

Nuclear Structure of W Isotopes

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The W isotope having atomic number $Z=74$ and neutron number N varies from 86 to 116. These isotope contain various band i.e. ground state band, $K=0$ β -band, $K=2$ γ -band, $K=4$ band which depends on the combination N and Z . In 2022, the Lifetime measurements in the tungsten isotopes $^{176-180}\text{W}$ studied in A. Harter et al. [1]. The interpretation of $R_{4/2}$ is close to $SU(3)$ limit of ^{180}W and transitional phenomena observed around $N=108$.

We see the variation in the energy of spin $I=2$ $E(2_1^+)$ [2], is 609.9 keV, maximum at $N=86$, which falls to 123.2 keV at $N=98$. Thereafter, $E(2_1^+)$ is almost constant up to $N=108$. Again the energy $E(2_1^+)$ rises up to 219 keV at $N=118$. Here the slope of decreasing or increasing energy on two sides of $N=108$ shows shape phase transition.

The systematics of energy ratio $R_{4/2}$ [$= E(4_1^+)/E(2_1^+)$], versus N is illustrated for $^{160-190}\text{W}$ is shown in Fig. 1. For $N=86$, $R_{4/2}$ of 2.07, close to $U(5)$ symmetry signifies the vibrational nature of the ^{160}W . For $N=88$, $R_{4/2}=2.26$, corresponding to $E(5)$ symmetry. At $N=90$, $R_{4/2}$ of 2.5, corresponds to $O(6)$ symmetry. $R_{4/2}$ for $N=96$ is close to $X(5)$ symmetry. For $N=102-108$, the nuclei lie

close to $SU(3)$ symmetry. For $N > 108$, $R_{4/2}$ decreases from 3.29 to 2.73. Thus, the W isotopes cover the full range of the shape symmetry from the $U(5)$ to $SU(3)$, with the range different on two sides for N greater than 108 and N less than 108.

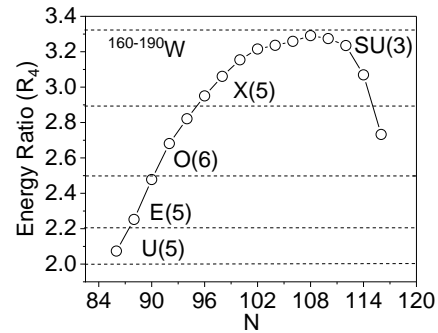


Fig. 1. Critical point symmetry diagram for $^{160-190}\text{W}$ with energy ratio R_4 versus N .

The systematics of power index 'b' of the power index formula $E(I) = aI^b$ [3] is plotted in Fig. 2 with spin (I) for $^{178-182}\text{W}$ nuclei. For $N=104$, at spin $I=4$ to spin $I=6$, the power index rises, then from spin $I=6$ to spin $I=10$ is almost uniform and from spin $I=10$ to spin $I=12$ decreases for ^{178}W nucleus. For ^{180}W nucleus, the power index 'b' having high value and shows similar variation as like ^{178}W rises with rises slope. The power index 'b' for ^{182}W nucleus, at spin $I=4$ is 1.74 and

maximum, sharp rises to spin $I=6$, then gradually rises to spin $I=10$, and after that almost saturated from spin $I=10$ to spin $I=12$. On the other hand, for $N=110$ ^{184}W , at spin $I=4$ the value of 'b' is 1.71 and rises similar to ^{182}W , but with minimum increament, having different slope and nature of structure variation as well as shape phase transition at both side i.e. for neutron number $N>108$ and $N<108$.

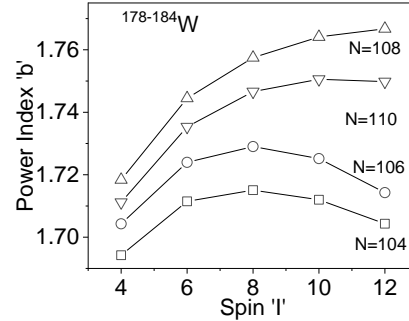


Fig. 2. Systematics of power index 'b' with spin (I) for $^{178-184}\text{W}$.

Here the plot of $B(E2; 0_1^+ - 2_1^+)$ in e^2b^2 with $1/E(2_1^+)$ (MeV^{-1}) for $^{178-186}\text{W}$ is shown in Fig. 3. For $N=104$ to $N=108$, the energy $E(2_1^+)$ for spin $I=2$ decreases, its inverse increases and this inverse of energy plotted with electromagnetic transition $B(E2)$ from spin $I = 0$ to 2, decreases from $N=104$ to $N=108$. For $N=110-112$, the $B(E2)$ values are small and inverse of energy $E(2_1^+)$ lies lower and shows different slope in the fig. 3. Here for $N< 108$ and $N> 108$, the W isotope shows different shape and transition.

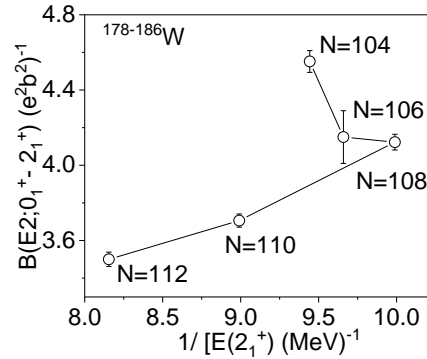


Fig. 3. The plot of electromagnetic transition $B(E2; 0_1^+ - 2_1^+)$ with $1/E(2_1^+)$ for $^{178-186}\text{W}$.

Reference:

[1] A. Harter et al. Phys. Rev. C. 106 (2022) 024326.
 [2] NNDC (<http://www.nndc.bnl.gov/ENSDF>)
 [3] J. B. Gupta, A.K. Kavathekar and R. Sharma, Phys. Scr. **51** (1995) 316.
 [4] Krishna Kumar and Michel Baranger, Nuclear Physics A122 (1968) 273.
 [5] R. Sahu, Phys. Rev. **C29** (1984) 1486.

Also the ratio of electromagnetic transtion ($B_{4/2}$) between spin $I=4$ to spin $I=2$ and spin $I=2$ to spin $I=0$ shows shape phase transition (to be shown in poster).

Result: Here we see, the shape changes in W nuclei both side of $N=108$, with energy of spin $I=2$ $E(2_1^+)$, energy ratios $R_{4/2}$, power index 'b' and $B(E2; 0_1^+ - 2_1^+)$ with $1/E(2_1^+)$. This is also observed in the energy's and $B(E2)$'s in [4,5].