Nuclear Structure of Transitional Strontium (Sr) Nuclei near Shell Closure N = 50

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Introduction

The spectroscopic aspects (experimental and theoretical) of transitional nuclei in the mass A $\sim$ 85 region have been studied extensively in the last a few decades. In the last a few years, a number of ΔI = 1 rotational bands have been observed in a large number of nuclei having small deformation (nearly spherical). It was discovered that these bands arise due to a new type of excitation which arises due to the coupling of proton and neutron angular momenta to produce total angular momentum which precess around the rotational axis. The phenomenon was called Magnetic Rotation (MR) [1]. These MR bands were characterized by the appearance of enhanced M1 transitions with weak/absent E2 crossover transitions. Several ΔI = 1 bands with enhanced M1 transitions and weak E2 transitions having multi-quasiparticle configurations were observed in nuclei in the mass A $\sim$ 85 region. In the present thesis work, the spectroscopic aspects of Strontium nuclei have been studied experimentally as well as theoretically.

Experimental details

The pelletron accelerator facility at Tata Institute of Fundamental Research (TIFR), Mumbai was used to obtain the ^{13}C beam. A ^{76}Ge target of thickness 850 μg/cm^2 on 7.6 mg/cm^2 backing of ^{181}Ta was used. The de-exciting γ-rays were detected using the Indian National Gamma Array (INGA) at Tata Institute of Fundamental Research (TIFR), Mumbai. This array is a Compton suppressed clover detector array with a provision of 24 clover detectors at different angles with respect to the beam direction. The detectors can be mounted at 157°, 140°, 115°, 90°, 65°, 40° and 23°. Three detectors can be mounted at each angle except 90° at which six detectors can be kept. In the present experiment, four clover detectors were kept at 90°, three detectors at 157° and two detectors each at 140°, 115°, 65° and 40°. The online collection of data was done via XIA based triggerless Digital Data AcQuisition (DDAQ) system. The data were sorted using MARCOS program. The coincidence events were analyzed offline using the RADWARE and DAMM software packages. The lifetimes of the states have been obtained using the LINESHAPE code based on the Doppler Shift Attenuation Method (DSAM).

Results and Discussion

High-spin states of the ^{85}Sr nucleus has been populated via the ^{76}Ge(^{13}C, 4n) reaction at a beam energy of 45 MeV. New levels and γ-ray transitions have been placed in the level scheme [2]. The highest observed spin in the ^{85}Sr nucleus is $35/2^-\hbar$ having 7.5 MeV excitation energy. The states have been assigned spin and parity on the basis of DCO ratios and polarization asymmetry measurements. The shell-model calculations using the JUN45 and jj44b interactions, in the 28-50 valence shell, consisting of $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ orbitals have been carried out to support the experimental observations and are found to be in good agreement. The configurations of different states have also been obtained using the shell-model. The lifetime measurements using the code of J.C. Wells [3] have been carried out for a number of states in different bands. The transition

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rates (B(M1)) are used to predict the MR phenomenon in bands (band 2 and 3). In Band 2, the B(M1) transition rates decreases with increase in spin which is a characteristics of the MR phenomenon. From the TAC calculations the 3-qp $\pi(g^2_{9/2}) \otimes \nu g^{-1}_{9/2}$ configuration is assigned to band 2 with $\epsilon_2 = 0.11, \gamma = 60^o$. Band 3 may also possess the MR character with the 5-qp $\pi[(g_{9/2})^2(f_{5/2})^2] \otimes \nu(g_{9/2})^{-1}$ configuration having $\epsilon_2 = 0.115$ and $\gamma = 60°$. Band 4 (negative-parity) is a highly staggered band and do not show the expected MR phenomenon [4]. In band 4, low-spin states have 3-qp $\pi[g^1_{9/2} \otimes (p_{1/2}/f_{5/2})^1] \otimes (\nu g^{-1}_{9/2})$ configuration, while the 5-qp $\pi[g^1_{9/2} \otimes (p_{1/2}/f_{5/2})^1] \otimes (\nu g^{-3}_{9/2})$ configuration is assigned for the high-spin states. In band 4, the experimental observables like γ-ray energies, BM1) transition rates etc., show the staggering phenomenon. The observed transition rates, B(M1) and B(E2) have been compared with the shell-model calculations. This negative-parity band 4 shows abrupt change of rotational axis from principal to tilted axis.

The high-spin spectroscopy of the ^{86}Sr nucleus has been done using the ^{76}Ge(^{13}C, 3n) reaction. The highest observed spin in a positive-parity band is $I^\pi = 19^+$ having excitation energy of 10.9 MeV. The results of the DCO and polarization measurements were utilized to obtain the multipole character of γ-ray transitions. The results of polarization asymmetry measurements for the levels in the ^{86}Sr nucleus [5] have been reported for the first time. The experimental observations have been compared with the shell-model calculations using the JUN45 and jj44b effective interactions in the 28-50 valence shell consisting of the $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ orbitals. The wave-functions of different positive and negative-parity states have been obtained using the shell-model. From the calculations, it is predicted that the major component of the $\pi(g_{9/2})^2 \otimes \nu(g_{9/2})^{-2}$ and $\pi[(f_{5/2})^{-1}(g_{9/2})^1] \otimes \nu(g_{9/2})^{-2}$ configurations are responsible for the structure of Bands 3 and 4, respectively. The TAC calculations were also done to understand the structure of Band 3 (band head at 6878-keV excitation energy having spin $I^\pi = 12^+$) having dipole γ-ray transitions. From the TAC calculations, the 4-qp $\pi(g_{9/2})^2 \otimes \nu(g_{9/2})^{-2}$ configuration is assigned to the lower-part up to spin $I^\pi = 16^+$ and above this spin a nucleon pair $f^1_{5/2}(p_{1/2}/p_{3/2})^1$ of nucleons is aligned and the band has 6-qp $\pi[(g_{9/2})^2(f_{5/2})^1(p_{3/2}/p_{1/2})^1] \otimes \nu(g_{9/2})^{-2}$ configuration. The calculations for 4-qp and 6-qp configurations, results in minima at $\epsilon_2 = 0.095$ and $\gamma = 60°$, and $\epsilon_2 = 0.110$ and $\gamma = 60°$, respectively. The lineshape analysis using the LINESHAPE code has also been carried out for the states of band 3. The B(M1) transition rates obtained from the lifetime measurements confirm the MR phenomenon in this band. The TAC calculations are also in favour of the MR nature of this band [4].

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