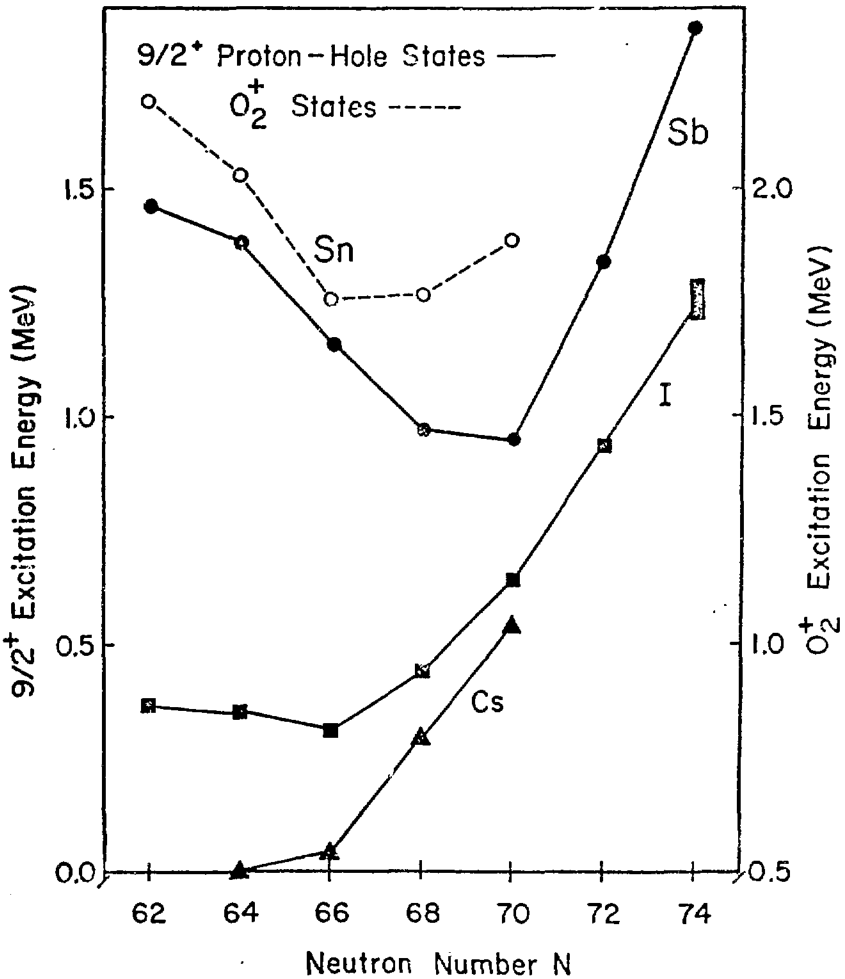

9/2⁺ Proton−Hole States
0_2^+ States
Sn
Sb
I
Cs
1.5
1.0
0.5
0.0
2.0
1.5
1.0
0.5
62
64
66
68
70
72
74
Neutron Number N
9/2⁺ Excitation Energy (MeV)
0_2^+ Excitation Energy (MeV)

Fig. 6

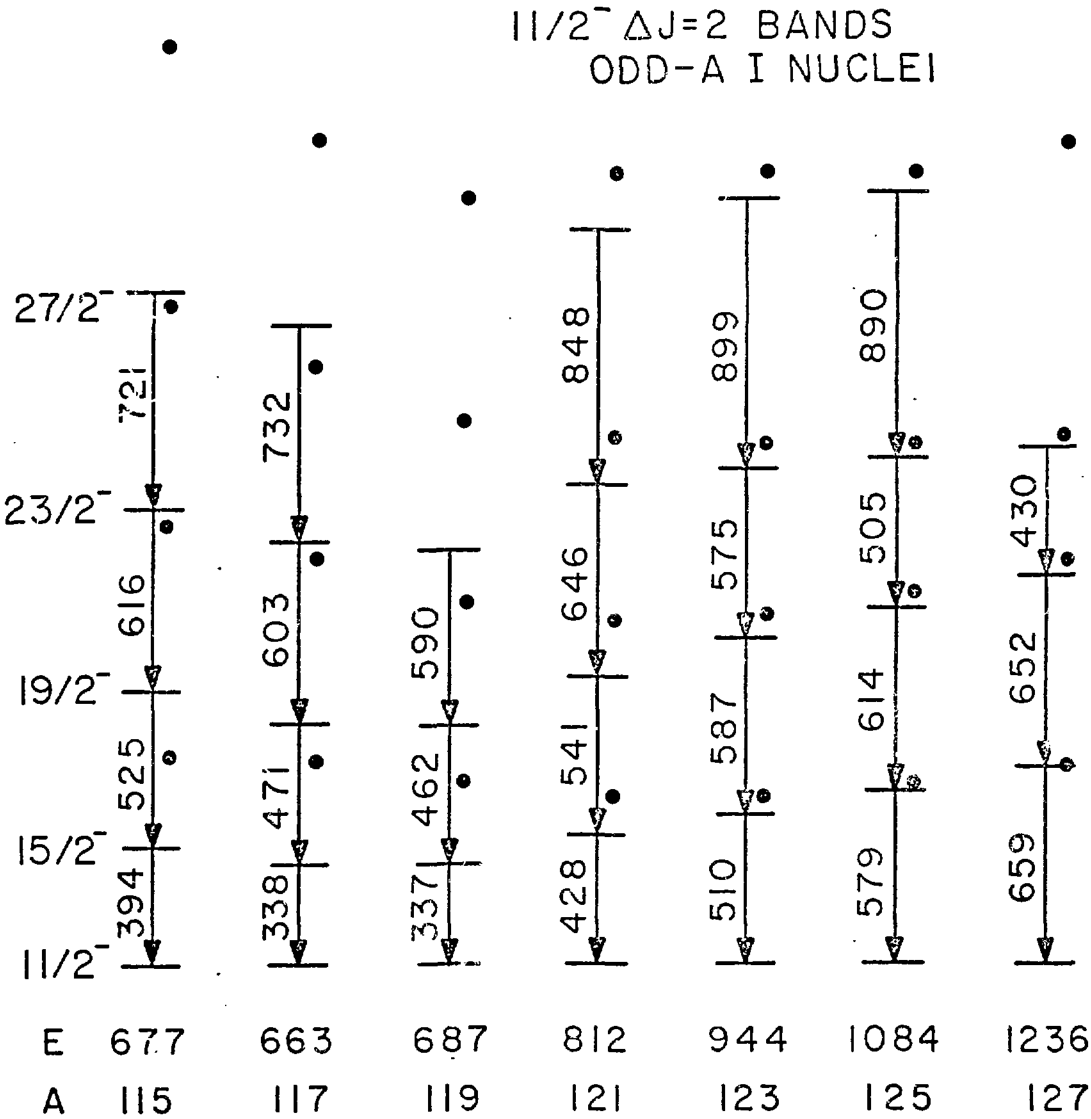

11/2⁻ ΔJ=2 BANDS
ODD-A I NUCLEI
27/2⁻
23/2⁻
19/2⁻
15/2⁻
11/2⁻
721
616
525
394
732
603
471
338
590
462
337
848
646
541
428
899
575
587
510
890
505
614
579
430
652
659
E 677 663 687 812 944 1084 1236
A 115 117 119 121 123 125 127

Fig. 7

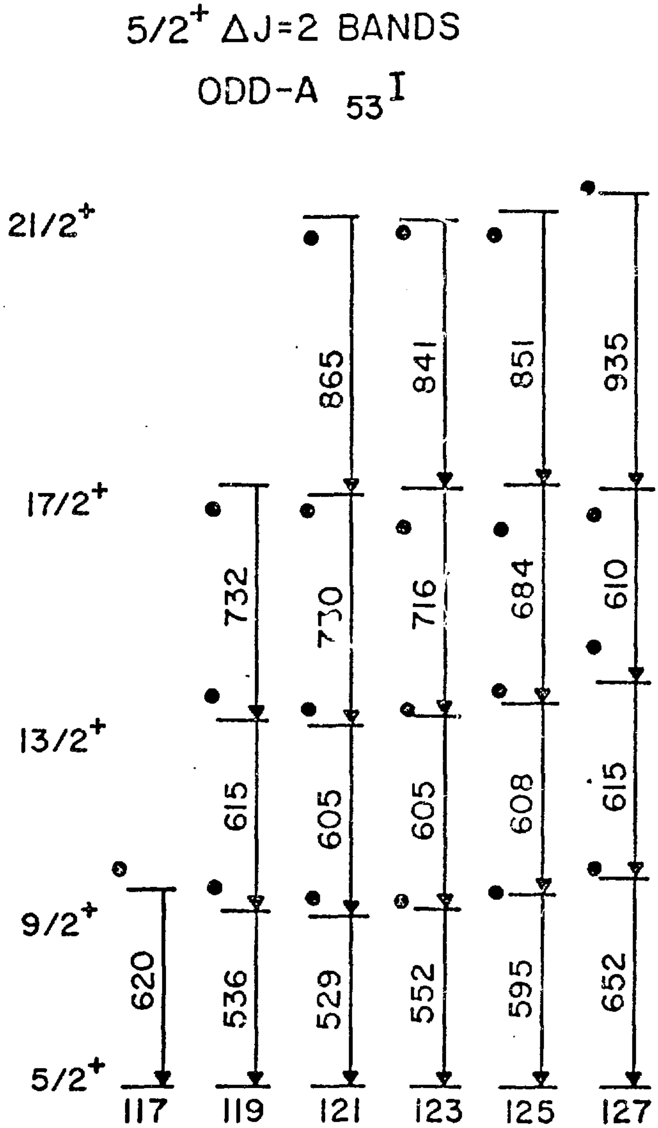

5/2+ ΔJ=2 BANDS
ODD-A 53I
21/2+
17/2+
13/2+
9/2+
5/2+
865
841
851
935
732
730
716
684
610
615
605
605
608
615
620
536
529
552
595
652
117
119
121
123
125
127

Fig. 8

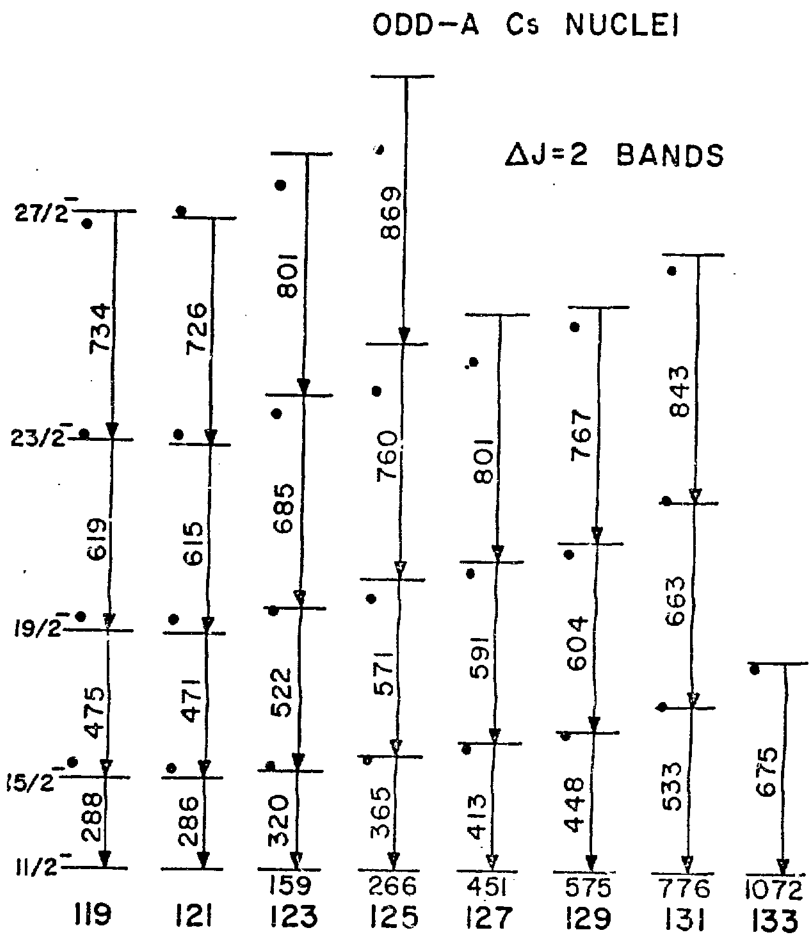

ODD-A Cs NUCLEI
ΔJ=2 BANDS
27/2⁻
23/2⁻
19/2⁻
15/2⁻
11/2⁻
734
619
475
288
726
615
471
286
801
685
522
320
869
760
571
365
801
591
413
767
604
448
843
663
533
675
159
266
451
575
776
1072
119
121
123
125
127
129
131
133

Fig. 9

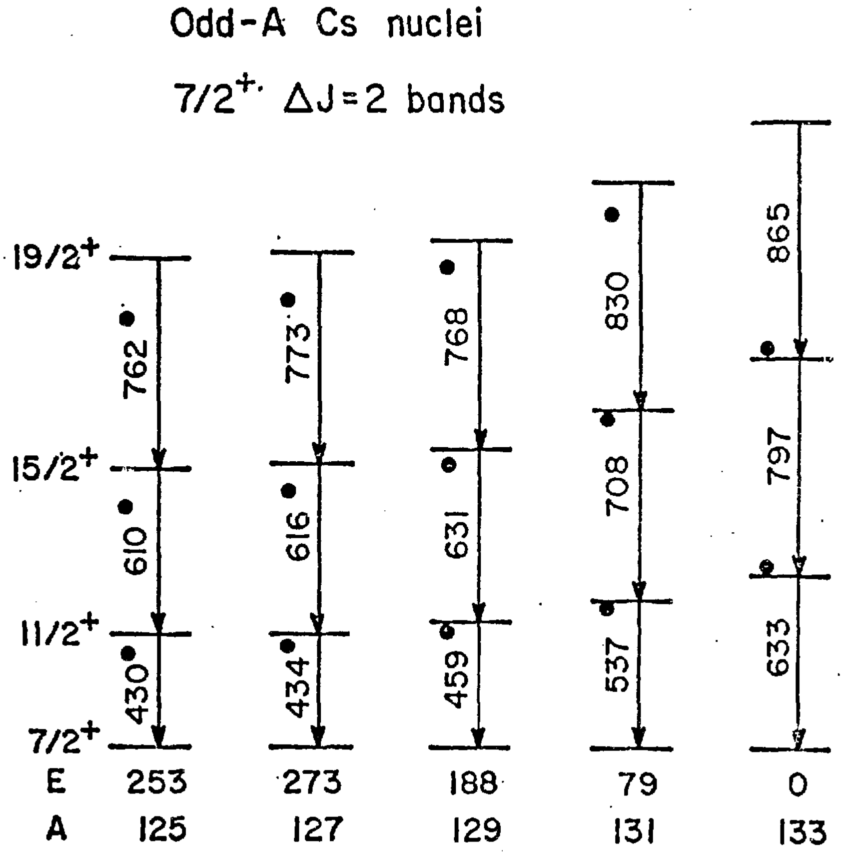
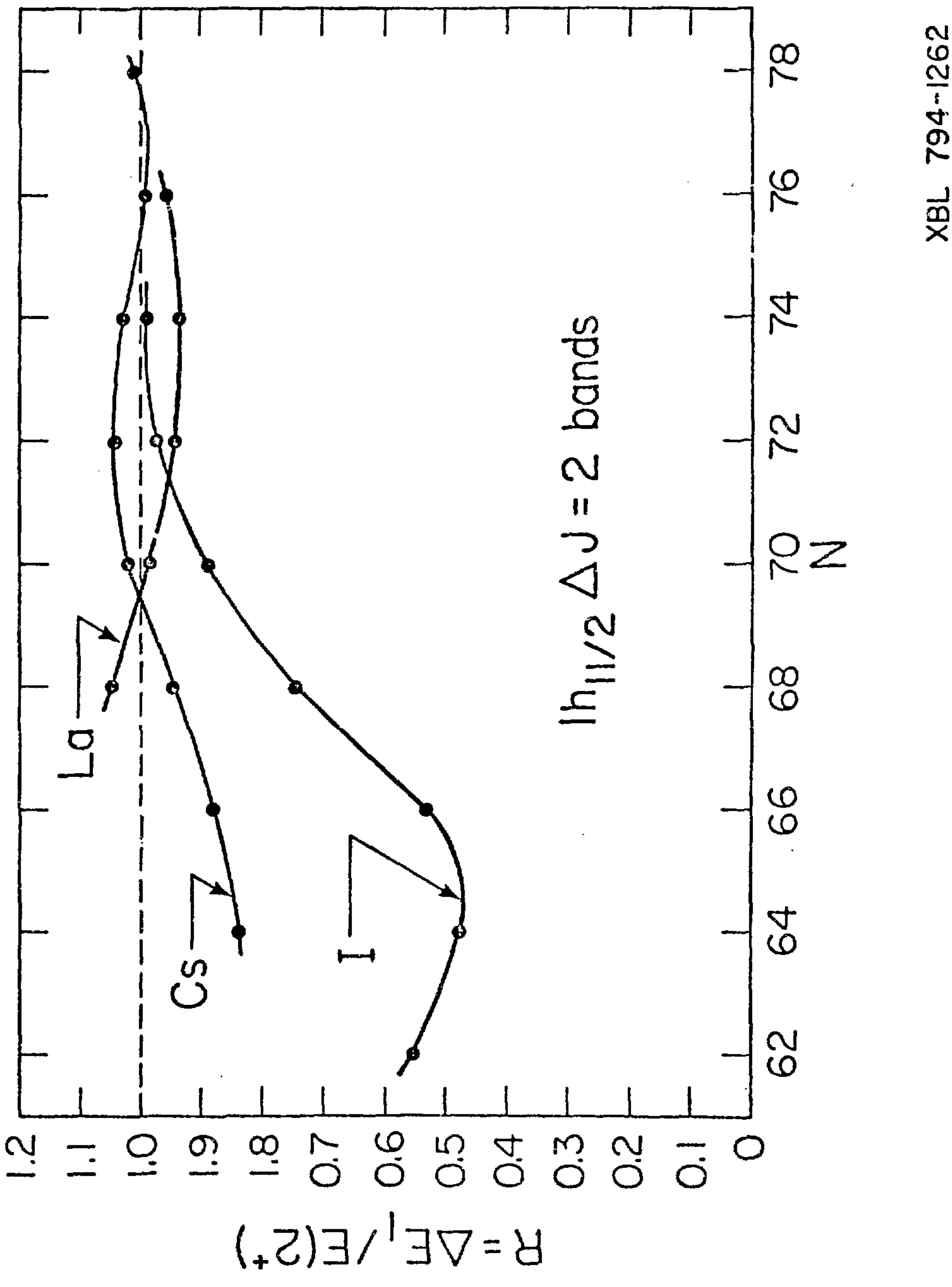

Odd-A Cs nuclei
7/2+ ΔJ=2 bands
19/2+
15/2+
11/2+
7/2+
762
610
430
773
616
434
768
631
459
830
708
537
865
797
633
E
253
273
188
79
0
A
125
127
129
131
133

Fig. 10



1h11/2 ΔJ = 2 bands
N
R = ΔE1/E(2+)
La
Cs
I
62
64
66
68
70
72
74
76
78
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1.8
1.9
1.0
1.1
1.2
XBL 794-1262

Fig. 11

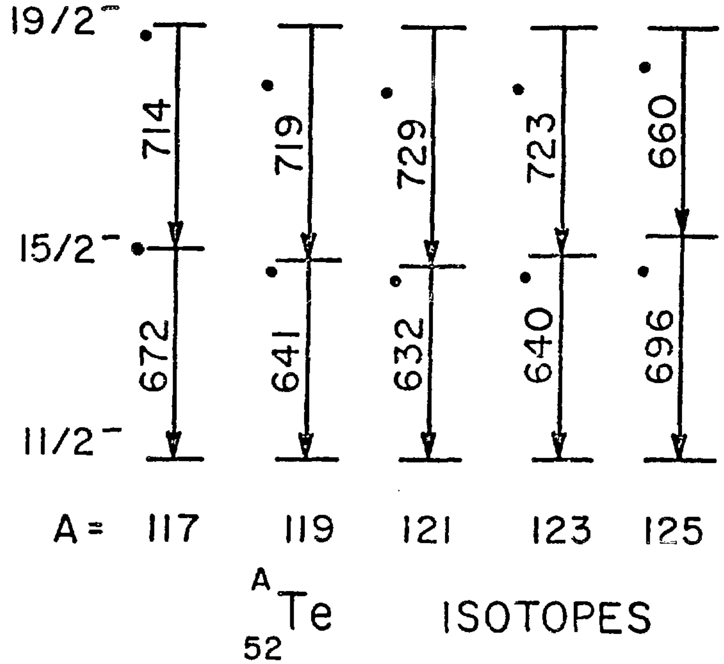

19/2⁻
15/2⁻
11/2⁻
714
672
719
641
729
632
723
640
660
696
A = 117 119 121 123 125
$^{A}_{52}Te$ ISOTOPES

Fig. 12