Comparison of the Weisskopf estimates in spin and K-isomers

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Introduction

Nuclear isomers are the excited metastable states, which exist due to the hindrance on their decay. Study of isomers has recently become very popular due to advances in the experimental techniques and also the arrival of radioactive beams. Large amount of new experimental data is becoming available. The very first "Atlas of nuclear isomers" lists more than 2460 nuclear isomers with the half-life cut off at 10 ns [1].

Spin isomers mostly exist due to the difficulty in meeting the spin selection rules and cluster around the semi-magic regions. The isomers far from the magic-numbers, which lie in the well-deformed region, mostly exist due to the goodness of the K-quantum number and large K-difference between the decaying states. They are known as K-isomers.

It is expected that the single particle Weisskopf estimates should be able to explain the half-life of semi-magic isomers, i.e. nearly spherical ones. In this paper, we apply the Weisskopf estimates to the K-isomers in the deformed region as well. We have compared the experimental and the Weisskopf estimated half-life systematics of the Z=50, semi-magic isomers and the Z=70, well deformed isomers.

Systematics of the experimental half-lives

We have plotted the experimental half-lives for the isomers of the odd-A Z=50 and the odd-A Z=70 isotopes in the top panels of the Fig. 1 and Fig. 2, respectively. The vertical scale represents the log value of the half-life in µsec. The $3/2^+$, $11/2^-$, $19/2^+$, $23/2^+$ and $27/2^-$ isomers have been taken for the Z=50 isotopic chain. The beta-decaying isomers have been excluded from the study.

The $1/2^-$, $3/2^-$, $5/2^-$, $7/2^-$, $7/2^+$, $11/2^-$ and $13/2^+$ isomers for the Z=70 isotopic chain have been chosen for the comparative study. The $13/2^+$ isomers lie near the N=82 shell-closure. Other isomers lie in the well deformed region, and show a dip in half-life at N=103, close to the N=104 deformed magic number. The collectivity increases at the deformed magic configuration, so that the transition probability increases, and results in a decrement of half-life.

Weisskopf estimated half-lives

The bottom panels of the fig. 1 and 2 show the Weisskopf estimated half-lives systematic for the Z=50 and the Z=70 isomers respectively. The calculations have been done by using the RULER code [2].

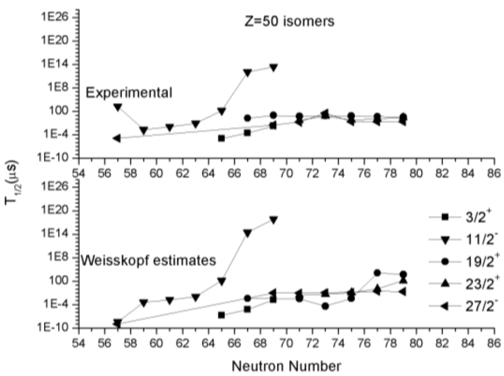

Fig. 1 The experimental and the Weisskopf estimated half-lives for the Z=50 isomers.

We can see that the calculated trend for the Z=50 isomers almost follow the experimental trend. The calculated estimates of nearly spherical semi-magic isomers are in a good agreement with the experimental data, as expected.

On the other hand, the deformed isomers are not expected to follow the Weisskopf estimates so much. It is interesting to note that the calculated trend of the well deformed Z=70 isomers also follow the experimental trend up to a good extent. The magnitude of the isomeric half-life differs, but not the trend. It is obvious that the hindrance on the decay is large for these cases. This may be explained in terms of the appearance of the K-quantum number and the associated selection rules, which result in a large hindrance. Despite this, Weisskopf single particle estimates appear to be good enough to explain the trend of the half-lives of the well deformed Z=70 isomers. The Weisskopf estimated half-lives of these isomers also show a sharp dip at N=103, as in the experimental data.

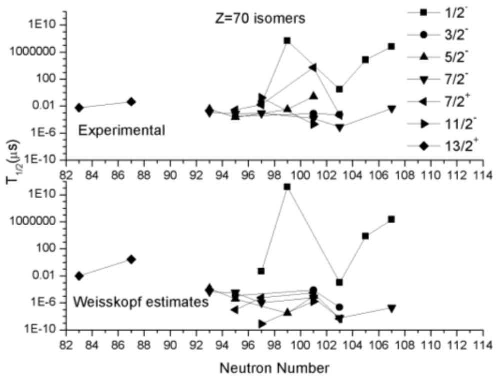

Fig. 2 Same as Fig. 1 for the Z=70 isomers.

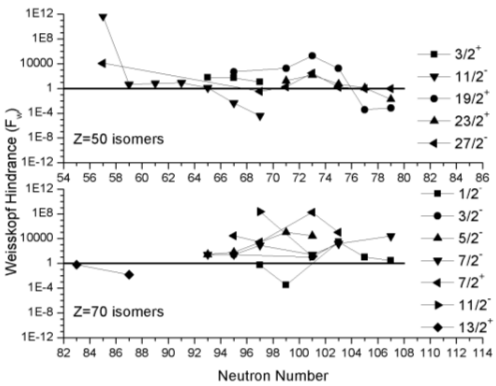

Fig. 3 Weisskopf hindrance for the Z=50 and Z=70 isomers.

Weisskopf Hindrance

We have plotted the Weisskopf hindrance for the Z=50 and the Z=70 isomers in the top and the bottom panels of the fig. 3, where the hindrance is defined as the ratio of experimental half-life and the Weisskopf estimated half-life. The vertical scale represents the logarithmic value of the Weisskopf hindrance. If the hindrance equals to 1, then it means that the experimental half-life is 10 times larger than the calculated one. If the hindrance is less than 1, then it means that experimental half-life is lower than the calculated one; reverse will be true for greater than 1 hindrance value.

We can see that the hindrance of the Z=50 isomers mostly lie around the value 1. The $11/2^-$ isomer shifts from this value around the mid-shell, where it undergoes a sharp energy transition and come towards the ground state due to the dominant role of the $h_{11/2}$ orbital.

On the other hand, the $27/2^-$ isomers, which have the good seniority at v=3, after the mid-shell, have a peak in the experimental half-life at N=73, when the valence $h_{11/2}$ orbital becomes half-filled [3]. This results in the peak for the hindrance of the same. The $19/2^+$ and $23/2^+$ isomers, are again seniority v=3 isomers, but also have contribution coming from the $d_{3/2}$ and $s_{1/2}$ orbitals besides the $h_{11/2}$ orbital [4]. This results in a peak at N=73, but afterwards the value declines below 1.

The well deformed Z=70 isomers have large hindrance, as expected. The interesting fact is that the calculated half-life systematics for these various isomers behaves exactly similar to the experimental ones. All the isomers, except the $13/2^+$ isomers which lie near the N=82, lie in the well deformed region, and have large hindrance due to the K-isomerism in addition to the usual angular momentum rules. Therefore, most of the cases have large experimental half-life than the calculated one.

To conclude, it is remarkable to note that the simple Weisskopf estimates are able to explain the half-life trend for the spherical i.e. spin isomers as well as for the well deformed i.e. K-isomers.

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References

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