High-spin states in neutron-rich ^{102}Mo nucleus*

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Abstract High-spin states in neutron-rich ^{102}Mo nucleus have been studied by measuring the prompt γ-rays in the spontaneous fission of ^{252}Cf. The previous level scheme has been updated and some new levels and transitions are identified. The one-phonon γ-band is expanded and a band head level of the two-phonon γ-band is proposed. The systematic characteristics of yrast bands, one-phonon γ-bands, two-phonon γ-bands and quasi-particle bands in ^{102}Mo, ^{104}Mo and ^{106}Mo are discussed.

Key words spontaneous fission, neutron-rich nucleus, γ-band, quasi-particle band

PACS 21.10.Re, 23.20.Lv, 27.60.+j

1 Introduction

The study of high-spin states in neutron-rich nuclei around $A \sim 100$ region can provide valuable information of the nuclear structure, such as the sudden onset of the large quadrupole deformation at $N \simeq 60$, triaxial deformation, shape transition from the prolate to the triaxial, shape coexistence[1—3], and systematic one-phonon and two-phonon γ-vibrational bands[4—9].

Here we report on new high-spin states in ^{102}Mo. In previous report[10], some high-spin levels of ^{102}Mo have been studied using (α,^{238}U) reaction. The ground-state band was established up to 16^+ and two side rotational bands were observed[10]. The low excitation levels have been studied through β-decay[11].

2 Experiment and result

High-spin states in neutron-rich ^{102}Mo nucleus have been studied by measuring the prompt γ-rays emitted after their formation in the spontaneous fission of ^{252}Cf. The measurement was carried out at the Lawrence Berkeley National Laboratory. Prompt γ-γ-γ coincidence studies were performed with the Gammasphere detector array consisting 102 Compton-suppressed Ge detectors. A ^{252}Cf source of strength ∼ 60 μCi was placed at the center of the Gammasphere. A three-dimensional histogram of 5.7×10^{11} coincidence events was constructed. The coincidence data were analyzed with the Radware software package.

The level scheme obtained in the present work is shown in Fig. 1. Most results reported in Ref. [10] have been confirmed. Besides, a total of 12 new levels and 39 new transitions were identified comparing the results in Refs. [10, 11]. The new transitions have been marked with an asterisk (∗) before the transition numbers in the scheme, as shown in Fig. 1. Some levels and transitions in lower spin states reported in Ref. [10] have been re-arranged or updated.

3 Discussion

In the Fig. 1, band (1) is ground state band, and

Received 3 September 2008

∗ Supported by National Natural Science Foundation of China (10575057, 10775078), Major State Basic Research Development Program (2007CB815005), Special Program of Higher Education Science Foundation (20070003149) and U.S. Department of Energy under Grant and Contract Nos. DE-FG05-88ER40407, DE-AC03-76SF00098

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bands (3) and (6) belong to the two quasi-neutron excitation bands[10]. The second 0^+ state at 697.2 keV level labeled (5) is still considered as the band head of β-vibrational band. We add an 1244.9 keV level inside the band (2) with spin and parity $I^\pi = 3^+$ according to the level energy and the de-excitation transition relationships. Thus, the band (2) is updated.

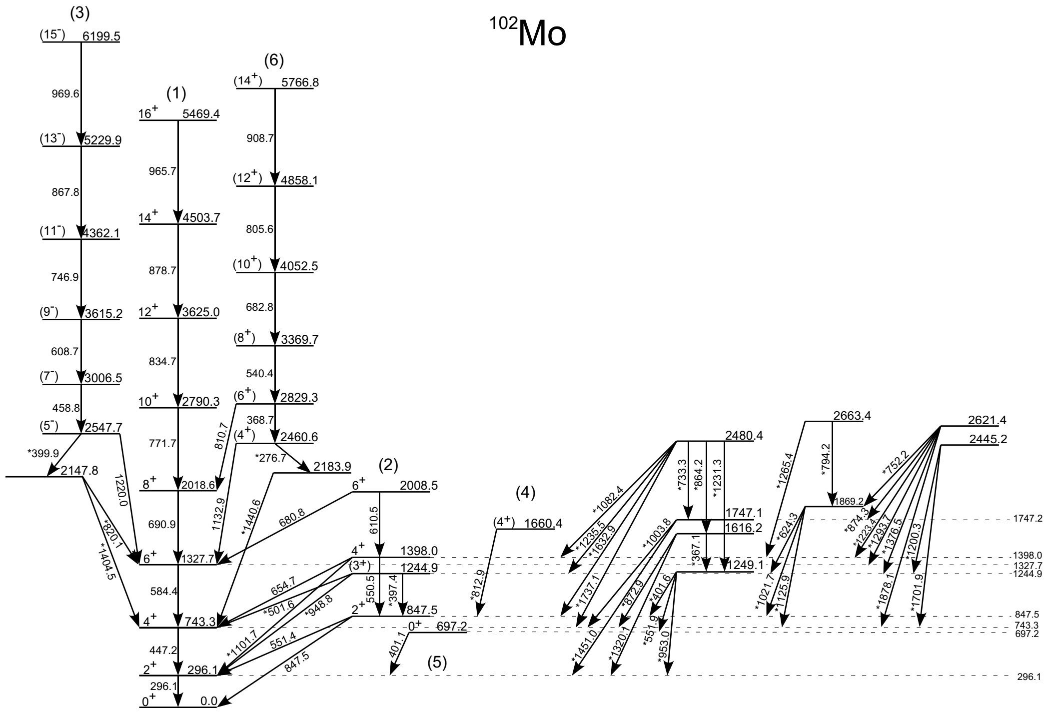

Fig. 1. Level scheme of ^{102}Mo obtained in present work. The new transitions have been marked with an asterisk(*) before the γ-transition energy numbers.

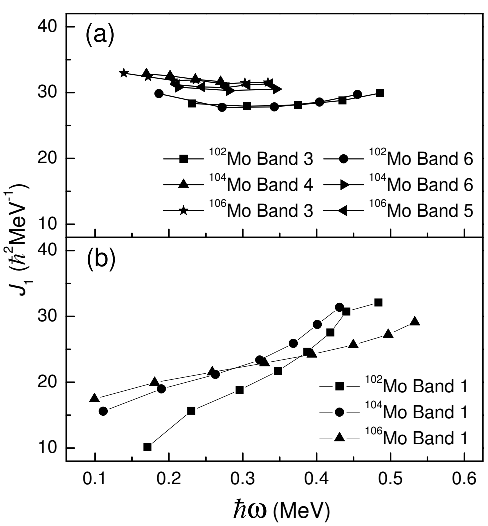

Fig. 2. Plots of moments of inertia J_1 versus rotational frequency $\hbar\omega$ (a) for quasi-particle bands in ^{102}Mo, ^{104}Mo and ^{106}Mo, and (b) for yrast bands in ^{102}Mo, ^{104}Mo and ^{106}Mo.

In the previous report[10], the I^π's for the band head levels in bands (3) and (6) have been tentatively assigned as 4^+ and 5^-, respectively. However, according to the systematic comparison with the neighboring Mo isotopes and the analysis of moment of inertia in these bands, we re-assigned the I^π's of the band head levels in the bands (3) and (6) as 5^- and 4^+ respectively. Thus the I^π's for the other levels of the bands (3) and (6) are re-assigned also, as shown in Fig. 1. Similar quasi-neutron bands were observed in ^{104}Mo and ^{106}Mo. Plots of the moment of inertia of bands (3) and (6) in ^{102}Mo, along with quasi-neutron bands (4) and (6) in ^{104}Mo[6], bands (3) and (5) in ^{106}Mo[7], are shown in Fig. 2(a). One can see that they have similar behaviors. This gives an evidence for the quasi-particle band assignments for the bands (3) and (6) of ^{102}Mo. From partial Nilsson diagram[12], the possible configurations for band head levels of bands (3) and (6) are proposed as $\nu\{[413]5/2^+\otimes[532]5/2^-\}5^-$ and $\nu\{[411]3/2^+\otimes[413]5/2^+\}4^+$ respectively. The two new levels at 2147.8 and 2183.9 keV below bands (3) and (6) do not belong to the members of the bands (3) and (6) respectively, as both the level spacings of 399.8 and 276.7 keV are too low to meet the smooth variation of the moment of inertia with $\hbar\omega$ in the plots.

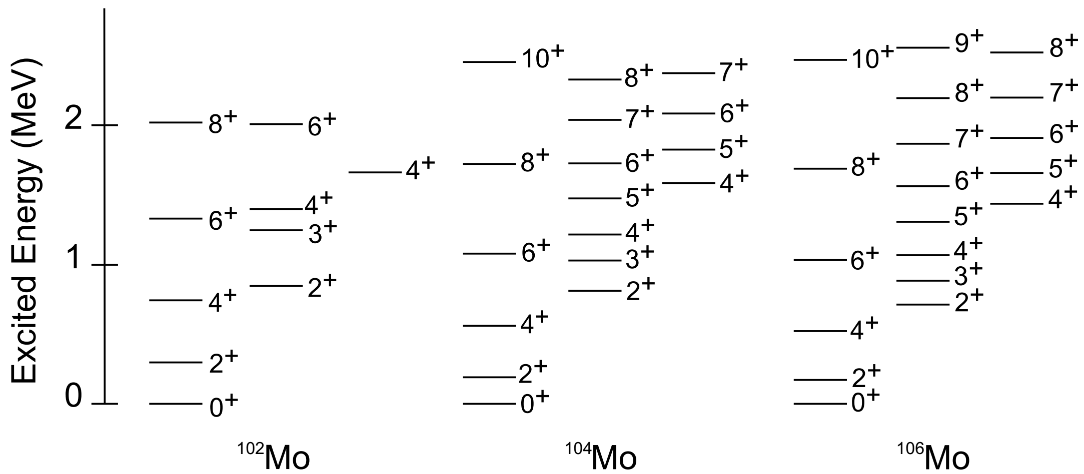

Fig. 3. Systematic comparison of one-phonon γ- and two-phonon γ-bands in ^{102}Mo, ^{104}Mo and ^{106}Mo.

The band (2) based on 847.5 keV level has been assigned as one-phonon γ-band[10]. We have added a new level at 1244.9 keV with 3^+ state in this band. Based on the systematic comparison with the neighboring isotopes ^{104}Mo[6] and ^{106}Mo[7], the I^π of 1660.4 keV level labeled (4) in the scheme is tentatively assigned as 4^+. This level most probably is the band head level of the two-phonon γ-band. Fig. 3 shows a systematic comparison of levels in the one-phonon γ- and two-phonon γ-bands in ^{102}Mo, ^{104}Mo[6] and ^{106}Mo[7]. From this figure one can see that they have similar structural character and the level structures agree with the systematics. But the level energies with same spin value in ground-, one-phonon γ-, and two-phonon γ- bands are decreasing with the neutron number increasing. This variation is reasonable because the deformation parameter β_2 becomes larger with the neutron number increasing in the neutron-rich Mo isotopes, as we can see that the $E(4^+)/E(2^+)$ ratios of the ground state bands of ^{102}Mo, ^{104}Mo and ^{106}Mo are 2.51, 2.92 and 3.05 respectively.

Figure 2(b) shows plots of moments of inertia J_1 against the rotational frequency $\hbar\omega$ for the yrast bands of ^{102}Mo, ^{104}Mo[6] and ^{106}Mo[7]. One can see that at the low rotational frequency, J_1's of ^{104}Mo and ^{106}Mo are larger than that of ^{102}Mo obviously. When the $\hbar\omega \geqslant 0.35$ MeV, J_1's of ^{102}Mo and ^{104}Mo are larger than that of ^{106}Mo. No obvious back-bending is observed in ^{102,104,106}Mo isotopes.

The characters of the newly observed levels on the right side in the Fig. 1, including 1249.1, 1616.2, 1747.1, 2480.4, 1869.2, 2663.4, 2445.2, 2621.4 keV are not clear. It needs to do further work.

4 Conclusion

The high-spin states of ^{102}Mo is presented. Previous level scheme has been updated, and many new levels and transitions are identified. The one-phonon γ-band has been expanded and the band head of two-phonon γ-band is proposed. The systematic characteristics of ground bands, quasi-particle bands, one-phonon γ-bands and two-phonon γ-bands have been discussed.

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