Investigation of (n, p) reaction cross section for some structural material at 14.0 MeV

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Introduction

This paper describes the measured cross section data for (n, p) reaction for selected structural materials of reactor. Structural materials are the base materials of any reactor either fusion or fission. The structural material should have properties such as high strength, long durability, thermal stability, radiation shielding, less radiation transmutation and activation. As these materials are used for a reactor structure, they are getting irradiated by the neutrons produced from the fission or fusion mechanism of reactor. In fusion reactor DT fusion reaction will produce high energetic 14 MeV neutrons. It is necessary to have all the known cross section for this neutron energy to calculate nuclear activation and transmutation, nuclear heating, nuclear damage. Above few MeV (n, p) reaction channel easily opens for most of the materials. In this paper following reaction cross sections is measured using neutron activation technique.

^{75}As(n,p)^{75}Ge
^{64}Zn(n,p)^{64}Cu
^{66}Zn(n,p)^{66}Cu
^{55}Mn(n,p)^{55}Cr

The cross sections were measured at 14.0 MeV and compared with the existing data available in EXFOR (Exchange Format) data base. These are the base materials and used as structural material in reactor. The measured cross section is important for the fusion reactor as well as for the Advance Accelerator based Sub-Critical Systems. Theoretical calculations for these data was done using TALYS-1.6 nuclear data evaluation code. Detail nuclear model consideration will be discussed at the time of presentation.

Experimental Method

The AN-400 Van de Gradff Accelerator of Banaras Hindu University, India was used to produce 14 MeV neutron via ^{3}H(d, n)^{4}He reaction using thick target of 8 Ci at 280 keV deuteron energy [1]. Uniformly mixed Al with the isotope of interest (^{75}As, ^{66}Zn, ^{64}Zn, ^{55}Mn), pressed into form of pellet of 2.0 cm diameter and thickness often 2-3 mm each. Five pellets were used as a cylindrical experimental target. A ^{152}Eu disc source of same diameter was placed between the pallets at different positions. Gamma spectrum at each position measured with high resolution HPGe detector (1.8 keV FWHM at 1332 keV gamma energy) and 4096 channel multi-channel analyzer. Efficiency of detector was calculated at different energies of ^{152}Eu without and with sample to remove self-shielding effect of the sample. Five sample of each isotopes were irradiated with a beam current of 30 μA for 2 to 6 hours. The reaction products were identified by characteristics gamma rays, as tabulated in table-1. The gamma spectra were obtained for each sample using the above mentioned detector setup. The cross section of the interested (n, p) reaction was calculated from the measured peak counts using the following activation equation.

$$\sigma = \frac{\mathbf{AiA}_{\Gamma}\boldsymbol{\lambda}}{(\mathbf{N_T}\cdot\mathbf{N_P}\cdot\mathbf{I_\Gamma}\cdot\boldsymbol{\varepsilon})(\mathbf{1}-\mathbf{e}^{-\lambda\cdot t_i})\cdot(\mathbf{1}-\mathbf{e}^{-\lambda\cdot t_c})\cdot(\mathbf{e}^{-\lambda\cdot t_w})}$$

where,

A_i = Gram Atomic Weight of the target

A_Γ = Peak Counts of gamma energy

t_c = Counting time

t_i = irradiation time

t_w = Cooling time

N_T = No of targets

N_P = Incident neutron flux

λ = Half-life of the product isotope

I_g = Gamma intensity

ε = Efficiency of detector at gamma chosen

Table 1: Measured Cross-section data compared with existing data in EXFOR data base

Reaction / Half-life of daughter	Gamma Energy (KeV)/ abundance (%)	Measured σ (mb)	EXFOR Database (Latest) σ (mb)
^{75}As(n,p) ^{75}Ge (82.78m) [2]	264.65(11) 198.60(1.19)	27.2 ± 2.8	25.5 ± 13 (a)
^{66}Zn(n,p) ^{66}Cu(5.120 m) [3]	1039.23 (9)	55.5 ± 5.7	57.7 ± 4.8 (a)
^{55}Mn(n,p) ^{55}Cr(3.497 m) [4]	1528.3 (0.037)	65.8 ± 9	107.5 ± 62.3 (a)
^{64}Zn(n,p) ^{64}Cu(12.7h) [5]	1345.84 (0.473)	170 ± 18	207 ± 14 (a)

(a) Cross Section value available in EXFOR database

Theoretical Calculation Using Nuclear Model

Theoretical nuclear model calculation has been performed to estimate of the cross section of all the above said reactions using nuclear modular code TALYS-1.4 [6]. Illustrative example for ^{66}Zn(n, p)^{66}Cu is shown in Fig. 1. The required parameter for the input file such as nuclear mass, discrete level energy levels, optical model potential, level densities etc. have been taken from latest RIPL-3. The calculation for all the reactions with optimized parameters will be presented at the time of presentation.

Conclusions

Cross section of (n, p) reactions for the isotopes ^{64}As, ^{66}Zn, ^{55}Cr and ^{64}Zn were measured at 14.0 MeV using activation analysis. The measured data has been compared with the recent EXFOR data as well as the cross-section calculated with nuclear model calculation TALYS-1.4. Preliminary results indicate that the comparison of the experimental results are reproduced by the theoretical calculations within the limits of the experimental errors of 8 to 12%. Detailed results will be discussed during the symposium.

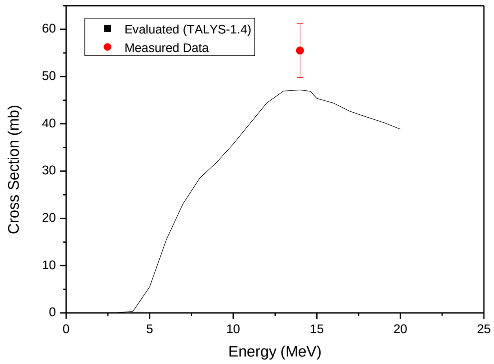

Fig. 1 Comparison of our measured cross-section for ^{66}Zn(n, p)^{66}Cu with TALYS-1.4

References

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