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RESEARCH ARTICLE

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Back bendinginTungsten (W) Isotopes

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ABSTRACT
We have developed a special computing code for calculation of nuclear deformation parameters (β) ofTungsten Isotopes. It has been shown from these calculations that by increasing neutron number, deformation parameter also increase for heavier isotopes which means more deformation from spherical shape. By comparison with Nilsson level diagrams we can infer quadrupledeformation parameter (β_2) of these isotopes.
Keywords: Yrast states, Back bending, Deformation parameter, Shape change.

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INTRODUCTION

We know that nuclei in many cases have large quadruple moments (Q) and they don't behave like a point charge, rather a spherical or elliptical shape with an axis of symmetry is considered for these nuclei. By knowing the quadruple moments, we can measure deformation parameters which can be used to define the shape of nuclei. There are different theoretical and experimental methods for calculation and measurement of nuclear electric quadruple moments [1-7].

In this paper we present a new method for calculation of quadruple moments of Tungsten isotopes. By study of rotational gamma-decay cascades in different bands of these isotopes and drawing the experimental yrast level energies versus moments of inertia for each band, we look for back bending phenomenon[8] for each W isotope. If there is a back bending, then it means that there is a change of moment of inertia,which is happening by excitation of a nucleon to another state with different angular momentum. Thus changing the total spin of nucleus. By comparison with related Nilsson diagram [9], we can find the location of displaced nucleon and thus find the related quadrupledeformation parameter (β_2) at that excitation energy. By finding the deformation parameter we can calculate the quadruple moment of the deformed isotope and study shape changes.

Theoretical Calculation and Discussion

Nuclei can be obtained in very high angular momentum states, mainly through heavy-ion induced reactions (HI, xn). The states that are populated subsequently decay, through a series of statistical low-spin transitions, into the high-spin lower energies yrast structure.

It has been shown that a large amount of angular momenta can be obtained by collective motion (i.e. a coherent contribution of many nucleons to the rotational motion). It is important that the nucleus exhibits a stable, deformed shape. Subsequently, rigid rotation will contribute angular momentum Jand energy E according to the expression

$$E = \frac{\hbar^2}{2I} J(J+1) \qquad (1)$$

Where I is the moment of inertia.

Besides the collective rotational motion, angular momentum can be acquired by non-collective motion. Here, the alignment of the individual nuclear orbits along the nuclear symmetry axis contributes to the total nuclear spin. The system does not have large deformed shapes but remains basically spherical or weakly deformed.

The excited states should cascade down toward the ground state through a sequence of E2 gamma transitions. The observation of these cascade E2 transitions provides a way to study these excited states. In particular, we can study whether the assumption of a fixed constant moment of inertia remains valid at such high excitations. One way to test this assumption is to plot the energies of the states against I(I + 1) and to see if the slope remains constant. Figure 1 is an example of such a plot for ^{158}Er and ^{174}Hf nucleiand as it can be seen there appears to be some deviation from the expected linear behavior[8].

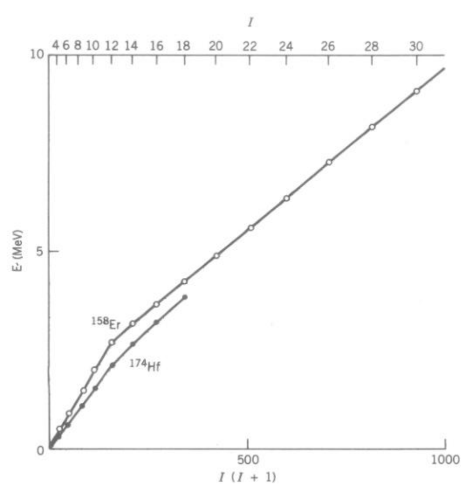

Fig. 1 E versus I(I + 1) plot for Er and Hf nuclei[8].

If we assume that the moment of inertia is not constant but increases gradually as we go to more rapidly rotating states. This effect known classically as "centrifugal stretching" would not occur for a rigid rotor but would occur for a fluid. Because rotating nuclei have moments of inertia somewhere between that of a rigid rotor and of a fluid, it is not surprising that centrifugal stretching occurs. There is a more instructive way to plot the data on the rotational structure. From equation (1) the energy of a transition from state I to the next lower state I -2 is

$$E(I) - E(I-2) = \frac{\hbar^2}{2\mathcal{I}}(4I-2) \qquad (2)$$

Or by rearranging the terms

$$\frac{2\mathcal{I}}{\hbar^2} = \frac{4I-2}{E(I)-E(I-2)} \qquad (3)$$

By plotting the left hand side of the above equation versus the square of rotational frequency ω^2 , there appears to be a gradual increase in moment of inertia among the lower angular momentum states, then a radical change in behavior and then again a return to the gradual stretching as shown in figure 2. This effect which is known as back bending occurs in some heavy nuclei because the rotational energy exceeds the energy needed to break a pair of coupled nucleons. When this effect occurs, the unpaired nucleons go into different orbits and change the nuclear moment of inertia [8].

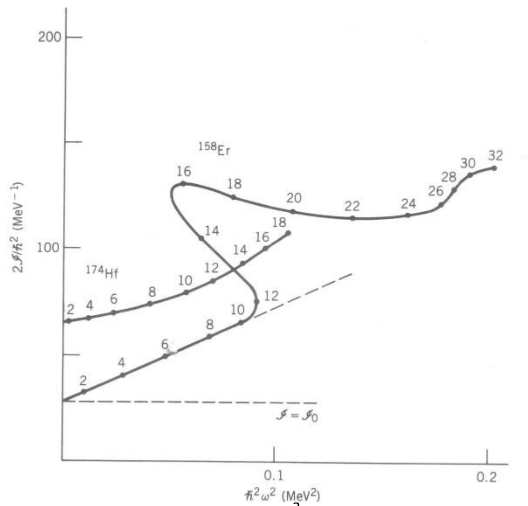

Fig. 2 Moment of inertia versus ω^2 showing back bending[8].

Shape Changes in Tungsten Isotopes

Tungsten Isotopes have 74 protons. In this paper we studied rotational gamma decays of Isotopes from A=175 to A= 178. Figure 3 clearly shows back bending for these Isotopes. Using this plot and comparison with Nilsson diagrams, we find quadruple deformation parameters of theseisotopes.The changes in deformation parameters for Tungsten isotopes are summarized in table 1.

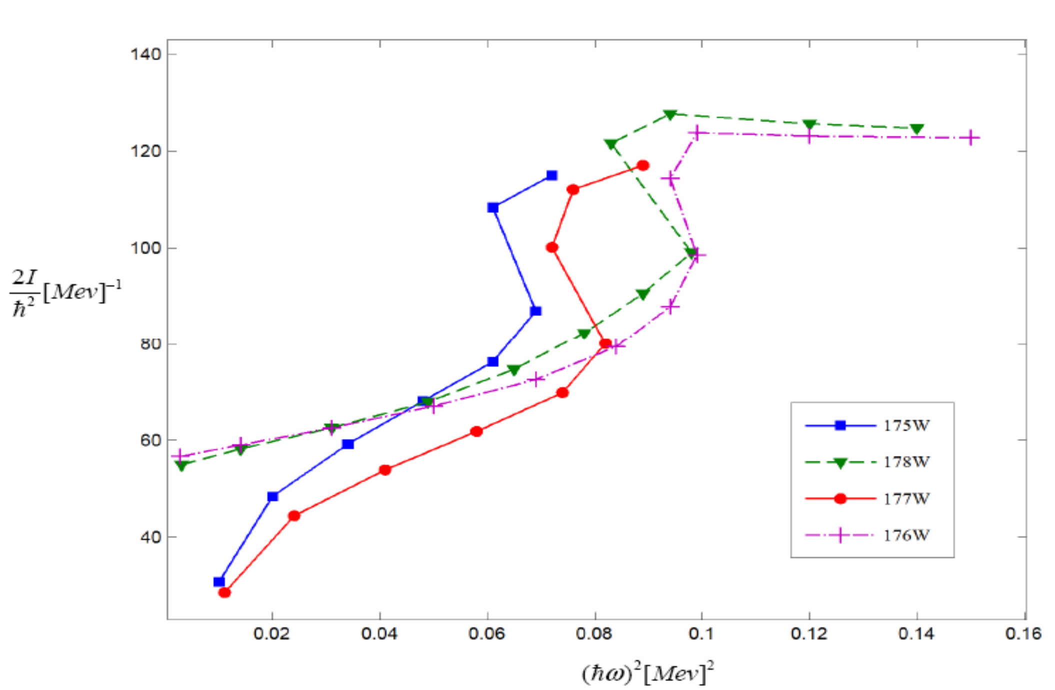

Fig. 3 Back bending for Tungsten isotopes.

A	ε_2	β_2	ε_4	β_4
175	0.18	0.19	0.0054	0.0056
176	0.23	0.24	0.0086	0.0090
177	0.17	0.18	0.0048	0.0050
178	0.23	0.24	0.0086	0.0090

Table 1. Deformation parameters and for Tungsten isotopes

As it can be seen from the above table, all Tungsten isotopes have positive deformation parameter which changes from one isotope to another one.

CONCLUSIONS

It has been shown from these calculations that by increasing neutron number of Tungsten isotopes, deformation parameter decrease for odd-A isotopes which mean less deformation from spherical shape, whereas for even-A isotopes it is constant. By comparison with Nilsson level diagrams we can infer deformation parameter (β) and calculate quadruple moments of these isotopes. This means that there are small shape changes for odd-ATungsten isotopes. Since all deformation parameters are positive, we expect prolate deformations in these isotopes.

REFERENCES

1. DeShalet A. and Feshbach H., 1990, Theoretical Nuclear Physics, Volume 1 John Wiley & Sons, ISBN 0471523666.
2. Mårtensson-Pendrill A. M., et al, 1992, Isotope shifts and nuclear-charge radii in singly ionized $^{40–48}$Ca, Phys. Rev. A 45, pp4675-4681
3. Otsuka T., Fukunishi N. and Sagawa H. 1993, Structure of exotic neutron-rich nuclei, Phys. Rev. Lett. 70, pp1385-1388
4. Baumann T. et al, 1998,Longitudinal momentum distributions of ^{16,18}C fragments after one-neutron removal from ^{17,19}C, Phys. Lett. B439, pp256-261
5. Brown B.A. and Wildenthal B. H., 1987,Empiricallyoptimum M1 operator for sd-shell nuclei,Nucl. Phys A, 474, pp290-306
6. Cederberg J., et al, 1998, Nuclear electric quadruple moment of ^{6}Li, Phys. Rev. A57, pp 2539-2543
7. Nörtershäuser W., et al, 1998, Isotope shifts and hyperfine structure in the 3d $^2D_J \rightarrow$ 4p ^2P_J transitions in Calcium II, Eur. Phys. J. D 2, pp33-39
8. Krane K.S., 1988, IntroductoryNuclearPhysics, John Wiley & Sons, ISBN 0471859141
9. Nilsson S.G., 1955, Binding States of Individual Nucleons in Strongly Deformation Nuclei, Das-Math. Pys., Vol.29, No.16.