# Evaluation and systematics study of the β-delayed neutron emission probabilities for nuclei with 40 < Z < 50

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## Introduction

The beta-delayed neutron emission is a phenomena occurs in the neutron rich nuclei. For such nuclei, when the β-decay feeds the states which lie above the neutron separation energy ($S_n$) in the daughter nucleus, the β-decay is followed by the emission of neutron. The experimental and theoretical investigation of such processes is one of the most interesting topics in recent years [1, 2] as it has great importance in several applications such as r-process nucleosynthesis network calculations [3], reactor operation, and nuclear fuel post processing [4, 5] etc. It is experimentally difficult to access many of the β-delayed neutron emitters and hence, several phenomenological models based on systematics have been developed [6, 7] for better prediction of β-delayed neutron emission probabilities ($P_n$) in such nuclei. Therefore, it is important to have a data base of the evaluated values of β-delayed neutron emission probability ($P_n$) compiled from various experiments. Considering its present importance a coordinated research project (CRP) has been initiated by the International Atomic Energy Agency (IAEA) on a Reference Data base for Beta-Delayed Neutron Emission [8]. As a part of this project, evaluation of the data on 103 known and potential β-delayed neutron emitters (including 10 excited isomeric states) for the nuclei in the range of Z = 41 ï 48 has been carried out and presented here.

## Evaluation methodology

Data published until the end of 2016 on the β-delayed neutron emitters and potential emitters have been considered for compilation and evaluation. The potential emitters were identified which satisfied the condition:

$$Q_{\beta^-} - S_n > 0 \quad (1)$$

Where, $Q_{\beta^-}$ is the Q-value for the $\beta^-$ decay and $S_n$ is the neutron separation energy. One- two and there neutron emitters have been considered.

Two different data tables were made, one for compilation and another on the evaluated and adopted values. The compilation table consists of the reference, halflife ($T_{1/2}$) in sec (s), $P_{in}$ (where i = 1, 2 and 3) values in percent (%), the experimental methods used to obtain the Pn values, whether neutron spectra are provided and a comment on $T_{1/2}$ measurement. These have been compiled for each reference corresponding to every nucleus. There were several references for each nucleus. The ENSDF, XUNDL, NSR [9] and NUBASE [10] data bases were checked for the compilation.

In the evaluated table, we have provided the adopted values of $T_{1/2}$ and $P_{in}$ (if available) along with the adopted uncertainties (quoted in ENSDF style) and detailed comment on the basis of the adopted values.

## Results and Some Systematics on the Evaluated Values

As mentioned before, we have made a comprehensive compilation table and provided the evaluated values (a single adopted value for each parameter) of $T_{1/2}$ and $P_n$ (wherever known) for 103 nuclei in the mass region of A = 103 ï 134 for isotopes of Nb (Z = 41) to Cd (Z = 48), including 10 isomeric states. Out of these 103, only 32 have experimental data on $P_{1n}$. All others are potential β-delayed neutron emitters and it would be useful to measure the Pn values of those nuclei. No $P_{2n}$ or $P_{3n}$ emitters were found for the elements considered in this work.

It is understood that the equation (1) for the potential β-delayed neutron emitters would be satisfied for the neutron rich nuclei only. The neutron separation energy and the Q-values are the two important parameters which controls the neutron emission probability.

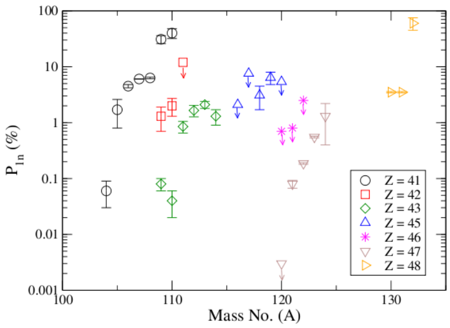


*Fig-1: Variation of β-delayed 1-neutron emission probability ($P_{1n}$) with mass number (A) for different elements.*

Variation of the measured β-delayed 1-neutron emission probability ($P_{1n}$) is shown in Fig.1 with mass number (A) for the elements evaluated in the present work. It shows a general trend of increasing $P_{1n}$ with mass number i.e with the more neutron rich isotopes of a particular element. This is, most likely, due to the decrease in the Sn values with neutron number (as shown in Fig.2). It is interesting to note that a few elements do not seem to follow the general trend.

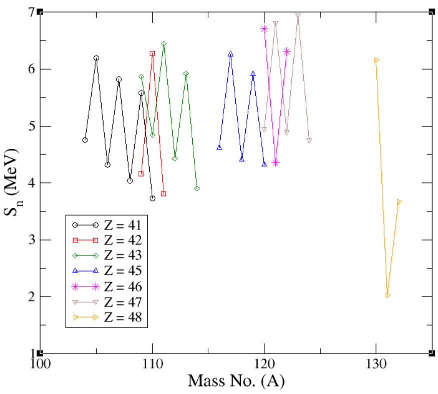


Fig.2: *Calculated neutron separation energy (Sn) vs. mass number (A) for different elements.*

The evaluated values of the measured β-delayed 1-neutron emission probabilities for all the nuclei under discussion are shown in Fig.3. It clearly shows two groups which is due to the odd-even effect of the Sn values (see Fig.2). Apart from a few outliers, the $P_{1n}$ values in each group again follow a general feature of increasing $P_{1n}$ values with decrease in $S_n$. Lower value of $S_n$ increases the phase space for the neutron decay which causes the $P_{1n}$ to increase. However, it is interesting to further study the nuclei which do not follow the general systematics to look for any structure effect that may influences the $P_n$ values.

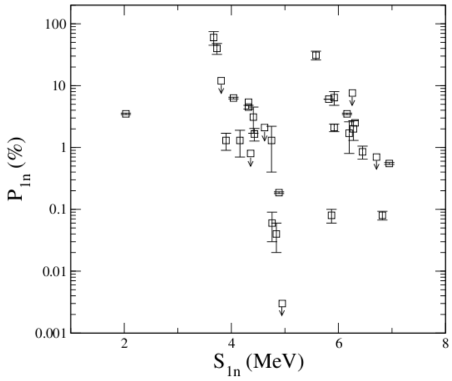


Fig.3: *Variation of beta-delayed 1-neutron emission probability ($P_{1n}$) with neutron separation energy ($S_n$) for different elements.*

## Acknowledgement

The guidance of Prof. B. Singh (McMaster Univ., Canada) and Dr. Paraskevi Demetriou (IAEA, Austria) are gratefully acknowledged. The help of NNDC in getting many of the references are also acknowledged. The work is done under the IAEA Research Contract No. 17877 awarded to the authors.

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