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Evaluation of nuclear structure data and its spin-offs

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Evaluation of nuclear structure data is a world wide effort to standardize the published nuclear data. This standardization led to generation of table of isotopes, Nuclear Data sheets, Nuclear Wallet Cards etc. This paper deals with two aspects of evaluation of nuclear structure data. First, the problems arising out of some of the recent publications and how to tackle them at pre-publication stage. Second, there is large amount of experimental data available on the NNDC site[1]. Of these data the half-life values, spin and parity is the most important set of values to understand the nucleon-nucleon interaction within a given nucleus. However, it is observed in our work that the quantum of half-life, spin and parity values measured, in comparison to the number of excited states, in any given nuclei, is very low. Thus, indicating that very few experimental results are available in terms of half-life measurements, spin measurements and determination of parity. 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.

Keywords: Evaluated nuclear structure data, half-life values, spin values and parity of different levels ENSDF

1 Introduction

Evaluation of nuclear data is a world wide effort to standardize the published nuclear data. Nuclear Data Evaluation and standardization of data[2] started in the mid-1930s to "collect, compile, review and disseminate nuclear and atomic data". This then led to generation of table of isotopes[3], Nuclear Data sheets[4], Nuclear Wallet Cards[5] etc. But besides these offshoots of the evaluation program, the individual evaluators involved with the process have certain spinoffs at local level.

During the evaluation of atomic mass, A=139, ^{139}Ba was a special case. The $T_{½}$ of the ground state of ^{139}Ba was measured in 13 different experiments. The values were distributed in two different groups. The values can be seen[6] in Table 1.

Since the $T_{½}$ values did not agree with each other a new experiment was carried out which resulted in a new and more precise measurement of 83.25 ± 0.08 min thus leading to an adopted value of 83.09 ± 0.09 min. Thus an example of how the data evaluation process has resulted in newer experiments. Additionally, this experiment also resulted in 3 γ transitions in the decay of 139Ba, being reassigned to another nuclei which belong to contaminants in the target.

Further data evaluation of other nuclei has resulted in similar spin-offs and this paper deals with two such spin-offs as discussed above.

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1.1. Problems with published level-schemes

There are several issues which have been observed during publication of level schemes. Some of them are listed below.

A. Case of two experiments

Both having same reaction (including the beam energy), similar detection power in terms of types of detectors and their numbers, similar amount of data collected, etc.; resulting in level schemes where the placement of γ transitions is different from the previous published data. These discrepancies can be seen in Fig. 1. However, the discrepancies in the placements are not discussed in details on several occasions.

B. Intensity mis-matches

During several evaluations it is observed that authors do not include the uncertainties on the I_γ

Table 1 — $T_{½}$values of ^{139}Ba.

	Measured Half – life (min)	
	Group I	Group II
1	85.547 ± 0.015[7]	83.06 ± 0.28[15]
2	84.44 ± .22[8]	82.71 ± 0.18[16]
3	84.63 ± 0.34[9]	82.9 ± 0.2[17]
4	85.2 ± .8[10]	82.9 ± 0.1[18]
5	85 ± 1[11]	83.25 ± 0.08[19]
6	84.0 ± 0.2[12]	
7	85.0 ± 0.5[13]	
8	85 ± 1[14]	
AVG	84.54 ± 0.04	83.06 ± 0.12

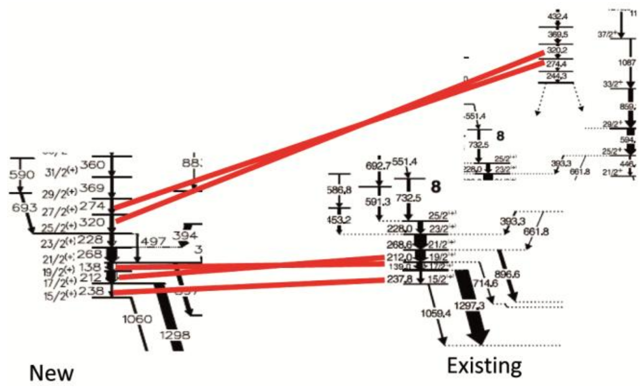

Fig. 1 — Where in placement of γ transitions is completely misplaced in two similar experiments.

measured. And on several occasions the feeding intensities are larger than depopulating intensities as can be seen in Fig. 2.

It is possible that sometimes the discrepancies arise after the conversion electron intensities are taken into account. However, there is no physics explanation offered on the discrepancies in such cases. It is advisable for the researchers to run some of the evaluation codes to identify the discrepancies before the results of their experiments are published.

1.2 Quantum of measurements of half-life values, spin values and parity of different levels in a given nucleus

A quantity, called P_h-value is defined as the number of levels whose half-life values are measured divided by the total number of energy levels in those nuclei. For example, if a nucleus has 137 energy levels (adopted by the nuclear data evaluators) and 17 of these levels have their half-life values measured. Then P_h= 17 x 100/137 = 12.4. Same is the case of P_s (spin measurement) and P_p (parity measurement).

The adopted data for each of the nucleus is stored in ENSDF (text) format on the site of National Nuclear Data Centre at Brookhaven National Laboratory[1]. P_h, P_s and P_p values were calculated for each of the nucleus in the nuclear chart. Results for which are listed below.

A . Value of P_h

In the year of 2019, when the survey was carried out, there were 3250 nuclei with A≤260. Nuclei above A=261 have very little experimental measurements and so were ignored. Of the 3250 nuclei those nuclei, especially very close to drip line, which have no level measurements, were also removed from the list resulting in a balance of 3207 nuclei. There were 76

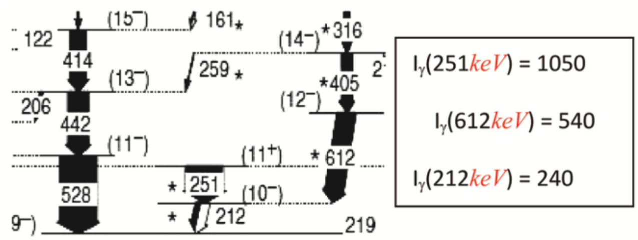

Fig. 2 — A case where the (total) Iγ (251 keV) is 1051, Iγ (612 keV) is 542 and Iγ (212 keV) is 242.

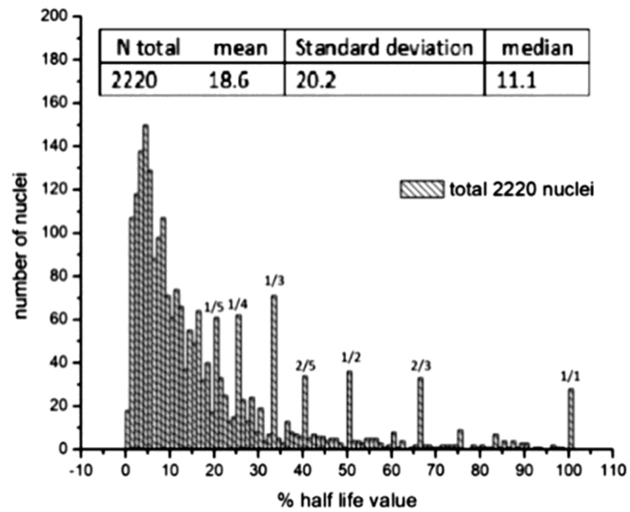

Fig. 3 — P_h values calculated for all the 2220 nuclei.

nuclei which have no half-life value measured, and thus will be reported separately leaving 3131 nuclei to be observed.

Nuclei very close to drip line region are very difficult to study experimentally and usually have only 1 or 2 excited states. Such nuclei were left out of the survey and hence finally 2220 nuclei were studied and their P values measured. The distribution of P_h values can be seen in Fig. 3.

From Fig. 3 it can be seen that P_h value has a median of 11.1. This implies that for 50 percent of the nuclei only 11 percent of their observed energy levels, half-life values are measured. The peak of the distribution is at an abysmally low value of 4 percent, implying that for around 150 nuclei; only 4 percent of their levels have half-life measurements.

Note, that 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.

Figure 4 shows the distribution of P values where more than 50 percent of their levels have their half-life values measured. From Fig. 4 it can be seen that there are certain mass numbers were not a single isobar has P value greater than 50.

There are 403 nuclei who have half-life values measured for only the ground state. Of these 403 nuclei, there are 227 nuclei who have more than 10 levels observed but only the ground state half-life value measured. The list of 76 nuclei with absolutely 0 half-life measurements is attached at the end of the paper.

B . P_s values

In this work, similar to P_h, P_s values too were calculated for 2220 nuclei. The distribution of the Ps value can be seen in Fig. 5. There are 485 nuclei where there is NO confirmed spin value measurement. Of these 485 nuclei there are 289 nuclei which have more than 10 energy levels observed, i.e experimentally reasonably well studied. From Fig. 5 it can be seen that there are 15 percent of nuclei where less than half of the levels have confirmed spin values assigned to it.

It is also worth noting that in case of spin many of the confirmed spins are assigned not by measurements but based on the model considerations. Hence the determination of spin by polarization/ DCO ratios or conversion electron measurement is much less.

These 485 nuclei, which have no confirmed spin value assignment can be seen, as a function of A and Z values in Fig. 6a and 6b. In Fig. 6b, it can be clearly seen that there are 4 elements (Z = 41, 59, 75, and 89) where not a single isotope of these elements have any confirmed spin assignments. On the other hand there

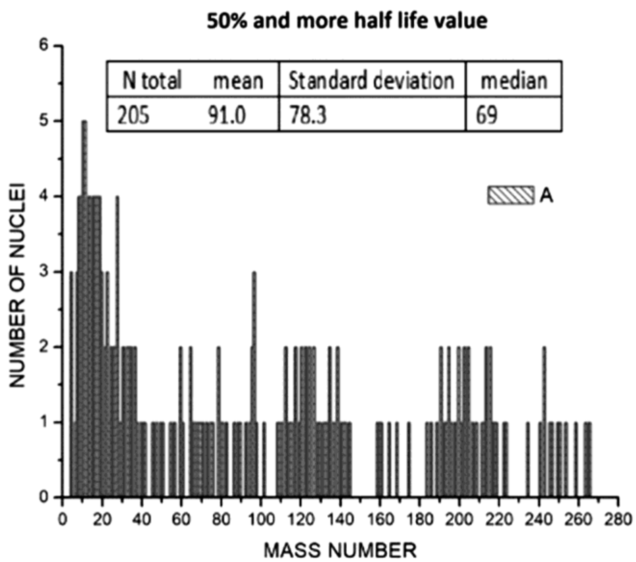

Fig. 4 — Distribution of nuclei, as a function of mass number, whose P_h values are larger than 50.

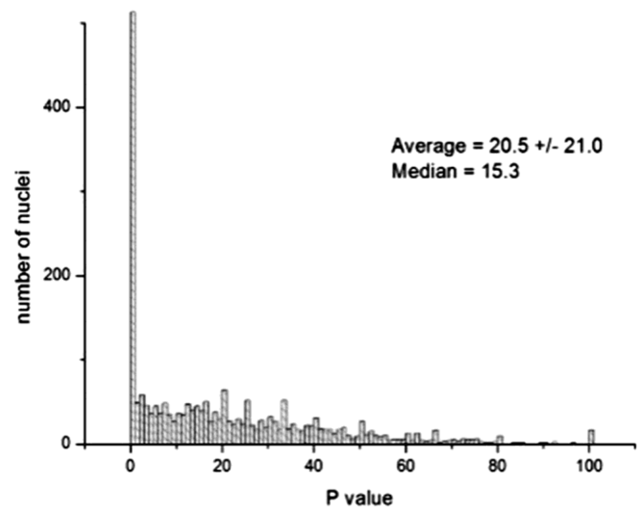

Fig. 5 — Distribution of Ps values calculated for all the 2220 nuclei.

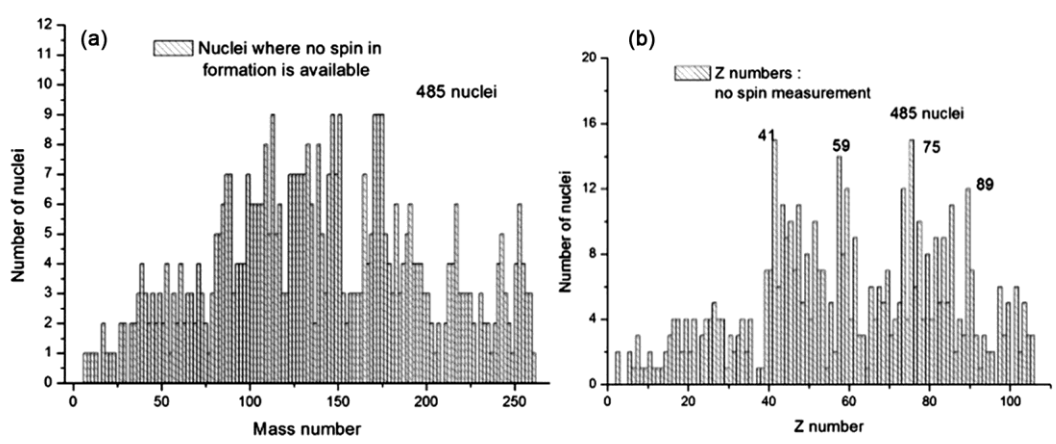

Fig. 6 — Distribution of nuclei, as a function of mass number, whose P_h value is absolute 0.

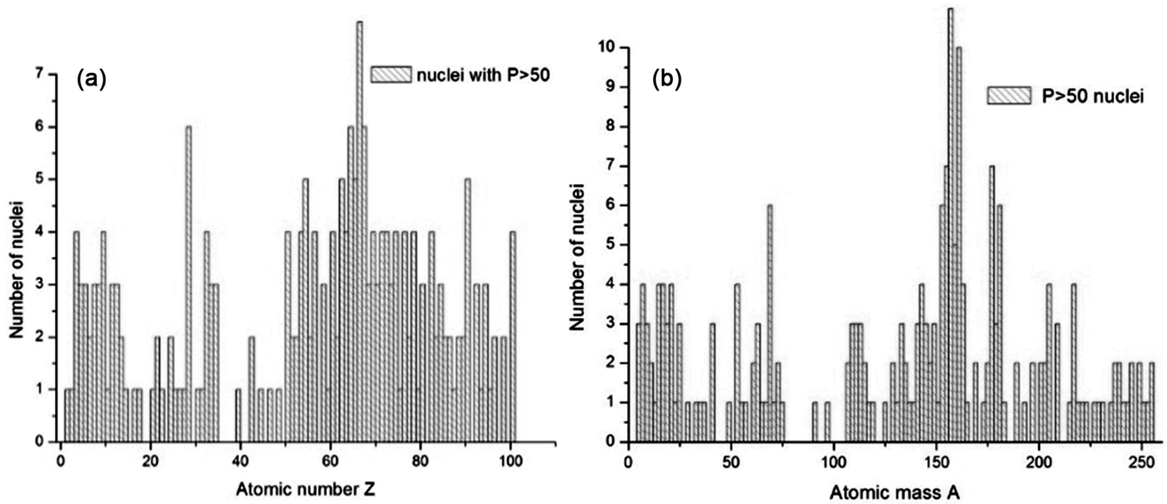

Fig. 7 — Distribution of nuclei, as a function of mass number, whose Ps values are larger than 50.

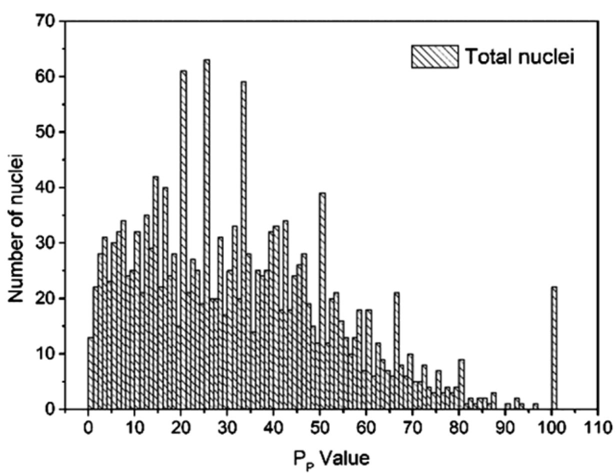

Fig. 8 — The distribution of Pp for all 2220 nuclei.

are 215 nuclei who have more than 50 percent spin assignment. The distribution of these nuclei can be seen in Fig. 7a and 7b.

C . P_p values

In case of parity, there is no direct measurement and one confirmation can lead to confirmation of parity values for many levels. In spite of this information, the distribution of P_p is reported for the sake of completeness, in Fig. 8.

2 Conclusions

From the data analysed, following points stand out:

(i) These data are from adopted data set. On an average the adopted data is around 5 to 10 years old. Hence the data presented above does not include experimental measurements of last 5 to 10 years. This survey and analysis are under progress.

(ii) The P values on XUNDL files are under calculations.

(iii) 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.

This data should be very useful to future research scientists to determine the areas of nuclear chart that need more attention than others.

Acknowledgement

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