Title
ROTATIONAL BANDS IN ODD-ODD HOLMIUM ISOTOPES

Authors
Leigh, J.R.
Stephens, F.S.
Diamond, R.M.

Publication Date
1970-08-01

Submitted to Physics Letters

UCRL-19955
Preprint

c.2

ROTATIONAL BANDS IN ODD-ODD HOLMIUM ISOTOPES

J. R. Leigh, F. S. Stephens, and R. M. Diamond

August 1970

AEC Contract No. W-7405-eng-48

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

DISCLAIMER

ROTATIONAL BANDS IN ODD-ODD HOLMIUM ISOTOPES*

J. R. Leigh, F. S. Stephens, and R. M. Diamond

Nuclear Chemistry Division, Lawrence Radiation Laboratory
University of California
Berkeley, California 94720

August 1970

ABSTRACT

Coriolis-mixed rotational bands have been observed in ^{160}Ho and ^{162}Ho with apparent moments of inertia approximately twice the rigid-body value. The combined effects of the two odd particles, occupying the unique-parity Nilsson orbitals 7/2- [523] ($h_{11/2}$-proton) and 5/2+ [642] ($i_{13/2}$-neutron), are thought to be responsible.

The use of high resolution Ge(Li) detectors and small on-line computers for data acquistion and analysis has made possible the study of odd-odd nuclei following heavy ion, xn reactions. Two of the more interesting cases recently studied are presented here.

The following reactions have been used to populate high-angular-momentum states in ^{160}Ho and ^{162}Ho; ^{154}Sm(^{11}B,5n)^{160}Ho, ^{159}Tb(^{4}He, 3n)^{160}Ho and ^{160}Gd(^{7}Li, 5n)^{162}Ho. The schemes presented in fig. 1 are established by γ-γ coincidence measurements. Angular distribution measurements indicate a series of cascading M1-E2 transitions, where the E2 admixture is a few percent. Excitation functions indicate increasing angular momentum up the band. Complete experimental details will be published later.

*Work performed under the auspices of the U. S. Atomic Energy Commission.

The 6^- state of ^{162}Ho has been assigned as the p 7/2- [523] n 5/2+ [642] configuration [1]. Comparison of the band intensity and that of the decay of the 106 keV 6^- level suggests that the observed band is based on this 6^- state. In ^{164}Ho, three rotational levels have been attributed [2] to this same 6^- configuration, and the similarity of that band to the one discussed here lends support to the present assignment. (The similarity of these two bands would be even more striking using an alternative assignment discussed in ref. 2). This 6^- configuration should also occur in ^{160}Ho and the band observed there is most probably also based on this state; however, assignment of the 6^- state itself is not so certain in this case, since the 118 keV and 169 keV levels are both possible candidates. The 118 keV state might be assigned as the base of the band since the 51 keV transition (169 keV → 118 keV) has the energy and multipolarity expected if it were also a band member. On the other hand the 169 keV state might be selected on the basis of the very great similarity between the sequence of transitions based on this state and the bands in ^{162}Ho and ^{164}Ho. Also the observed small oscillation in the energy level spacings has the same sign as that in ^{162}Ho if the 169 keV state is the 6^- state, but disagrees for the 118 keV assignment. The 169 keV level is tentatively assigned as the 6^- state, but further work is being carried out to decide more conclusively between these two possibilities. With the 6^- assignment for the 169 keV state, a possible configuration for the 118 keV state would be 5^-, p 7/2- [523] n 3/2+ [402].

The rotational sequence has been fitted with the expression

$$E_I = E_o + AI(I + 1) + BI^2(I + 1)^2 + CI^3(I + 1)^3 + (-1)^{I+K} A_{2K} \frac{(I + K)!}{(I - K)!} \quad (1)$$

The band has three rather striking properties; 1) an apparent moment of inertia approximately twice the rigid-body value (A = 3.3 keV for ^{162}Ho and 3.5 keV for ^{160}Ho); 2) a positive rotation-vibration interaction term (B = +22 eV for ^{162}Ho and +21 eV for ^{160}Ho); and 3) a small oscillating term of order 10^{-14} keV for both. This is precisely the behaviour expected from highly Coriolis-mixed bands and is not surprising in this case since bands based on the proton and neutron states involved in this configuration show large Coriolis mixing in neighboring odd-A Ho [3] and Er [4] isotopes respectively.

Coriolis mixing has been treated rather comprehensively [4,5] and the largest effects come from the unique-parity, high j Nilsson orbits within each shell. In the odd-odd case, coupling can take place through both proton and neutron states and many more states become important. For the present band in ^{162,160}Ho, both the proton and neutron occupy the above mentioned orbitals for their respective shells, namely the $h_{11/2}$ and $i_{13/2}$ orbits.

The lowest order effect of the mixing on the level spacing is to increase the apparent moment of inertia in the band. Thus, neutron states associated with the $i_{13/2}$ orbit in odd-A nuclei in this region have moments of inertia close to the rigid-body value [6] or above in special cases [7]. Likewise the $h_{11/2}$ proton states have exceptionally large moments of inertia, though less dramatic than those of the above neutron states. The coupling of these two states in the 6^- band combines the contributions to the moment of inertia due to each one, producing the enormous effective moment observed. In such highly compressed bands there is a general higher-order effect leading to positive B terms, in accordance with the observations on the present bands.

The oscillation in the energy levels observed in strongly Coriolis-mixed odd-A bands can be described as due to the successive coupling of states with K, K - 1 . . ., etc. back to the 1/2 band, the decoupling parameter of this band being responsible for the oscillation. The magnitude of the oscillation is reduced at each stage and hence is smallest for highest K. In the odd-odd case, K = 0 bands generally exhibit a displacement of the even-spin levels relative to the odd-spin ones [8], which can be transmitted to the K = 6 band. In the case of $\Omega_n = \Omega_p = 1/2$, the Coriolis mixing of the K = 0 and K = 1 bands gives a contribution to this displacement. For the $\Omega = 1/2$ bands of interest here, namely n 1/2+ [660] and p 1/2- [550], the Coriolis effects will be large and likely to dominate other sources of displacement. If so, one can predict A_{2K} (eq. 1) to be negative. This is, indeed, in accordance with the observed sign. However, the last term of eq. 1 does not reproduce the observed I dependence of the oscillation very well, probably due to contributions from other bands and from higher-order terms.

Several two-quasi-particle states with I ~ 6 are expected to exist below 300 keV, and bands based on these states would normally be populated approximately equally, resulting in very complex spectra. In these Ho nuclei the large effective moment of inertia of this particular 6^- configuration considerably lowers the high-spin members of this band relative to all others. The heavy ion, xn reaction is then particularly selective and the population is funnelled predominantly into the compressed band, resulting in remarkably uncomplicated spectra.

We are indebted to Drs. K. H. Maier, K. Nakai, and J. L. Quebert for their interest and helpful discussions. The HILAC crew are to be congratulated for maintaining their usual high performance level. One of us (J.R.L.) would like to express his appreciation to Prof. I. Perlman for the opportunity to take part in these experiments at the L.R.L.

REFERENCES

1. C. Ekström, T. Noreland, M. Olsmats, and B. Wannberg, Nucl. Phys. A135 (1969) 289; M. Jørgensen, O. B. Nielsen, and O. Skilbreid, Nucl. Phys. 24 (1961) 443.

2. H. D. Jones and R. K. Sheline, Nucl. Phys. A150 (1970) 497.

3. R. M. Diamond and F. S. Stephens, unpublished data.

4. K. A. Hagemann, S. A. Hjorth, H. Rydé, and H. Ohlsson, Phys. Letters 28B (1969) 661; S. A. Hjorth, H. Ryde, K. A. Hagemann, G. Løvhøiden, and J. C. Waddington, Nucl. Phys. A144 (1970) 513.

5. F. S. Stephens, D. M. Holtz R. M. Diamond, and J. O. Newton, Nucl. Phys. A115 (1968) 129.

6. O. Nathan and S. S. Nilsson, Alpha-, Beta-, and Gamma-Ray Spectroscopy, edited by K. Siegbahn, (North-Holland Publishing Co., Amsterdam, Vol. 1, Ch. X).

7. O. Schult, et al., Phys. Rev. 154 (1967) 1146.

8. N. D. Newby, Jr., Phys. Rev. 125 (1962) 2063.

FIGURE CAPTION

Fig. 1. Level schemes for ^{160}Ho and ^{162}Ho. Relative transition intensities are indicated and are those obtained following ^{154}Sm(^{11}B, 5n)^{160}Ho and ^{160}Gd(^{7}Li, 5n)^{162}Ho reactions.

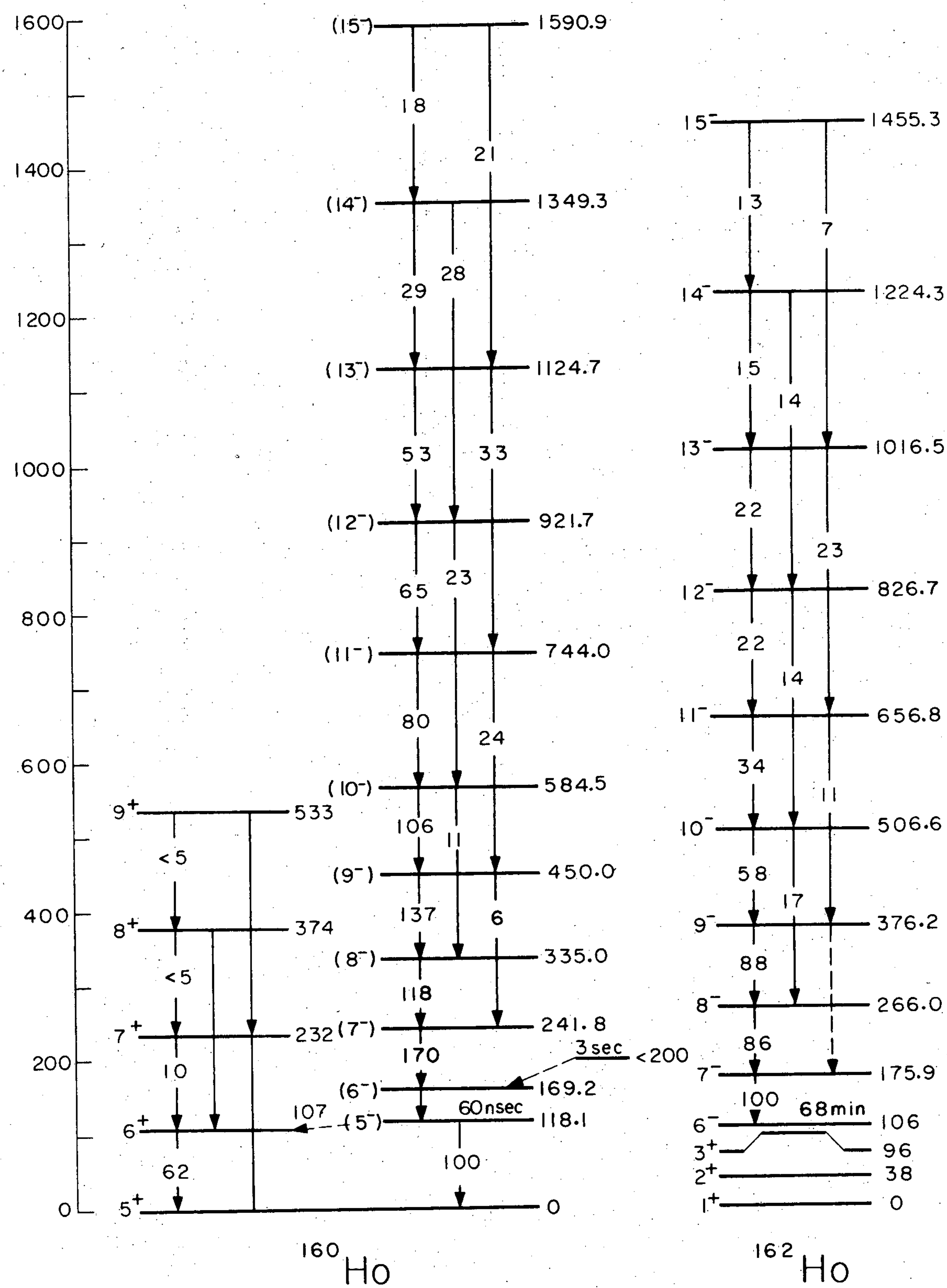

Fig. 1

XBL707-3363

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720