A Role of Valence Particles Number Equal to 20

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The importance of the N_pN_n parametrization was first demonstrated by Casten [1-3] in connection with the role of the proton-neutron interaction in the growth of deformation away from shell closures, and there have subsequently been many developments in this theme. The symbols N_p and N_n are number of valence particles/holes of protons and neutrons, respectively (where nucleons are counted as holes beyond the middle of a major shell). The observables which reflect collective structure in the deformed mass region for even-even nuclei such as E(2^+), $R_{4/2}$≡E(4^+)/E(2^+) and B($E2$) have behaved smoothly with N_pN_n.

Isotope with lowest energy of 2^+ state			Isotope with (maxi N_pN_n) value	
Isotope	Valence Z+N	N_pN_n values	Isotope	N_pN_n values
$^{76}_{30}$Zn$_{46}$	2+18 = 20	8	$^{68}_{30}$Zn$_{38}$	20
$^{76}_{32}$Ge$_{44}$	4+16 = 20	24	$^{70}_{32}$Ge$_{38}$	40
$^{76}_{34}$Se$_{42}$	6+14 = 20	48	$^{72}_{34}$Se$_{38}$	60
$^{76}_{36}$Kr$_{40}$	8+12 = 20	80	$^{74}_{36}$Kr$_{38}$	80
$^{76}_{38}$Sr$_{38}$	10+10 = 20	100	$^{76}_{38}$Sr$_{38}$	100
$^{120}_{52}$Te$_{68}$	2+18 = 20	28	$^{118}_{52}$Te$_{66}$	32
$^{120}_{54}$Xe$_{66}$	4+16 = 20	64	$^{120}_{54}$Xe$_{66}$	64
$^{120}_{56}$Ba$_{64}$	6+14 = 20	84	$^{122}_{56}$Ba$_{66}$	96
$^{120}_{58}$Ce$_{62}$	8+12 = 20	96	$^{124}_{58}$Ce$_{66}$	128
$^{120}_{60}$Nd$_{60}$	10+10 = 20	100	$^{126}_{60}$Nd$_{66}$	160

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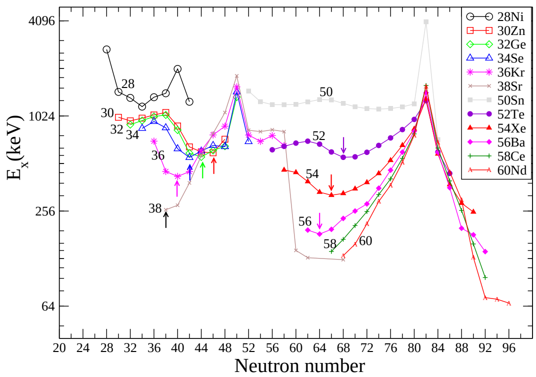

FIG. 1: Experimentally known energies of the first excited 2^+ states in the even-even nuclei. The lowest excitation energy of the first excited 2^+ state is observed for an isotope which has the valence particles 20 in the isotopic chain by keeping the same shells for valence protons and neutrons. As proton number increases by 2 the minimum shifts towards less neutron number by 2, keeping the valence particles number equal to 20.

TABLE I: The lowest excitation energy of the first 2^+ state and maximum N_pN_n value of isotopes in the isotopic chain by keeping the same shells for valence protons and neutrons. As proton number increases by 2 the minimum shifts towards less neutron number by 2, by keeping the valence particles number equal to 20.

The maximum and minimum N_pN_n values of isotopes have been observed at the middle of a shell, and at the beginning/closing of the shell, respectively. Since,the maximum number of valence neutron particles/holes are observed at the middle of a shell. Therefore, one can expect lowest 2^+ energy at the graph of $E(2^+)$ $vs.$ neutron number, for an isotope which has maximum value N_n *i.e.*, corresponds to maximum valence neutron particles/holes.

Experimentally, the lowest energy of 2^+ state has been observed for a particular isotope which has the valence particles number equal to 20 for any isotopic chains by keeping the same shells for valence nucleons (see Fig. 1) and not for the isotope which has maximum N_pN_n value. Here, same shells mean, let us take barium isotopes ${}^{106-138}_{56}Ba_{50-82}$, here valence nucleons are in same shells of (82), and valence nucleons are in different shells for the barium isotopes having mass $A > 138$.

The examples of Zn, Ge, Se, Kr, Sr, for the shells of (50) and Te, Xe, Ba, Ce, Nd for the shells of (82), have been listed in table I. As an example of Zn isotope chain for the shells of (50), the lowest energy of 2^+ state has been observed for ${}^{76}_{30}Zn_{46}$ isotope which has (2) valence protons and (18) valence neutrons *i.e.*, 20 valence particles. However, the ${}^{68}_{30}Zn_{38}$ isotope has maximum N_pN_n value for the shells of (50). Now taking the example of Ge isotopic chain which has (2) protons more than Zn isotope, the lowest energy of 2^+ state has been observed for ${}^{76}_{32}Ge_{44}$ isotope which has (4) valence protons and (16) valence neutrons *i.e.*, 20 valence particles. Isotope ${}^{70}_{32}Ge_{38}$ has maximum N_pN_n value for the shells of (50). As proton number increases by 2 the minimum shifts towards neutron number less by 2, keeping the valence particle number equal to 20. The maximum N_pN_n value presents for different isotope in the isotopic chain. Before, we approach any conclusions, more experimental data is needed to address what will happen to the shifting of the lowest energy of 2^+ state, when proton number becomes more than neutron number keeping the valence particles number equal to 20. In other words proton rich nuclei data are needed.

References

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