Neutron activation and cross-section calculation for tungsten as a Divertor material in Fusion Reactor

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Introduction

In a DT fusion machine, neutrons arise from the deuterium-tritium reaction D+T-> He+n. Neutrons leave the plasma and interact with the surrounding materials i.e. the first wall, divertor, blanket, vacuum vessel, cryostat, which are critical components of a fusion reactor.

Tungsten is an obvious choice as Plasma Facing Component (PFC) in fusion devices as the first wall of a blanket and a divertor plate on account of its excellent physical and mechanical properties [1] i.e. low sputtering yield, high melting point, lower erosion rate and low tritium retention. The present paper describes activation calculations using European Activation System (EASY) [2] and cross-section calculations using recent nuclear reaction code TALYS-1.6 [3], for tungsten as a plasma facing material, after exposure to a flux of 14 MeV neutrons.

Activation calculations

Activation calculations have been performed by activation code EASY-2007 [4] which solves the large number of coupled differential equations (the Bateman equations) which govern the generation and decay chains for the many nuclides involved. The code package has been used to obtain the activation characteristics of tungsten material. They include the specific activity, decay heat, dose rate, inhalation dose and ingestion dose, list of isotopes at shutdown and dominant isotopes versus cooling rates, related to the tungsten material present in the divertor [5-6].

Nuclear model calculations

In addition to the activation calculation, nuclear reaction cross-section calculations with the help of TALYS-1.6 has also been performed to compute the cross-sections of $^{180}W(n,2n)^{179m,g,,tot}W$, $^{184}W(n,2n)^{183\ m,g,tot}W$ reactions from threshold to 20 MeV neutron energy. The required inputs like nuclear masses, discrete energy levels, optical model potential and level densities of the nuclides involved in the calculations have been taken from latest RIPL-3 [7]. Before running the TALYS code, we have optimized the input file.

The theoretical results are compared with the existing experimental data in EXFOR [8-9] data library as well as Evaluated data files.(ENDF) [10].

Figures 1 & 2 show the illustrative cases of $^{184}W(n,2n)^{183m}W$, $^{184}W(n,2n)^{184tot}W$ reaction cross-section. Energy spectra of primary and secondary neutrons have also been calculated.

The details of activation calculations and cross-section calculations with important outcome will be presented.

Conclusion

The paper presents the important response function (specific activity, decay heat, dose rate, inhalation dose and ingestion dose) of tungsten as a plasma facing material when irradiated by 14 MeV neutrons. Some of the important calculations of cross-section will be highlighted for tungsten isotopes specially for meta-stable state, where very few data with large discrepancy are available.

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[9] EXFOR, Experimental Nuclear Reaction Data, Database Version of August 20, 2014

[10] ENDF, Evaluated Nuclear Data Library, Database Version of March 14, 2014

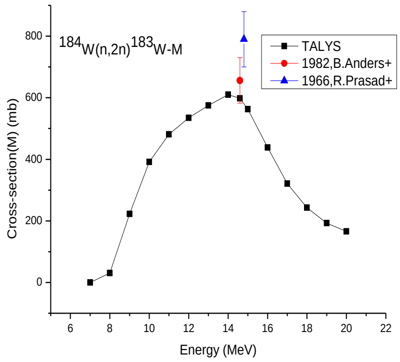

Figure-1

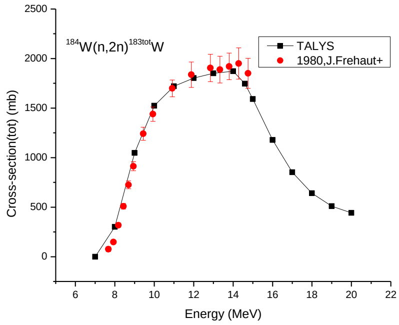

Figure-2

Figs. 1 & 2 TALYS-1.6 based excitation Functions of (n,2n) reactions along with Experimental data and Evaluated data Files