Correlation between ground state lifetime and valence nucleons for isotopic chains of Odd-Odd Nuclei

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It is well known that various properties of nuclei may be correlated with the number of valence nucleons in a simple manner. A prime example is the N_pN_n parametrization, whose importance was first demonstrated by Casten [1] in connection with the role of the neutron-proton interaction in the growth of deformation away from shell closures. Here, N_p and N_n indicate the number of valence particles/holes for protons and neutrons, respectively. Obviously, if the number of valence nucleons lie below the middle of a major shell, they are considered as particles; otherwise they are taken to be holes.

There have subsequently been many developments of this theme. Simplified parametrizations of various nuclear quantities have been obtained if they are plotted as a function of N_pN_n or some variants of it. Essentially these simple functions are seen to represent the n-p interaction and bear smooth relationships with various observables throughout medium and heavy nuclei.

We consider the parameter

$$\xi = \frac{N_n}{(N_n)_{max}} \qquad (1)$$

For a chain of isotopes, the denominator of ξ, $(N_n)_{max}$, is calculated taking the maximum N_n value for the chain, which obviously corresponds to the middle of a shell. This normalized value may be seen to represent the fraction of the integrated p-n interaction with respect to its maximum value in the chain of isotopes for a given shell.

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In the present work, nucleon numbers 28, 50, 82 and 126 have been taken as magic numbers. We will show that, depending on the nature of the valence nucleons, and whether they occur in the same shell or in different shells, the lifetimes show similar trends. In our notation, P and H refer to particle and hole type nucleons, respectively. A suffix d indicates that the valence protons and neutrons occur in different shells.

Efforts were made towards a unified ξ, treatment for the lifetime of ground state in Kumar *et al* [2] for even-even and odd-even nuclei. It was obseverved that the lifetimes of ground states evolve smoothly with respect to the parameter ξ with different trends for different valence regions. It is our purpose to look for odd-odd nuclei isotopes as a function of the parameter ξ. The data are from the ENSDF database[3].

It is seen that a particular region exhibits similar trends (rising or falling) with the parameter ξ. Naturally, it would be useful to find some parameter or quantity shared by all the regions showing a similar trend. The ground state decay contains nuclear structure effects, and may be thought to depend on the overlap between the actual ground state configuration of the parent and the configuration of the daughter state(s).

It is also noticed, besides other quantities, lifetime should depend on N_n^p, the number of neutron particles/holes in the parent nucleus, and N_n^d, the corresponding number for the daughter. The changes in the N_n value depends on the way a nucleus decays, either (EC/β^+) or (β^-), as well as whether neutrons are particle-like or hole-like. We observe that the difference in valence neutron particle/hole

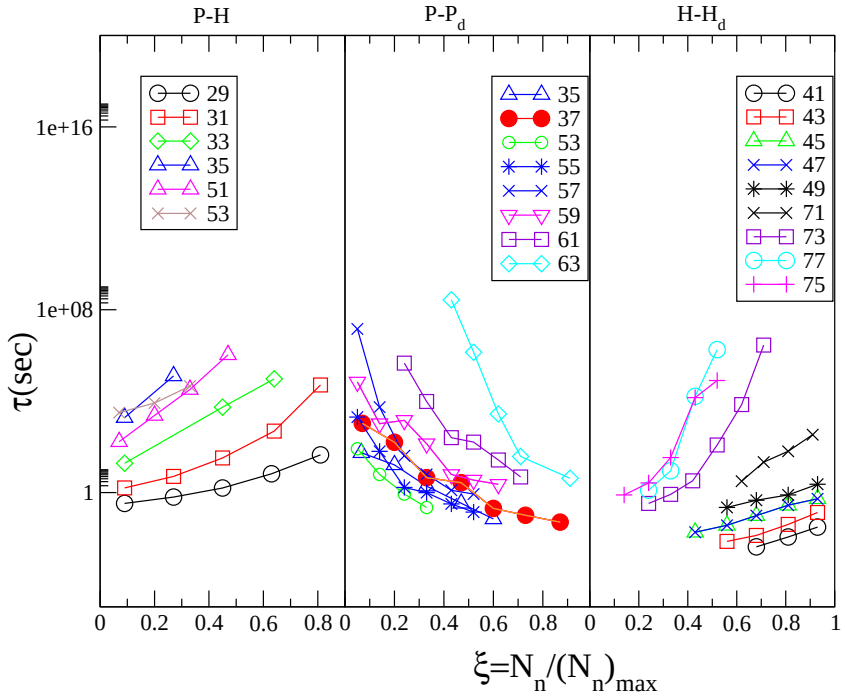

FIG. 1: The half-life values of ground states of nuclei for different valence regions in various chains of isotopes. The atomic number (Z) of isotopic chains are indicated in the figure. The lines are only for guiding the eye.

numbers between the parent and the daughter, $\delta = N_n^p - N_n^d$, has the character that it is the same for all the nuclei showing a similar trend. It is clear that a value of +1 (-1) corresponds to increase (decrease) of lifetime with ξ.

However, what is interesting is that the most of the curves in any particular region show similar slopes, as evident from Fig. 1, indicating the role of the parameter ξ. Even when the proton numbers vary over a large range, for example when we look at the elements belonging to similar valence regions in different shells, we find that the curves are very similar. This indicates that it may perhaps be possible to obtain simple prescriptions for lifetime estimates with ξ as a parameter. Of course, this can give only a general trend as the nature of the decay critically depends on the energy, spin-parity and configuration of the parent state and the daughter state(s), the forbiddenness of the decay, etc.

The beta decay lifetime values for ground states of a large number of isotopes are seen to exhibit simple variations with the ratio of the numbers of valence neutrons (particles or holes) and the maximum possible valence neutrons in medium and heavy nuclei. The variations display distinct and unique trends in different valence regions. In a valence region, the variation of the lifetime with the above mentioned ratios follow similar curves, indicating the possible role of the ratio.

References

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