# Estimation of (n, p) cross section using Systematics for Fusion Reactor Magnetic Material (Sn)

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## Introduction

Magnetic materials of extreme importance in the fusion reactor and are selected very carefully. Such materials have properties to have long term stability and no degradation of magnetic field. These materials are getting irradiated during the operation of the fusion reactor. In fusion reactor like International Thermonuclear Experimental Reactor (ITER) during the plasma shot DT fusion reaction will produce 14.1 MeV neutrons. These neutrons will irradiate materials of the reactor. It is very necessary to estimate the cross-section of all possible reaction around 14 MeV on different isotopes.

In ITER $Nb_3Sn$ conductors are selected for making ITER toroidal field coil [1]. As these field coils are located just after the blanket, these will get irradiated with the neutrons produced from the fusion. Also Sn (~1.5%) was used in design of the U. S. based BWRs and PWRs with Zircaloy as core structural material [2]. It is necessary to have the exact information of the cross section for different neutron induced reactions for this material. The precise data for the reaction cross section are of prime importance from the view point of its nuclear applications, transmutation, shielding effect, radiation damage, long term activation etc. It is found from the Exchange Format (EXFOR) database that there is lack of measured cross section data of (n,p) and (n,2n) reactions for Sn in the energy range 14 to 15 MeV. The cross section data can be evaluate using different systematic formulae given in the table-2 at 14.5 MeV for (n,p) reaction. Also the same data will be evaluated using TALYS-1.6 nuclear data evaluation codes. This data will be compared with the existing data available in different nuclear data library and evaluated with EASY-1.6. The present study highlights the discrepancy and scarcity of the available experimental data for (n,p) and (n,2n) reactions cross-section of stable Sn isotopes, and our effort to make a thorough study on that using systematics given by different authors and optimized calculations of cross-section using nuclear reaction modular code TALYS-1.6

## Status of Cross section data for (n,p) and (n,2n) reactions for stable isotopes of Sn

The experimental cross-section data are available in EXFOR database for (n,p) and (n,2n) reaction on different isotopes of Sn till date are given in table-1[3-13] and table-3 respectively. There are some systematic formulae that are available for calculating the cross section for (n,p) and (n,2n) reactions at 14.5 MeV. The calculated cross section for all the stable isotopes of Sn using the systematic formulas by different authors are given in table-2 for (n,p) and in table-3 for (n,2n).

**Table 1:** Latest Experimental Cross Section of (n,p) reaction for Stable Sn isotopes in EXFOR

| A | Abundance (%) | σ (mb) (14.5 MeV) | σ (mb) (14.6 MeV) |
|---|---|---|---|
| 112 | 2.55 | No data | 33.0±6.0 (a) |
| 114 | 0.66 | No data | 23.0±15.0 (a)<br>105±30.0 (a) |
| 115 | 0.34 | No data | 36.0±2.8 (a) |
| 116 | 14.54 | 22.0 ± 2.0 (a) | 10.0±1.5 (a) |
| 117 | 7.68 | 16.0 ± 4.0 (a) | 8.1±1.7 (a) |
| 118 | 24.22 | 9.0 ± 3.0 (a) | 5.41±0.36 (a) |
| 119 | 8.59 | 10.0 ± 2.0 (a) | No data |
| 120 | 32.58 | 4.3 ± 0.7 (a) | 2.7±0.5 (a) |
| 122 | 4.63 | No data | 0.18±0.06 (a) |
| 124 | 5.79 | No data | No data |

**Table 2:** Calculated Section of (n,p) reaction for stable Sn isotopes

| Cross section σ (mb) for (n,p) reaction | | | | | |
|---|---|---|---|---|---|
| A | Levkovski [4] | Ait-Tahar [5] | Doczi et al. [6] | Habbani et al. [3] | Forrest [7] |
| 112 | 45.490 | 56.142 | 59.951 | 29.934 | 48.512 |
| 114 | 27.053 | 33.214 | 41.492 | 22.218 | 49.512 |
| 115 | 21.006 | 25.724 | 34.566 | 15.269 | 50.512 |
| 116 | 16.383 | 20.012 | 28.824 | 13.395 | 51.512 |
| 117 | 12.832 | 15.636 | 24.060 | 9.938 | 52.512 |
| 118 | 10.093 | 12.268 | 20.104 | 8.216 | 9.601 |
| 119 | 7.971 | 9.666 | 16.816 | 6.564 | 6.958 |
| 120 | 6.320 | 7.646 | 14.081 | 5.124 | 5.048 |
| 122 | 4.020 | 4.841 | 9.906 | 3.245 | 2.664 |
| 124 | 2.594 | 3.110 | 7.000 | 2.087 | 1.413 |

**Table 2:** EXFOR (latest) and Calculated Cross Section data of (n,2n) reaction for stable Sn isotopes

| Cross Section σ (b) for (n,2n) | | | | | |
|---|---|---|---|---|---|
| A | Chatterjee et al. [8] | Lu and Fink [9] | Bychkov et. al [10] | Habbani et al. [3] | Measured (14.5 MeV) |
| 112 | 1.2766 | 1.1878 | 1.1519 | 1.1598 | No data |
| 114 | 1.3241 | 1.3444 | 1.2446 | 1.1681 | No data |
| 115 | 1.3479 | 1.3993 | 1.2869 | 1.2768 | No data |
| 116 | 1.3718 | 1.4434 | 1.3268 | 1.2477 | No data |
| 117 | 1.3958 | 1.4794 | 1.3645 | 1.3579 | No data |
| 118 | 1.4198 | 1.5091 | 1.4003 | 1.3299 | 0.794±0.109 (a) |
| 119 | 1.4439 | 1.5340 | 1.4341 | 1.4413 | No data |
| 120 | 1.4680 | 1.5551 | 1.4663 | 1.4149 | No data |
| 122 | 1.5165 | 1.5893 | 1.5261 | 1.5024 | No data |
| 124 | 1.5652 | 1.6163 | 1.5807 | 1.5925 | No data |

***(a) Experimental data available in EXFOR data library***

## Conclusion

The experimentally available measured data for stable isotopes of Sn from EXFOR data library are given in table -1 and table-3. Careful observation of the EXFOR data base shows that same energy (either 14.5 or14.6 MeV) contains different values of the cross section published, and it is not clear which value to be taken. Therefore latest value has been taken for reference. The systematically calculated cross section data can help to estimate the exact value of the cross section (table -2 and table -3).

Cross section for isotope $^{124}$Sn (5.79%) has been calculated as no measured data available for the energies 14.5 and 14.6 MeV. There is very less data available for Sn (n,2n) reaction, hence systematically cross section have been calculated.

To estimate the exact values of cross-section, nuclear model calculations and systematic study are required. Theoretical calculation of the cross-section using nuclear reaction modular codes (Talys-1.6) and their comparison with the systematics will be discussed at the time of presentation.

## References

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