High spin states in ^{38}K

Abhijit Bisoi[1*], S. Ray[2], M. Roy Basu[3], D. Kanjilal[2], S. Nag[4], K. Selva Kumar[5], A. Goswami[2], N. Madhavan[6], S. Muralithar[6], R. K. Bhowmik[6], S. Sarkar[1], and M. Saha Sarkar[2]

[1]*Indian Institute of Engineering Science and Technology, Shibpur, Howrah - 711103, India*
[2]*Saha Institute of Nuclear Physics, Bidhannagar, Kolkata - 700064, India*
[3]*University of Calcutta, Kolkata - 700009, India*
[4]*National Institute of Technology, Raipur Chhatisgarh - 492010, India*
[5]*Indian Institute of Technology, Kharagpur-721302, India*
[6]*Inter University Accelerator Centre, New Delhi - 110067, India*
**Email: abijitbisoi@gmail.com*

Introduction

Nuclei in the neighbourhood of doubly closed ^{40}Ca usually exhibit characteristics of spherical single particle excitations and their excitation spectra are well explained by spherical shell model [1]. However, several nuclei *viz.*, ^{40}Ca [2], ^{36}Ar [3], ^{35}Cl [4] in this mass region have also revealed deformed states even superdeformation at relatively higher excitation energies and the observed Superdeformed (SD) bands in these nuclei were explained in terms of particle-hole excitations in the shell model. Therefore, this region gives us a unique opportunity to investigate experimentally the interplay between single particle and collective degrees of freedom and interpret them microscopically through large basis shell model (LBSM) calculation involving the cross-shell correlation [4,5].

^{38}K is an odd-odd (N=Z=19) nucleus in this mass region. This nucleus was studied by C. J. Van Der Poel et. al. [6] through heavy ion reaction. They have extended the level scheme upto 11 MeV and assigned the spin and parity of these levels from DCO measurements or shell model results. However, most of these assigned spins and parities were not confirmed. In the present work, we have investigated ^{38}K to extend the level scheme and remove some of these uncertainties. The large basis shell model (LBSM) calculation has also been carried out to know the microscopic origin of these states.

Experiment

High-spin states in ^{38}K have been populated through ^{12}C+^{28}Si (110 MeV) reaction in the inverse kinematics. The relevant details of the experiment have been discussed in Ref. [7]. Gamma - gamma coincidence measurement has been done using the multi-detector array of thirteen Compton suppressed Clover detectors (INGA setup) at Inter University Accelerator Centre (IUAC), New Delhi.

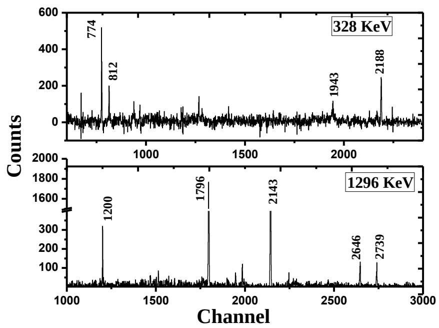

Fig.1: Background subtracted coincidence spectra obtained by putting gates on 328-keV (below the isomer) and 1296-keV (above the isomer)transitions.

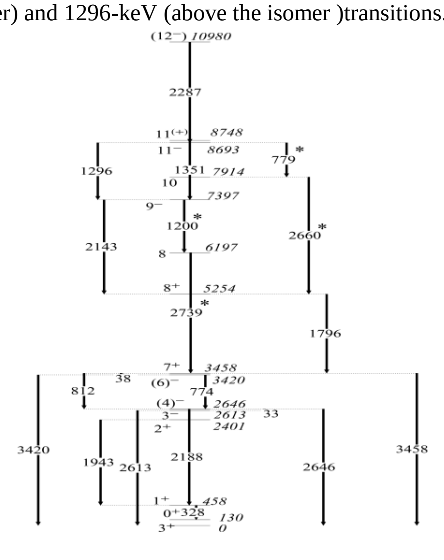

Fig.2: Partial level scheme of ^{38}K. Newly assigned γ transitions are indicated by *.

Results and Discussion

The data have been analyzed by using the improved version of the analyzing program INGASORT. Fig.1 shows a typical background subtracted coincidence spectra of ^{38}K. Since, we have a 31.9±1.0 µs isomer [6] at 3.46 MeV, the level scheme of ^{38}K was studied by putting gates on both above and below the isomer. From our analysis, 4 new gammas and 2 new excited levels have been placed above the 3.46 MeV isomer (Fig.2). These new gammas were observed from 1296 and 1796 keV gated spectra. The linear polarization measurement and angular correlation measurements have been done to assign their spin and parity. Based on our analysis, we have modified the existing level scheme [6] by changing the spin of 5.25, 7.40, and 8.69 MeV levels. For the new levels, we have assigned their spins from our DCO measurement. However, due to the low statistics of the decay out gamma transitions from these levels, the liner polarization measurement was not done. Hence, the parity of these levels were not assigned. Apart from these new levels, we have also observed 2.4 MeV level in our heavy ion experiment which was previously observed from light ion experiments [1].

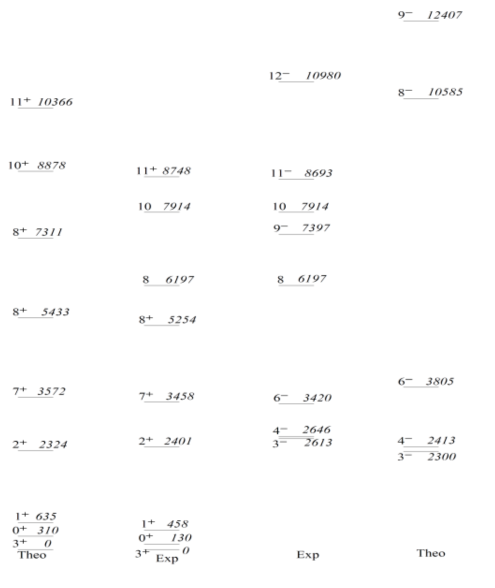

Fig.3: Comparison of theoretical and experimental level schemes for positive and negative parity states in ^{38}K. All these energies were plotted considering the ground-state energy (−251.345 MeV) as 0.

The mixing ratios of a few transitions in ^{38}K have also been measured.

We have performed LBSM calculation using OXBASH code [8] to understand the microscopic origin of these states. The valence space consists of $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$, $1f_{7/2}$, $1f_{5/2}$, $2p_{3/2}$ and $2p_{1/2}$ orbitals for both protons and neutrons above the ^{16}O inert core. The number of valence particles (protons + neutrons) in ^{38}K is 22. The “*sdpfmw*” interaction used is taken from WBMB *sd–pf* shell Hamiltonian [9]. During the calculation, different truncation methods were used to reproduce the experimental level scheme. For the positive parity states, 0p-0h ($0^+ \rightarrow 6^+$) and 2p-2h ($7^+ \rightarrow 12^+$) excitations were considered. The negative parity states were generated by exciting 1 particle to the *pf* shell. In these calculations, there was no particle restriction on $1d_{5/2}$ orbital and we have not changed the single particle energies (SPE) of *pf* orbitals. The mass normalization factors for each truncation were considered accordingly. The comparison between the experimental and theoretical level scheme obtained from LBSM calculation is shown in Fig.3. It shows that for high spin negative parity states ($>6^-$), the calculated energies are over-predicted by several MeV, indicating the need for inclusion of three particle excitation (3p-3h) to *pf* orbitals. Hence, calculation with 3p-3h will be performed for high spin negative parity states. LBSM calculations have also been performed for transition probabilities, magnetic moments etc.

Acknowledgments

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References

[1] www.nndc.bnl.gov
[2] E. Ideguchi et al., Phys. Rev. Lett. 87, 222501 (2001).
[3] C. E. Svensson et al., Phys. Rev. Lett. 85, 2693 (2000); C. E. Svensson et al., Phys. Rev. C 63, 061301(R) (2001).
[4] Abhijit Bisoi *et al.*, Phys. Rev. C **88**, 034303 (2013).
[5] E. Caurier, F. Nowacki, and A. Poves, Phys. Rev. Lett. 95, 042502 (2005); E. Caurier, J. Men_endez, F. Nowacki, and A. Poves, Phys. Rev. C **75**, 054317 (2007).
[6] C. J. van der Poel *et al.*, Nucl. Phys. A **394**, 501 (1983).
[7] S. Muralithar et al., Nucl. Instr. and Meth. A 622, 281 (2010); Sudatta Ray et al., Proc. DAE-BRNS International Symp. Nucl. Phys. (India), 54 (2009) 56.
[8] B.A. Brown, A. Etchegoyen, W.D.M. Rae, N.S. Godwin, MSU-NSCL Report No. 524, 1985, unpublished.
[9] E.K. Warburton et. al., Phys. Rev.C 41, 1147 (1990).