CONF-821143--13

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DE84 003277

LIFETIMES OF HIGH-SPIN STATES OF $^{160,161}\text{Yb}$

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Abstract Recoil-distance measurements of lifetimes of high-spin states of $^{160,161}\text{Yb}$ are described. While the results for the ground band of ^{160}Yb are not inconsistent with centrifugal stretching, the addition of one or more quasineutrons seems to cause a reduction in collectivity which depends on frequency but not, for the cases examined, on the type of quasineutron.

INTRODUCTION

The use of the recoil-distance method with fusion-evaporation reactions permits the measurement of lifetimes of high-spin states. From these data, one may examine the variation of nuclear deformation with angular momentum. The nucleus ^{160}Yb is known to have a strong backbend at about spin 12 and a number of well aligned sidebands,⁵ giving the possibility of studying the deformation for different configurations of the quasineutrons.

EXPERIMENTAL METHOD

Ytterbium isotopes were made by the reaction $^{116}\text{Cd}(^{46}\text{Ti}, \text{xn})$ and its inverse $^{46}\text{Ti}(^{116}\text{Cd}, \text{xn})$. In the former case, a 205-MeV ^{46}Ti beam from the 25-MV electrostatic accelerator at Oak Ridge was used, leading to a recoil velocity of 6.87 $\mu\text{m}/\text{ps}$. The ^{116}Cd beam was obtained by using the electrostatic accelerator as an injector for ORIC. The beam

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energy, 495 MeV, was chosen to give the same center-of-mass energy as in the titanium-induced reaction. This gave a recoil velocity of 19.3 $\mu\text{m/ps}$.

Our method differed in two respects from the standard recoil-distance technique. In order to provide some selection of reaction channel, we⁶ have constructed a recoil-distance device which fits into the annular opening of a 25-cm x 25-cm NaI detector, as illustrated in Fig. 1. It is designed so that the target foil is located near the center of the NaI crystal which is operated as a total-energy sum spectrometer. The "stopper" to catch the recoiling nuclei consisted of a high quality nickel foil onto which about 40 mg/cm^2 of lead was evaporated.

FIGURE 1. Schematic drawing of the Oak Ridge Recoil Distance Device. All of the principal components are labeled. The germanium detector for the system is not shown, but it fits in the annular opening of the NaI detector opposite the plunger mechanism.

The second modification to the usual recoil-distance technique was adopted for the inverse reaction. In order to avoid the severe Doppler broadening of the "unshifted" peaks due to the high recoil velocity, we replaced the stopper foil with a gold foil of thickness 4.5 mg/cm^2 . This slowed the recoils to $13.5 \text{ } \mu\text{m/ps}$. The recoils and the beam were finally stopped by a 30 mg/cm^2 lead foil positioned behind the gold foil such that only the first 2^+ state and ground state had appreciable population after the recoils had come to rest. Thus, at large target-retarder separations, the $2^+ \rightarrow 0^+$ transition appeared as three peaks — an unshifted, a less shifted, and a fully shifted. These were used to determine the recoil velocity.

Spectra were taken at eleven target-stopper separations with the ^{48}Ti beam and six target-retarder separations with the ^{116}Cd beam. Our primary interest in the inverse reaction was to obtain data at small target-retarder separations in order to gain some information about the states near the second backbend at spin 28^+ . Unfortunately, target problems prevented this, but useful additional points on the decay curves of the yrast states below the 20^+ were obtained. Figure 2 shows limited energy regions in the gated Ge(Li) spectra for some of the target-retarder distances. Because of the complexity of the spectra, it was not possible to obtain the areas of both the shifted and unshifted peaks of all transitions. To normalize the spectra obtained at different target-stopper separations, we chose to use the intensity of the continuum above the discrete peaks.

FIGURE 2. Sections of the γ -ray spectra in the "4n" gate recorded with flight times between the target and retarding foil of (a) 137 ps, (b) 29 ps, (c) 9.0 ps for the Cd-induced reaction. Only members of the yrast sequence are labeled.

RESULTS

The major problem in extracting lifetimes from the decay curves is that of feeding. In a (HI,xn) reaction the observed levels are populated through transitions from other unobserved levels whose lifetimes are, in general, comparable to those being measured. We have attacked the problem with an extensively modified version of a computer program originally due to H. Emling of G.S.I., Darmstadt. This program applies all of the usual corrections⁷ to the data, but handles the problem of feeding by direct solution of the Bateman equations. That is, given an ansatz for the decay scheme, the program adjusts the lifetimes and initial populations of the levels to obtain the best fit to the decay curves. This ansatz is shown in Fig. 3. At each point where sidefeeding is shown in Fig. 3, a cascade of two levels was used to model the time distribution of the sidefeeding intensity.

computed from the value ϵ_2 and γ corresponding to the initial or decaying level according to⁹

$$Q_0 = 4/3 Z e \langle r^2 \rangle \frac{\cos (30^\circ + \gamma)}{\cos (30^\circ)} \cdot \epsilon_2, \quad (2)$$

where

$$\langle r^2 \rangle = 3/5 (1.25 A^{1/3})^2 \text{ fm}^2. \quad (3)$$

Figure 4 shows the Q_t values of those g-band members of ^{160}Yb for which we currently have values. The value for the 6^+ state is preliminary. The difficulty in obtaining lifetimes for the higher g-band members arises from the complex feeding patterns from the sidebands into the 8^+ and 6^+ states (see Fig. 3). Although calculations⁸ show some evidence for "stretching" in the ground band, it is difficult to assess whether or not the limited experimental data substantiate or refute this.

FIGURE 4. A comparison of measured and theoretical quadrupole moments of g-band members of ^{160}Yb . The open circles are from the experimental data.

Figure 5 shows Q_t values for various quasiparticle bands in $^{160,161}\text{Yb}$. While the results in Fig. 4 are not inconsistent with centrifugal stretching, the results for ^{161}Yb in Fig. 5 show that the addition of one quasiparticle produces the opposite behavior. The two-quasiparticle bands of ^{160}Yb show a similar effect, but apparently with an increased rate of loss of collectivity with increasing rotational frequency. This latter difference, which we failed

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to recognize in our abstract due to a miscalculation of the Q_t value for the $17/2^+$ state of ^{161}Yb , is probably due to the $N=88$ core of ^{160}Yb being softer and more easily deformed than the $N=90$ core of ^{161}Yb . The results for ^{160}Yb also suggest that two $i_{13/2}$ quasineutrons have approximately the same effect on the core as an $i_{13/2}h_{9/2}$ pair.

FIGURE 5. Quadrupole moments of some quasiparticle-band members of $^{160,161}\text{Yb}$ versus rotational frequency.

Finally, Fig. 6 presents a comparison of the results for the s-band of ^{160}Yb and the theoretical calculations.⁸ Our result for the 16^+ yrast state is difficult to understand. It is unlikely that it is due to a mistake in allowing for feeding, firstly because the inferred lifetime is shorter than expected, and secondly because only 14% of the feeding of the 16^+ level is due to unobserved side-feeding, the remainder coming from the $18^+ + 16^+$ transition (see Fig. 3). If the dropoff in Q_t in Fig. 6 does indeed

arise from increasing positive γ -deformation, it appears that the theory fails quantitatively in predicting the large degree of triaxiality at the higher rotational frequencies.

FIGURE 6. A comparison of measured and theoretical quadrupole moments of s-band members of ^{160}Yb . The closed circles are the theoretical values.

ACKNOWLEDGMENTS

This work was supported by the U.S. Department of Energy under Contract No. W-7405-eng-26 with Union Carbide Corporation.

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