# Atlas of Nuclear Isomers

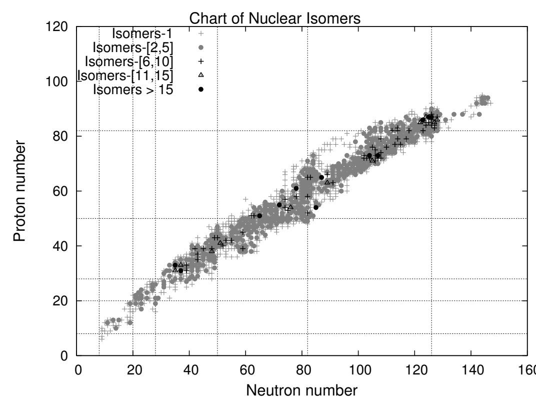
Monika Patial[1]*, A. K. Jain[1], P. Arumugam[1], Balraj Singh[2]
[1]*Department of Physics, Indian Institute of Technology, Roorkee-247667, INDIA*
[2]*Department of Physics, McMaster University, Hamilton, CANADA*
**monikapatial@gmail.com*

## Introduction

Nuclear isomers are long lived excited states of nuclei having significantly larger half-life than the normal excited states. We have taken the lower limit of half-lives as 1*ns* for nuclei to be called as isomers. They are divided into three classes on the basis of the change of their shape, spin and projection of spin on the symmetry axis [1]. The fission isomers result from the transition of an excited state to a lower state having different shapes and are also termed as shape isomers having superdeformed shapes. Spin isomers, which are most common, correspond to transition between states having large spin difference. Finally, we have the K-isomers [2,3] whose existence depends on the change of projection of nuclear spin on the symmetry while making the transition. Nuclear isomers have been known for a very long time [4] but their number has grown significantly in the last few decades. In spite of this, their systematics have not been studied in detail. As a prelude to our studies, we are preparing an atlas of isomers to highlight the extent of knowledge in this promising and highly interesting field.

## Chart of Isomers

The chart shown in figure 1 exhibits the presently known nuclear isomers for all the neutron and proton numbers. Each circle represents a nuclear isomer with the shading showing their number density. The magic numbers of proton and neutron are also shown by dotted lines. These data have been taken from the latest ENDSF files [5] for the adopted levels of each nucleus. We find that the predicted total number of nuclear isomers for the complete mass region is about 2858. Nuclei having single known isomer are 507 while nuclei having isomers between 2 and 5 comes out to be 559. Also the number of known isomers between 6-10, 11-15 and greater than 15 are 57, 11, and 12 respectively. Only one nucleus $^{68}As$, an odd-odd nucleus, exhibits as many as 30 isomeric states, although most of the lifetimes are known in the upper limit. Text books generally point out that most of the isomers are found below the magic numbers [5], but we find that the present scene has changed completely and nuclear isomers are found all over the nuclear chart, thanks to the advanced experimental techniques. However, most nuclei with largest number of isomers still fall near the magic numbers. In figure 1(b), we plot the nuclei having more than 15 isomers.



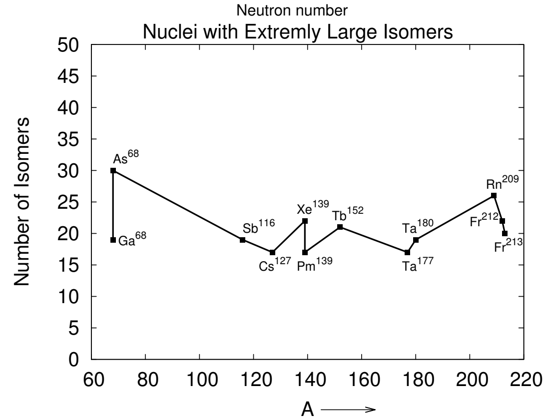




**Fig. 1** Chart of nuclear isomers (top) and nuclei with extremely large isomers (bottom).

## Half-lives

Since a large number of isomers primarily decay by electromagnetic processes i.e. $\gamma$-decay and or, internal conversion, the theoretical half-lives of transitions can be estimated by Weisskopff single particle estimates. In figure 2 we plot the ratio $\log(\tau_{1/2}/\tau_w)$, circles representing nuclei having quadrupole deformation $\beta_2 \leq 0.1$. Rest of the nuclei are deformed nuclei with $\beta_2 >$ 0.1 where the values of $\beta_2$ have been taken from Moller-Nix [5]. It can be seen that Weisskopff estimates are lower than the expected half-lives for a number of cases by order of magnitudes, nuclei above the zero line being such examples. Nuclei below this zero line have larger experimental half-lives compared to the Weisskopff single particle estimates. Special cases like $^{211}Po$ have been observed in which hindrance factor $F_w = \tau_{1/2}/\tau_w$ is $10^{-10}$ and in $^{180}$Hf, the hindrance factor is $10^{16}$.

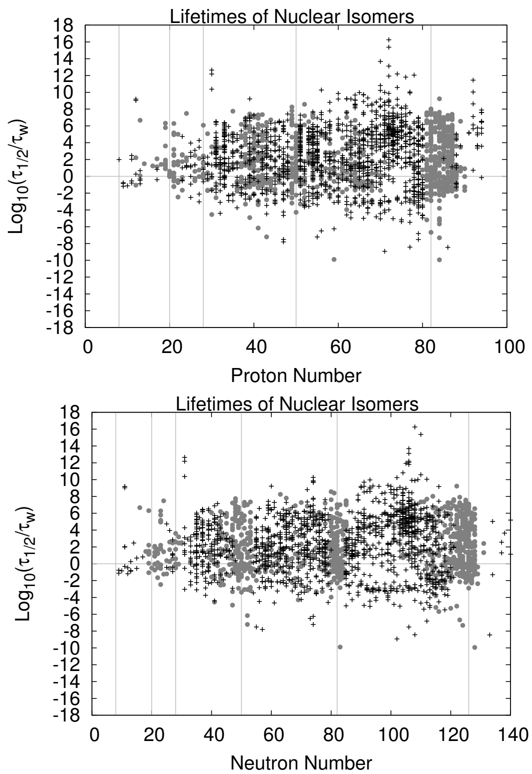



**Fig. 2** Lifetime of nuclear isomers with respect to proton (top) and neutron numbers (bottom).

Looking at the statistics of half-lives of the isomeric states, more numbers of isomers are found in the range 1 ns-100 ns. These numbers fall gradually with the increase in half-life of isomeric states up to 0.1s and then again small rise is observed at 10s-$10^3$s. These studies are based entirely on the basis of the experimental data from the ENDSDF files.

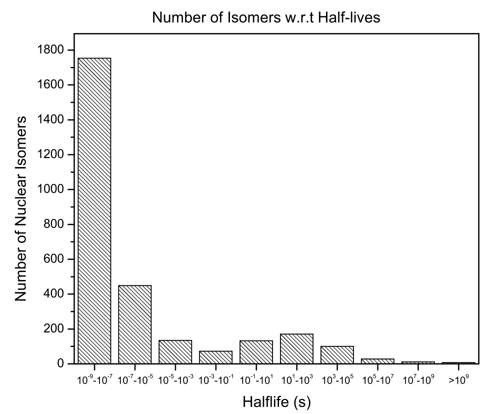



**Fig. 3:** Half-life statistics of nuclear isomers.

## Acknowledgement

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