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Yrast transition strengths in ^{126}Ba

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Abstract. Mean lifetimes of the high spin states in the yrast band of ^{126}Ba were measured by using the Doppler shift attenuation method in connection with the reaction ^{116}Sn (^{16}O, 2p4n)^{126}Ba at a beam energy of 73 MeV. The corresponding normalized B(E2) values are obviously reduced in the vicinity of the backbending. The results are compared with the theoretical predictions based on a realistic nucleon-nucleon interaction.

PACS. 21.60.-n Nuclear structure models and methods – 23.20.ck – 27.60.j $90 \leq A \leq 149$

1 Introduction

Lifetimes of yrast states in ^{126}Ba were measured by Seiler-Clark et al. [1]. The data indicate that E2 transition strengths are obviously reduced for 8^+ and 10^+ states, whereas the B(E2) comes rather close to symmetric rotor value for 12^+ state. This result is not in agreement with the theoretical calculation by Reinecke and Ruder [2] by using the particle-rotor model with VMI-core. But their model could describe successfully the backbending behaviour and reproduce very well reduction of experimental B(E2) value within the backbending region for even-even Ce isotopes [2]. Reinecke and Ruder predict that E2 transition strengths exhibit a minimum for the 12^+ state of the yrast band in ^{126}Ba while the B(E2) for all other yrast transitions remain the full rotational value. The results obtained by Schiffer et al. [3] are consistent in general with that reported in [1], however, are not in agreement with the model predictions of the symmetric rotor and with the IBA model.

In all the previous lifetime measurements for ^{126}Ba performed using the recoil distance Doppler shift (RDDS) method the data analysis was carried out in gamma single spectra. So the overlapping of neighbouring lines and the interference from the other evaporation channels is a troublesome problem in the RDDS analysis. The previously measured results indicated lifetimes for most of the yrast states in the range accessible to the Doppler shift attenuation (D S A) method apart from the lower excited states. It is of interest, therefore, to re-measure lifetimes of high spin states in ^{126}Ba by using the DSA method to further observe the electromagnetic transition strengths in the backbending region and to compare with theoretical calculations. In order to reduce the complication of the spectra by gamma rays associated with other reaction channels and the effect of the interference lines on analysis of line shape,and then to improve accuracy of the experimental results,in the present work the DSA measurements were performed by means of a multidetector array in gamma-gamma coincidence method.

2 Experimental procedure

High spin states in ^{126}Ba were populated with the fusion-evaporation reaction ^{116}Sn(^{16}O,2p4n)^{126}Ba at a bombarding energy of 73 MeV. The ^{16}O beam was provided by the HI-13 tandem accelerator of the China Institute of Atomic Energy, Beijing. The target used was a 92.8% isotopically enriched 970 μg/cm^2 thick ^{116}Sn foil which was evaporated on a 20 mg/cm^2 thick Pb backing in order to slow down and stop the ^{126}Ba recoils.

The gamma rays emitted from the evaporation residuals were detected using a multidetector array consisting of seven germanium detectors, each of which was equipped with a symmetric bismuth germanate Compton suppression device in order to enhance the photo peaks relative to the Compton background. The detectors were positioned as follows. Three at angle of 90° with respect to the beam direction and two at both 30° and 143°. The distance between each germanium detector and the target was 18 cm, thus the subtended solid angle was relatively small, thereby reducing the effects of angular Doppler broadening. Relative efficiency measurements and energy calibrations of the detectors were performed by means of the standard sources ^{60}Co and ^{152}Eu. The detectors had 15–30% efficiency and 1.9–2.1 keV energy resolution at 1.33 MeV photon energy for ^{60}Co. During the experiment the beam currents were limited to 10–15 particles nA. A condition was set on the data collection that for an event to be recorded at least two Compton suppressed germanium detectors had to fire simultaneously. In the present ex-

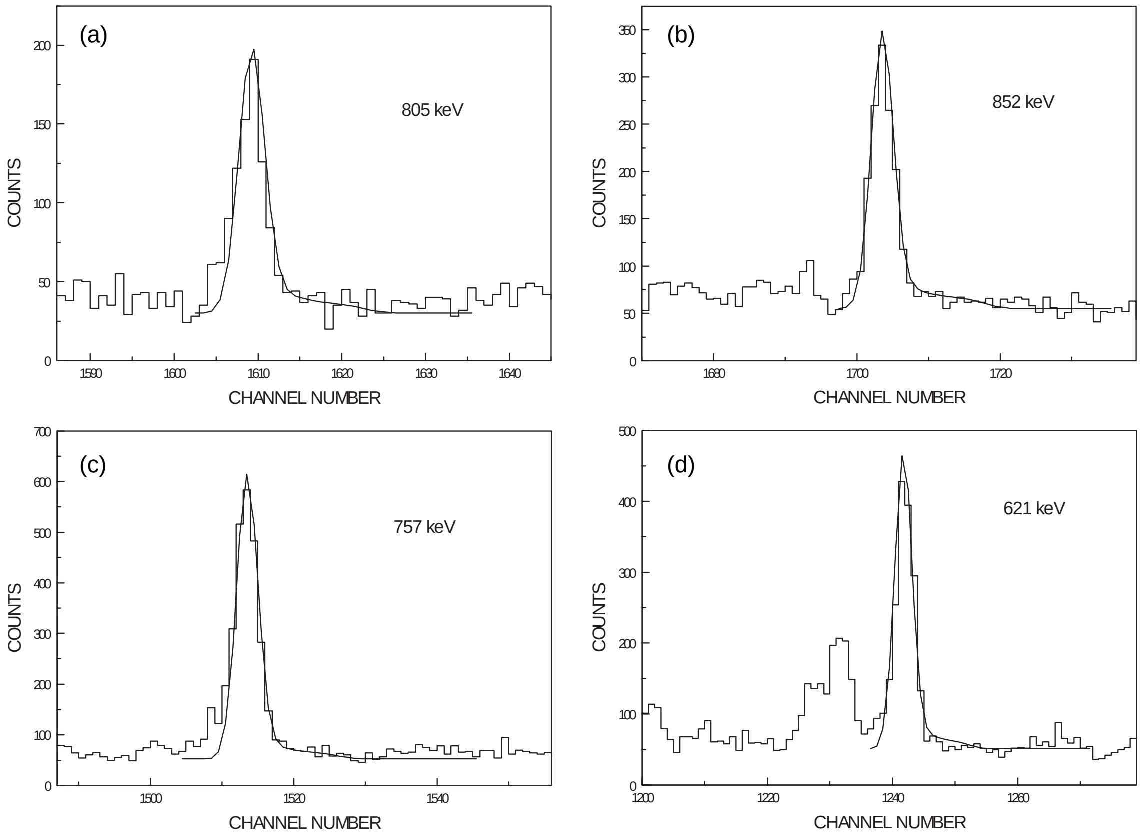

Fig. 1. Line shapes of the 805 keV $12^+ \rightarrow 10^+$, 852 keV $10^+ \rightarrow 8^+$, 757 keV $8^+ \rightarrow 6^+$ and 621 keV $6^+ \rightarrow 4^+$ transitions obtained from the gated spectra. The *solid lines* are the best fit to the experimental line shapes

periment a total of approximately 60 million coincidence events were stored on magnetic tapes in event by event mode.

3 Data processing and results

In off-line analysis, an angle-dependent two-dimension matrix was established from the event by event data following minor adjustments to gain match the detectors. This matrix was sorted with the 30° detector versus all the other detectors. The 30° spectra projected from the matrix was used for DSA analysis to determine lifetimes of levels. To remove overlapping gamma rays, the 30° coincidence spectra were obtained by setting gates in coincidence with ^{126}Ba transitions in the other detectors. The Doppler-broadened line shapes observed at 30° were analyzed using the program GNOMON developed by Hellmeister and Lühmann [4]. The method of the DSA analysis is described in detail in a recent paper [5]. The initial recoil velocity for ^{126}Ba recoils was calculated to be $v/c = 1.19\%$ from the reaction kinematics. In fitting the Doppler-broadened line shapes,the distribution in magnitude and angle of the initial recoil velocity, the finite target thickness, the finite solid angle and energy resolution of the detector, as well as the feeding pattern were taken into account. The line shape fitting process was started from the highest transition deexciting the topmost 18+ state of the yrast band without considering any feeding times. This provided an effective lifetime of 0.71 ± 0.10ps for this state. The measured lifetimes were taken as feeding time in fitting the line shapes of the gamma transitions deexciting lower states. The side feeding from unobserved states was also taken into account. The side feeding intensity was determined from the measured relative intensities of gamma rays. As an example, Fig. 1 shows the observed and fitted line shapes for the 805 keV $12^+ \rightarrow 10^+$, 852 keV $10^+ \rightarrow 8^+$, 757 keV $8^+ \rightarrow 6^+$ and 621 keV $6^+ \rightarrow 4^+$ transitions. The lifetime obtained from the present work are given in Table 1 together with previous results measured by using the RDDS method [1, 3]. A comparison of lifetimes accessible to the DSA and RDDS methods would be a more direct check for the present measurement. Our results are in agreement wih the previously reported values within experimental error limits and appears more coincide with the ones of [1] apart from the 12^+ and 14^+ states. The discrepancies for these two states would probably be attributed to the overlapping of neighbouring lines from all the reaction channels and the interference from the Doppler shifted components of some gamma rays resulting in a serious problems of unfolding the multiplets in the gamma single spectra in their RDDS measurements. In addition, in fitting the line shape of the 805 keV gamma transition deexciting the 12^+ state the measured lifetime

Table 1. Lifetimes for the yrast states in ^{126}Ba

E_x (keV)	I^π	E_γ (keV)	$\tau(ps)$		
			Present	ref.[1]	ref.[3]
256.1	2^+	256.1		$188\binom{10}{30}$	170(13)
711.2	4^+	455.1		$9.3\binom{10}{11}$	9.4(8)
1332.5	6^+	621.3	1.47(30)	$1.62\binom{100}{50}$	1.8(8)
2089.7	8^+	757.2	2.02(35)	$2.14\binom{35}{25}$	1.1(4)
2942.1	10^+	852.4	1.45(38)	$0.92\binom{20}{15}$	0.3(2)
3747.4	12^+	805.3	1.91(49)	$0.44\binom{30}{10}$	0.4(2)
4419.6	14^+	672.2	0.71(10)	$1.8\binom{3}{6}$	2.2(4)
5244.7	16^+	825.1	0.49(10)		0.3(2)
6195.5	18^+	950.8	<0.71[a]		

[a] Effective lifetime not corrected for feeding

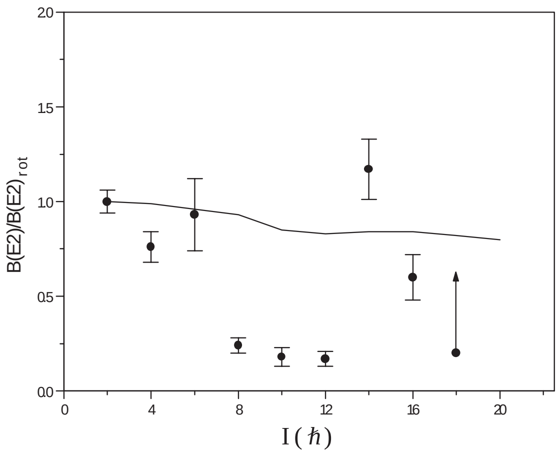

Fig. 2. The normalized B(E2) values for the yrast states in ^{126}Ba. The calculated values as single points are connected by a line to guide the eye

of the 14^+ state was taken as feeding time, and thus the different lifetime values of 14^+ state also affect lifetime result of 12^+ state.

4 Discussion

For the convenience of investigating the yrast transition strength in ^{126}Ba with increasing angular momentum, the experimental B(E2) values determined from the lifetime measurements were expressed in relative B(E2) values normalized to that of a symmetric rotor possessing a deformation characterised by the strength of the $2^+ \rightarrow 0^+$ yrast transition. The normalized B(E2) values are presented in Table 2 and are displayed in Fig. 2. In the absence of any shape change or band crossing the normalized B(E2) values as a function of angular momentum should remain constant.

Before the band crossing attributed to the alignment of a pair of $\upsilon h_{11/2}$ quasineutrons, the data show a reduction of the normalized E2 transition strengths. In the vicinity of the backbending, the E2 transition strengths are pronouncedly reduced and reach a minimum for the 10^+ and 12^+ states. Above the backbending, the normalized B(E2) recover to approximately the rotational values.

Table 2. B(E2) values for the yrast states in ^{126}Ba

E_x (keV)	I^π	E_γ (keV)	B(E2) (e^2fm^4)	B(E2)/B(E2) rot
256.1	2^+	256.1	4143(230)	1.00(6)
711.2	4^+	455.1	4497(478)	0.76(8)
1332.5	6^+	621.3	6064(1232)	0.93(19)
2089.7	8^+	757.2	1633(283)	0.24(4)
2942.1	10^+	852.4	1260(330)	0.18(5)
3747.4	12^+	805.3	1270(332)	0.17(4)
4419.6	14^+	672.2	8428(1187)	1.17(16)
5244.7	16^+	825.1	4378(893)	0.60(12)
6195.5	18^+	950.8	>1485	>0.20

The electromagnetic transition strengths for ^{126}Ba were calculated using the microscopic MONSTER code by Hammaren et al. [6]. The calculation is based on a realistic nucleon-nucleon interaction and project onto both good angular momentum and particle number. The calculated B(E2) values are also shown in Fig. 2. The theoretical predictions do not reproduce a sharp drop for the states around the backbend,whereas a rather constant normalized transition strength up to 20^+ state is predicted. The measured electromagnetic transition strengths are obviously smaller than the theoretical values.

It should be pointed out that the observed gross behaviour of the E2 transition strength of the yrast band in ^{126}Ba trends resemble that one in the neighbouring even-even Ce isotopes around $A = 130$ mass region. For example, in ^{132}Ce, the E2 transition strengths also display a pronounced reduction for the states around the backbend [7].

5 Summary

High spin states of ^{126}Ba were populated with the fusion-evaporation reaction ^{116}Sn(^{16}O,2p4n)^{126}Ba at an incident energy of 73 MeV. Mean lifetimes of the yrast band were determined through analysis of the Doppler-broadened line shapes. The data show that the normalized B(E2) values are pronouncedly reduced within the backbending region. The results are compared with the theoretical calculations of the MONSTER code. The experimental values are much lower than the theoretical values.

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