Survey of spin, parity and half-life measurements of nuclear levels, for A = 1-260

P.K. Joshi[1],* Debasish Chabanya[2], Tanmay Tanaji Pujari[3] and Sukhjeet Singh[4]
[1]*HBCSE, Tata Institute of Fundamental Research, Mumbai - 400088, INDIA*
[2]*NIUS Student, Department of Physics, Tezpur University, Assam-784028, INDIA*
[3]*NIUS Student, Physics Department, Sir Parshurambhau College (Autonomous), Pune-411030, INDIA*
[4]*Department of Physics, Akal University, Talwandi Sabo, Bathinda-151302, INDIA*
**email:pkjoshi@tifr.res.in.*

Introduction

This study aims to review the existing research on the measurement of half-life values, spin, and parity of excited states in nuclei. This work builds upon a previous survey conducted in 2019[1] and aims to compare and contrast the advancements made over the past five years. This survey besides being an indicator of the quantum of measurements carried out can also be a guide to future experimentalists by highlighting the areas of nuclear chart where measurements are fewer in number.

Data collection

The adopted data for each of the nucleus is stored in ENSDF (text) format on the site of National Nuclear Data Centre[2] at Brookhaven National Laboratory (https://www.nndc.bnl.gov/). To facilitate the retrieval of half-life, spin, and parity values of excited states from the ENSDF files, P.K. Joshi et.al [1] developed a computer code in C++. This code enables the extraction of the relevant data for each nucleus.

For each nucleus, the factors P_H, P_S, and P_P were determined. The quantity P_H (P_S or P_P) is defined as:
100 x number of energy levels with half-life (spin or parity) value measured / total number of observed energy levels in those nuclei.

Data analysis

The NNDC website provides data for 3427 nuclei for A ≤ 260. Of these, 2326 nuclei have at least their ground state and two or more excited states observed experimentally. This paper focuses exclusively on these 2326 nuclei. Nuclei A ≥ 261 have very little experimental measurements and so were ignored.

Spin: There are 535 nuclei with no confirmed spin values, not even for the ground state. For the remaining 1791 nuclei, the distribution of the P_S value is shown in Figure 1. The median P_S value is 22.02, and the mean is 26.54, indicating that for 50% of these nuclei, only 22% of the energy levels have confirmed spin values. Additionally, 124 nuclei have a P_S value less than 3, while 246 nuclei have a P_S value greater than 50, meaning that only in these 246 nuclei, more than 50% of energy levels have assigned spin value.

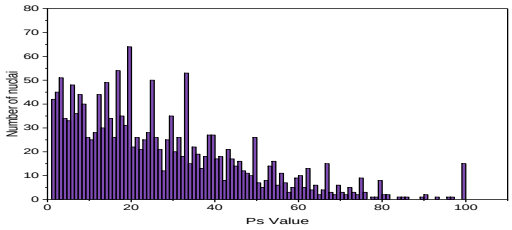

Fig. 1 Distribution of P_S values of all 1791 nuclei.

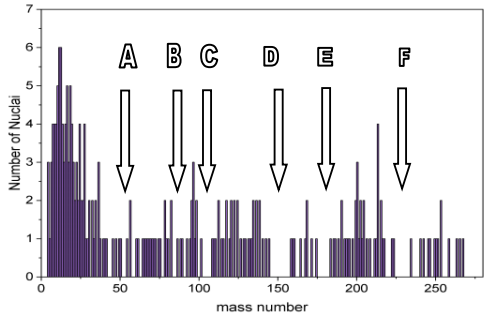

Fig. 2 Distribution of the mass number of nuclei which have $P_H \geq 50$.

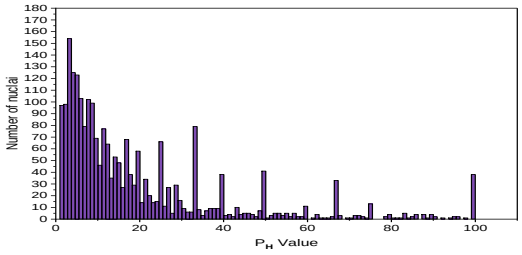

Fig 3. Distribution of values of P_H

Parity: There are 537 nuclei where absolutely no confirmed parity value is known, not even for ground state. After removing these nuclei from consideration, the distribution of P_P value for remaining 1789 nuclei has median value is at 17 and mean value is 32.58.

The number of nuclei which have P_P value less than 3 is 59 and P_P value greater than 50 is 375 that means only in 375 nuclei more than 50% of energy levels are assigned parity value.

Half-life: There are four nuclei with no known half-life values for their ground states. For the remaining 2322 nuclei, the distribution of the P_H value is shown in Figure 3. The median P_H value is 11.52, and the mean is 19.21, indicating that for 50% of the nuclei (1163), only 11.52% of energy levels have confirmed half-life values. Additionally, 242 nuclei have a P_H value less than 3, while 232 nuclei have a P_H value greater than 50, meaning that only in these 232 nuclei, more than 50% of energy levels have measured half-life values.

Figure 2 shows the distribution of mass numbers for nuclei with a P_H value greater than 50. The peak of the distribution is in the low mass region, with six regions labeled **A-F** (A=50, B=90, C=105, D=150, E=180, F=230) where half-life value measurements are notably low.

When compared to the distribution in 2019[1], it is observed that the gaps are still in the same range implying not much improvement in the last five years.

The spikes in Fig. 3 arise from the fact that when a nucleus has only 4 levels observed the P value can take values of 25, 50, 75 or 100, similar is the case where nuclei with very few levels observed, have discrete P values.[3]

Conclusion

From the data analyzed, following points stand out: These data are from adopted data set. On an average the adopted data is around 5 to 10 years old. During previous survey [1], the XUNDL dataset was not analyzed, which now has been surveyed and uploaded (Till May 2024) as well, and can be viewed at http://apps.hbcse.tifr.res.in/pradeep/.

Value of half-life is most important for calculation of transition probabilities, which is the meeting point of theory and experimental nuclear physics. However, from the data above it can be seen that very few nuclei have their half-life values measured. Same is the story with spin and parity measurement.

Table: Statistical data of histograms studied for the Spin, parity and half-life. (Comparison between 2019 and 2024)

SPIN PART	**Number of nuclei (2019)**	**Number of nuclei (2024)**
Distribution of Atomic number of Nuclei with spin Zero	485	535
Distribution of Atomic number of Nuclei with P_S<3	135	124
Distribution of Atomic number of Nuclei with $3 \leq Ps < 50$	1364	1421
Distribution of Atomic number of Nuclei with $P_S \geq 50$	234	246

PARITY PART	**Number of nuclei (2019)**	**Number of nuclei (2024)**
Distribution of Atomic number of Nuclei with Parity Zero	486	537
Distribution of Atomic number of Nuclei with P_P<3	63	59
Distribution of Atomic number of Nuclei with $3 \leq P_P < 50$	1303	1355
Distribution of Atomic number of Nuclei with $P_P \geq 50$	366	375

HALF-LIFE PART	**Number of nuclei (2019)**	**Number of nuclei (2024)**
Distribution of Atomic number of Nuclei with P_H Zero	3	4
Distribution of Atomic number of Nuclei with P_H<3	243	242
Distribution of Atomic number of Nuclei with $3 \leq P_H < 50$	1769	1848
Distribution of Atomic number of Nuclei with $P_H \geq 50$	203	232

This data from this survey, presented in the symposium, can be a guide to future experiments in Nuclear Physics. The detailed result from the present analysis will be presented during the symposium.

References

[1] P.K. Joshi, Rahul Pandey, Yash Jain and Sukhjeet Singh, Proceedings of the DAE Symp. on Nucl. Phys. 64 (2019), pp. 126-127

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[3] Evaluation of nuclear structure data and its spin-offs, P.K. Joshi, Indian Journal of Pure & Applied Physics, Vol. 58, May 2020, pp. 363-367