Isomers in ^{117,118}Sn and role of neutron $1h_{11/2}$ orbit

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Introduction

The long isotopic chain of Sn isotopes between two doubly magic nuclei ^{100}Sn and ^{132}Sn and beyond, has attracted attention of experimentalists as well as theoreticians to understand the evolution of nuclear structure from proton rich to neutron rich ones through the stability.

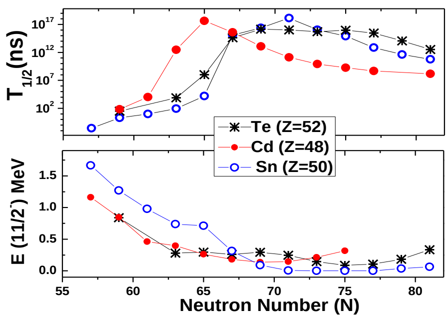

Fig. 1 Variation of the experimental energies and half-lives [1] of $11/2^-_1$ state in odd-A isotopes of Cd, Sn and Te.

The neutron (ν) $1h_{11/2}$ orbit plays an important role in structure of nuclei near Z=50, and N=50-82, because of its intruder nature. The relevant neutron single particle orbits for this region are $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$ and $1h_{11/2}$. For Sn isotopes, with N<64, at lower energies, $\nu 1g_{7/2}$, $\nu 2d_{5/2}$ orbits are the most important ones and $\nu 1h_{11/2}$ being at relatively higher energy does not affect low lying states significantly. However, with increasing neutron numbers, specifically beyond N=64, after $1g_{7/2}$, $2d_{5/2}$ orbits are filled up, $\nu 1h_{11/2}$ starts playing an important role in the low-lying spectra of the Sn isotopes. The downward evolution of the first $11/2^-_1$ state in the odd isotopes of Sn (Fig. 1) depicts it very well. Even with addition of protons (2 holes: Cd or 2 particles: Te), similar variation is observed.

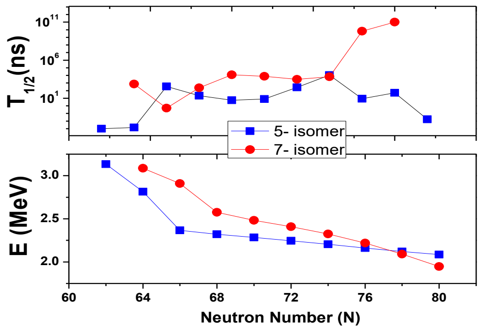

Fig. 2 Variation of the excitation energies and half-lives [1] of 5^-_1 and 7^-_1 isomeric states in even - A isotopes of Sn with increasing neutron numbers.

Relatively higher angular momentum and opposite parity of $\nu 1h_{11/2}$ orbit compared to the other positive parity ones ($2d_{3/2}$, $3s_{1/2}$) has been one of the reasons for observing very low lying isomers for odd Sn isotopes with N>64,. The Fig.1 shows the half-lives of these $11/2^-_1$ states which justifies this argument.

For even isotopes of Sn, evolution of similar negative parity low-lying isomers (5^- and 7^-) where $\nu 1h_{11/2}$ plays an important role, is also interesting (Fig. 2). The 5^-, 7^- states are isomeric for $^{114-120}$Sn isotopes. The angular momenta of these states are primarily generated from coupling of one unpaired neutron in $1h_{11/2}$ orbit with another in $3s_{1/2}$ or $2d_{3/2}$ orbits.

On the theoretical front, the isotopes of Sn from A=100-132 and beyond are investigated with different models. Shell model in large basis has been one of the most acceptable one to interpret the data. In the mid-shell for N> 64, full-space calculations involve large dimensionalities and therefore are difficult. Most of the low-lying states are expected to involve large mixing. However, the isomers discussed above are mostly expected to be of pure configuration, which may be one of the reasons behind the isomerism.

In the present work, lifetimes of negative parity isomers and low lying positive parity isomers in $^{117,\ 118}$Sn have been experimentally determined. Based on the arguments above, shell model calculations have been performed with severe truncations to probe whether the calculations can successfully reproduce the isomers.

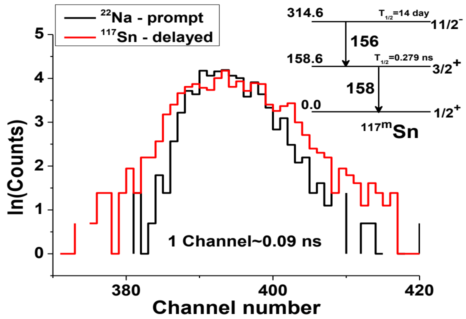

Fig. 3 The time spectra for ^{117}Sn with 156 vs 158 keV energy gates. The inset shows the decay scheme of ^{117m}Sn.

Experimental Details

Excited states of $^{117,\ 118}$Sn were populated from the decay of $^{117,\ 118m}$Sb in a recent irradiation experiment [2].

The $3/2^+_1$ state (E_x=158 keV) in ^{117}Sn is populated via decay of ^{117}Sb ($T_{1/2}$=2.8 h) as well from the decay of an isomeric state (I^{π}= 11/2$^-$, E_x=314 keV ; $T_{1/2}$=14 days) of ^{117}Sn (Fig. 3: inset). The cross-section of ^{117}Sn in the fusion reaction : ^{115}In+α (32 MeV) is 7% of total fusion (estimation from statistical model calculations). This isomeric state predominantly decays via emission of two coincident gamma rays of energies 156 keV ($11/2^- \rightarrow 3/2^+$) and 158 keV ($3/2^+ \rightarrow 1/2^+$). The 158 keV level lifetime was determined earlier as 0.279 (9) ns [1]. However, the prompt resolution of the system was ~ 920 ps [1], the relevant lifetime was determined by de-convolution of the delayed spectra with the prompt function.

In the present work, this half life has been re-measured using two fast timing set ups. The timing spectra were obtained using (i) $LaBr_3$(Ce) and BaF_2 scintillators selecting specific energy (~154-160 keV) (Fig. 3) in each detector and (ii) two $LaCl_3$(Ce) detector coincidence spectra and their energies acquired in a LIST mode. ^{60}Co and ^{22}Na were used to generate prompt spectra. As demonstrated in the figure, delayed curve is distinctly wider compared to the prompt resolution of the first setup (Fig. 3).

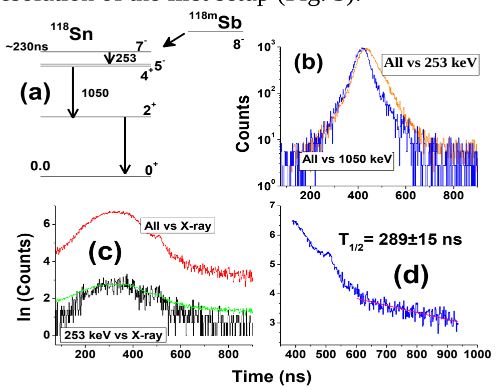

Fig. 4 The time spectra (TAC) for determining ^{118}Sn (7^-) state half-life. (a) Decay scheme of ^{118m}Sb, (b) all energy vs 253 keV (TAC), compared with typical prompt of all vs 1050 keV; (b) all vs x-ray and 253 keV vs x-ray energy gates, (d) the fitted decay curve.

The lifetime of the 7^- isomer in ^{118}Sn has been determined from time spectrum generated from two Clover detectors [2]. The preliminary value determined from Fig. 4d is close to earlier measurement (230 ns [1]).

Shell model calculations have been done to determine excitation energies and transition probabilities for the 7^- isomers in $^{114-120}$Sn in restricted model space. The results match reasonably well with experiment for ^{116,118}Sn with effective charge (neutron) e_n= 0.64e and for ^{114,120}Sn with e_n= 0.35e.

References

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[2] Sathi Sharma et al., presented in this Symposium, and references therein.