Large amplitude collective motion in ^{44}S[†]

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It is well known that neutron-rich $N \simeq 28$ nuclei exhibit strong quadrupole collectivity.[1,2] Using antisymmetrized molecular dynamics (AMD), we have discovered many interesting features such as triaxial deformation and shape coexistence in ^{42}Si and neighboring nuclei.[3,4] Herein, we report the large-amplitude collective motion (LACM) in ^{44}S.

Figure 1 shows the comparison between the energy curves and collective amplitudes of ^{40}Mg and ^{44}S. ^{40}Mg possesses the prolately-deformed energy minimum and the collective amplitude of the ground state is localized around it, whereas the 0_2^+ state is localized in the oblately-deformed region. Thus, ^{40}Mg depicts the coexistence of the prolate and oblate rigid rotors. In contrast, ^{44}S exhibits a significantly different structure: The energy curve is extremely flat as a function of γ and the collective amplitudes of the ground, and the 0_2^+ states demonstrate broad and non-localized distributions, which imply that ^{44}S possesses no rigid shape due to the LACM.

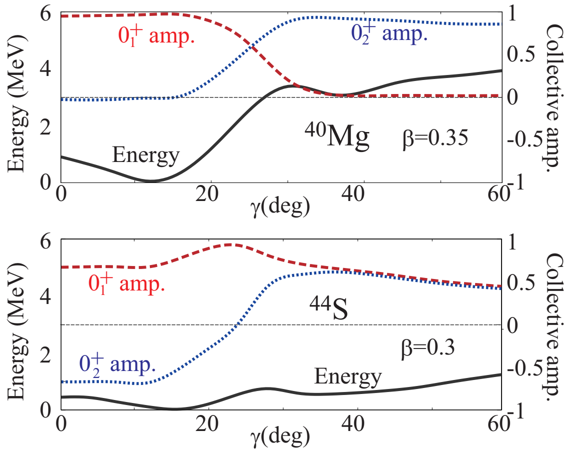

Fig. 1. Energy curves and collective amplitudes of the 0_1^+ and 0_2^+ states as functions of the quadrupole deformation parameter γ. The values of quadrupole parameter β are set to 0.35 and 0.30 for ^{40}Mg and ^{44}S, respectively.

Table 1. Electric ($E0$) and isoscalar ($IS0$) monopole transition strengths in Weisskopf unit (Wu).

	^{40}Mg	^{44}S (calc.)	^{44}S (expt.)[5]
$B(E0; 0_1^+ \to 0_2^+)$	0.0	0.04	0.022(2)
$B(IS0; 0_1^+ \to 0_2^+)$	0.0	0.38	

A general question is as follows: Based on which type of physical quantity, can we distinguish rigid-rotor and LACM? The monopole transition is the solution to this question. The monopole transition strength (Table 1) is strongly hindered in ^{40}Mg, whereas it is non-negligible in ^{44}S.[5] This feature can be explained using a two-configuration mixing model.[6] ^{40}Mg possesses prolate ground state and oblate 0_2^+ state; hence, the monopole matrix element is given as $\langle \text{obl.}|\mathcal{M}|\text{pro.}\rangle$, where $|\text{pro.}\rangle$ and $|\text{obl.}\rangle$ denote the prolate and oblate configurations, respectively, and $\mathcal{M}$ denotes the transition operator (1p1h operator). This matrix element vanishes because single-particle configurations of $|\text{pro.}\rangle$ and $|\text{obl.}\rangle$ differ by 2p2h. This is the reason why the transition is strongly hindered in ^{40}Mg.

Owing to LACM, we approximate ^{44}S as a mixture of prolate and oblate shapes with equal amplitudes,

$$|0_1^+\rangle = (|\text{pro.}\rangle + |\text{obl.}\rangle)/\sqrt{2}, \tag{1}$$

$$|0_2^+\rangle = (|\text{pro.}\rangle - |\text{obl.}\rangle)/\sqrt{2}. \tag{2}$$

In this case, the transition matrix read

$$\langle 0_2^+|\mathcal{M}|0_1^+\rangle = \frac{1}{2}\{\, \langle \text{pro.}|\mathcal{M}|\text{pro.}\rangle - \langle \text{obl.}|\mathcal{M}|\text{obl.}\rangle \,\} \tag{3}$$

Thus, the transition matrix is proportional to the difference in the squared-radii of the prolate and oblate shapes. Consequently, ^{44}S possesses non-negligible monopole transition strength. Using the single AMD wave functions with prolate and oblate deformation and Eq. (3), we obtain $B(E0) = 0.05$ Wu and $B(IS0) = 0.4$ Wu, which are close to the results of the full model space calculation listed in Table 1.

Thus, there is an interesting relationship between the monopole transition and LACM. In ^{40}Mg, the prolate and oblate rotors coexist, and the monopole transition is hindered as they do not mix with each other. In ^{44}S, there is a considerable mixture of prolate and oblate shapes due to LACM. This leads to the non-negligible monopole transition, which is roughly proportional to the difference in the squared-radii of the two shapes.

References

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