# Large scale shell model calculations for N=51 isotonic chain

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With the development of the first generation radioactive beam facilities over the last decade it is now possible to access very neutron rich nuclei towards and beyond $^{78}$Ni. Neutron rich nuclei between N=50 and N=82 shells cover waiting-point nuclei in the r-process. Some recent data has been provided on the energy levels of N=51 isotones in the mass region A=83-91[1-4].

In the present work we have performed large scale shell model calculations using Nushell code [5] for neutron rich $^{83}$Ge, $^{85}$Se, $^{87}$Kr, $^{89}$Sr and $^{91}$Zr nuclei which form the N=51 isotones chain. In our calculation $^{78}$Ni is chosen as core and the valence space comprises of $\nu(0g_{7/2}, 1d_{5/2}, 1d_{3/2}, 2s_{1/2}, 0h_{11/2})$ orbitals for neutron and $\pi(0f_{5/2}, 1p_{3/2}, 1p_{1/2}, 0g_{9/2})$ for proton. The effective interaction is based on the renormalization of CD-Born nucleon–nucleon potential [6] developed by G - matrix theory for nuclei above $^{78}$Ni core. The aim of this work is to test the suitability of the model space and the effective interaction in interpreting the experimental data of these highly unstable nuclei on the neutron rich side.

The results of our calculation for different isotones are shown in Fig.1. The experimental levels are given in Fig.2 for comparison. Most dominant configuration of the wave function for the ground state and first excited state are shown in Table. 1.

It is observed that the ground states spin $5/2^+$ has been correctly reproduced in our calculation. For all the isotones 1/2+ spin of first excited state is also correctly predicted for all the isotones except for $^{91}$Zr. One special feature of the energy spectra of N=51 isotones is increase in the $\varepsilon(1/2^+) \sim \varepsilon(5/2^+)$ splitting in going from Z= 32 – 40. This trend is also reproduced in the theoretical spectra. Ground state spin of $5/2^+$ for all the isotones is associated with the last odd neutron in $d_{5/2}$ state. Similarly $1/2^+$ spin of first excited state corresponds to excitation of the neutron from $d_{5/2}$ to $s_{1/2}$ level. This is also confirmed from the structure of ground state and first excited state wave functions in which occupancy in levels changes from $(d_{5/2})^1(s_{1/2})^0$ for ground state to $(d_{5/2})^0(s_{1/2})^1$ for first excited state .The structure of the proton wave function remains same. The increase in $\varepsilon(1/2^+) \sim \varepsilon(5/2^+)$ splitting in going from Z=32 to 40 is direct reflection of the monopole effect wherein the energy of $1/2^+$ state is gradually increasing with the filling of proton orbitals .

TABLE: 1 Wave function component for the ground state and first excited states for N=51 isotones.

| Nuclei | $J^\pi$ | Wave function Proton | Wave function Neutron | Probability |
|---|---|---|---|---|
| $^{83}$Ge | $5/2^+$ | $(f_{5/2})^2(p_{3/2})^0(p_{1/2})^0(g_{9/2})^2$ | $(d_{5/2})^1$ | 34.3 |
| | $1/2^+$ | $(f_{5/2})^2(p_{3/2})^0(p_{1/2})^0(g_{9/2})^2$ | $(s_{1/2})^1$ | 27.0 |
| $^{85}$Se | $5/2^+$ | $(f_{5/2})^4(p_{3/2})^0(p_{1/2})^0(g_{9/2})^2$ | $(d_{5/2})^1$ | 20.0 |
| | $1/2^+$ | $(f_{5/2})^4(p_{3/2})^0(p_{1/2})^0(g_{9/2})^2$ | $(s_{1/2})^1$ | 15.5 |
| $^{87}$Kr | $5/2^+$ | $(f_{5/2})^4(p_{3/2})^0(p_{1/2})^0(g_{9/2})^4$ | $(d_{5/2})^1$ | 19.0 |
| | $1/2^+$ | $(f_{5/2})^4(p_{3/2})^0(p_{1/2})^0(g_{9/2})^4$ | $(s_{1/2})^1$ | 14.3 |
| $^{89}$Sr | $5/2^+$ | $(f_{5/2})^4(p_{3/2})^2(p_{1/2})^0(g_{9/2})^4$ | $(d_{5/2})^1$ | 14.7 |
| | $1/2^+$ | $(f_{5/2})^4(p_{3/2})^2(p_{1/2})^0(g_{9/2})^4$ | $(s_{1/2})^1$ | 11.8 |
| $^{91}$Zr | $5/2^+$ | $(f_{5/2})^6(p_{3/2})^2(p_{1/2})^0(g_{9/2})^4$ | $(d_{5/2})^1$ | 12.4 |
| | $1/2^+$ | $(f_{5/2})^6(p_{3/2})^2(p_{1/2})^0(g_{9/2})^4$ | $(s_{1/2})^1$ | 9.1 |

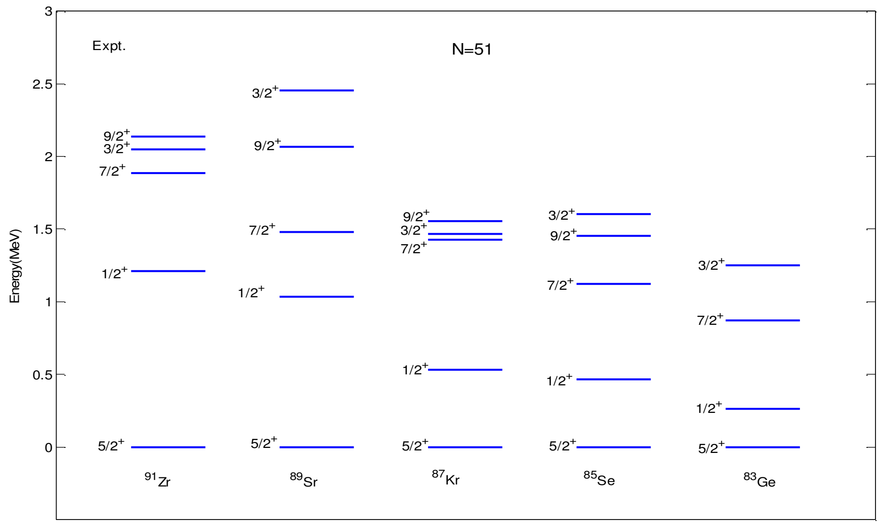


Fig.1 Experimental energy levels for N=51 isotones Ref. [1-4].

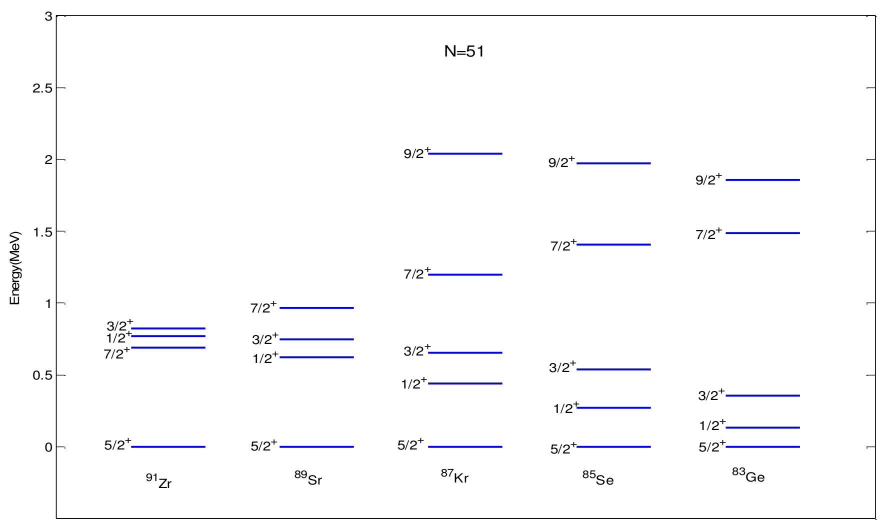


Fig.2 Calculated energy levels for N=51 isotones.

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